REEF RESEARCH

NEWSLETTER OF THE RESEARCH AND MONITORING SECTION

Great Barrier Reef Marine Park Authority

VOLUME 4 - No. 4 DECEMBER 1994

EDITORIAL

This issue of Reef Research brings us a wide variety of information from the crew at the Marine Park Authority and beyond. By the time that you are reading this, the Chairman of the Authority will have retired from his position here, but not before imparting some words of wisdom to the management and research community. His views on the continually developing rapport between managers and scientists provides justifiable encouragement for those who have laboured hard over the years to make science rewarding, productive and relevant to the needs of those charged with making decisions that will affect us all. Professor Kelleher has been with the Authority for fifteen years and is, I believe, looking forward to a short, but well earned, rest before heading on to further challenges and opportunities. I would like to take this opportunity to thank Graeme for his support in a number of tasks that I have carried out, not the least of these being as editor for this newsletter.

A particularly interesting article has been prepared by Ray Berkelmans and Hamish Malcolm regarding soft corals and mucus sheets. It possibly leaves more questions than answers and there is certainly scope for further research into the phenomenon. Ray would be pleased if any of you readers could tell him if you see soft corals in a similar condition so that we can better correlate observations with environmental parameters.

The crown-of-thorns starfish is also starting to cause some concern with the COTS team receiving reports of higher than usual numbers on many reefs off Lizard Island and Cairns. This will be the first time that an outbreak, if indeed this is an outbreak, has been observed from its origins. I urge all Park users to assist the COTS program, and the Great Barrier Reef as well, by filling in the COTSWATCH forms that complement the formal research and monitoring of this prickly customer.

O, and a Happy New Year.

Ed.

REEF RESEARCH is published quarterly by the Research and Monitoring Section of the Great Barrier Reef Marine Park Authority (GBRMPA).

Readers are invited to submit material for publication. Inclusion is the decision of the Editor. All contributions or inquiries should be addressed to:

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ISSN 103-0692

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AUSTRALIAN INSTITUTE OF MARINE SCIENCE

The Australian Institute of Marine Science is recognised as a leading authority on tropical marine science, and is a world leader in strategic research. Most of AIMS research is continuing to concentrate on understanding coral reefs, mangroves and tropical oceans and their functions. A significant part of the Institute's activities continues to be their liaison with various industries. The seafood, oil and gas, and tourism industries as well as government, environmental and consulting services all frequently utilise the Institute's expertise. Liaising with these industries plays a major part in the national development of expertise in the fields of mariculture, pharmaceuticals, instrumentation and environmental management.

The institute's contribution to the CRC Reef Research Centre includes the use of their scientific facilities and equipment and the expertise of their scientific and technical staff in the implementation of, and participation in, experiments, projects and monitoring programs.

Contact numbers for the Institute are :

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CRC Reef Research Centre

An unincorporated joint venture between:
Association of Marine Park Tourism Operators
Australian Instute of Marine Science
Great Barrier Reef Marine Park Authority
James Cook University
Department of Primary Industries
established under the
Cooperative Research Centres Program

UPDATE - *Chris Crossland*

Centre Activities

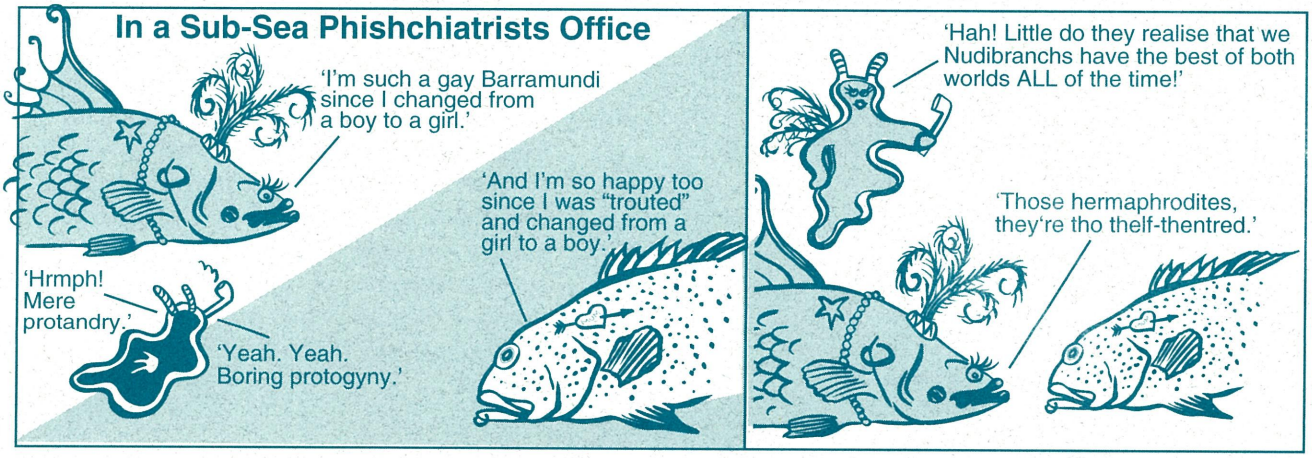
The CRC Reef Research Centre was officially launched in August by the Hon. E J (Ted) Lindsay, Federal Member for Herbert and Parliamentary Secretary to the Minister for Industry, Science and Technology. CRC Board Chairman, Sir Sydney Williams, addressed a large audience of members of Centre Parties and the media. The Centre was again in the news during September with a visit from Senator Peter Cook, who was briefed on the progress of collaborative research, particularly projects undertaken with the tourism industry. The past three months have also seen the compilation and publication of the Centre's first annual report, something of a milestone in the Centre's development. It contains summaries of the 38 research tasks which address 42 key issues identified by industry and managers. In just one year, 163 people have become collaboratively involved in Centre activities - 132 researchers and reef users, 12 postgraduate students, 15 advisory members and the small staff of the Secretariat. Copies of the report have been distributed to a wide range of people, and more are available if required by contacting the Centre.

In the same period the Extension Program has been vigorously expanded. The strategy of the Program is to facilitate communication between Centre stakeholders and to disseminate research results as well as to identify a variety of marketing themes and training opportunities. One of the first initiatives has been to assist various TAFE colleges to develop and run training courses with an emphasis on ecotourism. A certificate course, 'Heritage and Interpretive Tourism', is being developed in collaboration with local industry operators and will begin in Cairns, Townsville and the Whitsundays in 1995.

The SIRENS Project

A major issue for the conservation and ecologically sustainable development of the Great Barrier Reef is whether land-based runoff

Coralations **"Priscilla Queen of the Sea"** **Pongase**



has already reduced water quality enough to contribute to degradation of coral reefs, or whether present trends may in future lead to such degradation. A wide range of research and management agencies are currently addressing elements of this issue: Commonwealth Scientific and Industrial Research Organisation (CSIRO); Queensland Department of Primary Industries (QDPI); Queensland Department of Environment and Heritage (QDEH); Australian Institute of Marine Science (AIMS); Great Barrier Reef Marine Park Authority (GBRMPA); and universities in Queensland and New South Wales.

The Study of Inshore Reefs under Enhanced Nutrients and Sediments (SIRENS) project, an initiative of the Centre, will instigate its own research and seek to maximise the effectiveness of those elements of the research concerning coral reef responses to water quality variations. Planned to begin in 1996-97, SIRENS is intended to be a three to five year 'inshore' successor to the ENCORE experiment currently in progress at One Tree Island (an offshore reef). It seeks to determine key processes and thresholds which may elicit a management or regulatory response to ensure continued viability of coral reefs, their amenity and their resources.

SIRENS will involve a range of research activities based in the vicinity of the Orpheus Island Research Station of James Cook University.

Activities will include, but not be restricted to, experimental manipulation of water quality on sections of a fringing coral reef. Other activities envisaged include:

- hydrodynamic measurement and modelling of delivery and dispersion of sediments and nutrients;
- measurement and modelling of biological responses;
- aquarium studies of tolerance thresholds;
- studies of over-grazing and under-grazing; and
- mapping and measurement of natural spatial and temporal variation in benthic community structure and function within the vicinity of the main study area.

A steering committee has been formed, and researchers and institutions are invited to notify expressions of interest in this new coral reef research initiative by contacting Convenor Terry Done at the Centre.

Research Activities

a) Two full days were set aside in September for researchers from all disciplines to present brief outlines of their progress. More than 50 speakers gave short synopses of their work, with each session followed by questions from the floor. The days provided an opportunity for much informal discussion and exchange of ideas and information, and will be held annually in the future.

b) The Monkman Research Station has opened on Green Island. This has been built by Daikyo to replace the original research station which was demolished to make way for the new resort. The CRC will contribute $20 000 a year to cover upkeep and operating costs, and CRC researchers have free access to the laboratory bench space.

c) The first stage of a pilot study of tourists' perceptions and experiences began in September, with CRC research staff from the James Cook University Department of Tourism conducting surveys of passengers on the Magnetic Island ferries. This is the first psychographic profile of visitors to a world heritage region, and the results will be of immediate benefit to Reef operators in the tourist industry.

d) The Effects of Fishing Experiment (see *Reef Research* 3(3)) will begin in January 1995. The experiment has been designed, final details have been resolved, and the proposal is now in review. During the next six months extensive consultations will be held with recreational and professional fishermen, the tourist industry, and management agencies about their involvement in this major project.

e) A suitable site to carry out field work for the Water Resources and Environmental Pollution project on groundwater has been identified in the Whitsundays, and a visit has been made to inspect the groundwater quality monitoring network already in place on Heron Island. This is currently operated by personnel in the Chemical Engineering Department of the University of Queensland, with whom collaborative links have been established. In addition, a survey requesting information on water supply, wastewater quantities and disposal strategies has been sent to all relevant islands with tourist resorts.

GREAT BARRIER REEF RESEARCH AND MANAGEMENT - PAST, PRESENT AND FUTURE

Graeme Kelleher

There have been many changes in research and management applied to the Great Barrier Reef over the past 15 years. Many of these changes have been introduced as a result of painful experiences. It seemed to me that it would be worthwhile to consider briefly the lessons that we have learned over the past 15 years so that we can minimise the tendency to repeat the mistakes of the past. After all, a commonly accepted distinction between an intelligent person and a dumb one is that the former will learn from other peoples' experience.

How it was

Fifteen years ago research and management relating to the Great Barrier Reef were characterised by disintegration. There was disintegration within the research community, between research institutions and within research institutions and there was a lack of cooperation between management institutions and within them. There was little communication between research institutions and management institutions. The intensity of this phenomenon varied but it sometimes extended to hostility between individuals and organisations.

In those days, little was known about the Great Barrier Reef in physical, chemical, biological or ecological terms.

How it is

Today the situation is very different. There is cooperation between scientific institutions, between different management institutions and between the scientific and management communities. The extent of this integration has increased markedly recently, the most significant evidence of it being the creation of the Cooperative Research Centre for Ecologically Sustainable Development of the Great Barrier Reef. Now, we are less ignorant than we were 15 years ago but we are still far from understanding fully the processes which structure the Great Barrier Reef.

Comparative status

It is probably fair to say that in terms of integration, cooperation, scientific knowledge and its application to management of a large marine ecosystem, the group of researchers and managers working on the Great Barrier Reef leads the world. Nowhere else has there been such a development of specific programs for scientists and managers to work together for common objectives. When we work overseas we see little communication between the scientific and management communities and are surprised to see that this applies in the developing world as well as in the developed.

What have we learned?

The lessons that those of us who have been here for a long time have learned include:

- Scientists and managers must work together continuously if science is to be relevant to management and if science is to be applied to management decisions. It is not enough for the relationship between the two groups of people to be staccato or occasional;

- Science makes mainly marginal increases in understanding. The results are rarely unequivocal. There is dispute even on fundamental issues - in the case of the Great Barrier Reef on whether nutrients are adversely affecting the Great Barrier Reef or on whether trawling adversely affects either the bottom communities or adjacent coral reef communities;

- Managers must make decisions, whether or not unequivocal scientific information is available. We have learned that managers should base their decisions on:
  - trends rather than states,
  - the precautionary principle so that whether there is doubt about the outcome of the matter, the decision should err on the side of preventing environmental damage,
  - priorities i.e. management effort and scientific effort should be related to the importance of the issues. At present we are far from this,
  - managers and scientists, working together, must monitor the results of management decisions and adapt management to the results of that monitoring;

• Managers will never be successful without community support. In a democratic society, governments follow community opinion. Therefore managers and scientists must work so as to achieve community support for decisions which protect the ecology of the Great Barrier Reef;

• There are many enemies, both potential and real in the community. Our mutual efforts will only be successful if we minimise the creation of enemies and maximise the opportunities to identify common interests. A particular example of this is the issue of run-off from the mainland of nutrients and suspended sediments. Farmers are just as interested as we are in preventing the removal of these materials from their farmlands. Our presentations and attitudes should reflect the fact that we recognise the commonality of our interests.

What we should do

The lessons we have learned together over the last 15 years are that if we are to continue to be successful in our objective of providing for the protection, wise use, enjoyment and understanding of the Great Barrier Reef in perpetuity, scientists, managers and the community should work together to:

• Define problems which require a solution and prioritise them;

• Assess how science can help in determining correct management decisions;

• Design research cooperatively;

• Carry out research cooperatively, including publicising and reviewing the research during its progress, so as to both modify the research following preliminary outcomes and keep the public informed;

• Continuously interpret the results for the public and user groups so that outcomes are not unexpected;

• Work together to incorporate the results of research into management decisions, building on formal communication programs so that the public and the community supports, and is prepared for, management decisions arising out of research results;

• Rely on more than one point of communication if there are problems between scientists and managers or between scientists, managers and the community;

• Recognise that scientists and managers have similar ideals, but operate under different regimes. Scientists are driven by the need to provide scientifically reliable results, managers are driven by the necessity to make decisions whether or not the scientific basis for those decisions is adequate. We all must recognise the pressures and the environments within which each group operates.

The future

We are, compared to other areas of natural resource management, both in the sea and on the land, in a very good position. The CRC is providing a very effective mechanism for scientists, managers and the community to work together for the overall objective of ecologically sustainable development of the Great Barrier Reef. We should recognise that there are forces which work against cooperation between the different sectors.

These include:

• self interest and the desire for the maintenance of power, recognising that information confers power;

• arrogance, reflected in the belief that others do not need to know;

• concentration on the urgent rather than on the important;

• the difficulty of communication;

• old habits and prejudices which inhibit communication and cooperation.

If we recognise these negative forces and work determinedly together we have the opportunity of staying ahead of the rest of the world in managing what we all recognise as one of the great natural assets of Australia and of the world. One particular area of research on which I should like to see much more emphasis is the identification of indicator organisms which reflect the 'health' of coral reefs. The public clearly and correctly believes that the essential quality of coral reefs that distinguish them from other marine environments is the presence of hard corals. Acropora are of overwhelming ecological importance, are commonly the colonising corals and appear to be the most vulnerable to some environmental changes. There would, therefore, be advantages in selecting one or more species of Acropora, determining by experiment their sensitivity to environmental changes and monitoring them in places where environmental changes are most likely to occur. The Great Barrier Reef Aquarium and the research aquarium at the Sir George Fisher Centre at James Cook University are facilities at which this work could be done.

LET'S BRING THE SOCIAL SCIENCES INTO THE PICTURE

An outline of the Social, Cultural and Economic Research and Monitoring Program

Dominique Benzaken

The management of the Great Barrier Reef Marine Park (GBRMP) presents a challenge to provide protection and allow for sustainable multiple use. Management of uses and users is achieved primarily by:

- zoning of the Marine Park into areas of permitted activities,
- drafting of management plans in consultation with users,
- strategic planning with major stakeholders, and
- appropriate research and public education.

It reflects the Authority's philosophy of management 'through the community's commitment to the protection of the Great Barrier Reef and its understanding and acceptance of the provisions of zoning, regulations and management practices' (1992/93 Annual Report, p. 7). Effective management of activities taking place in the Great Barrier Reef Marine Park therefore requires appropriate knowledge and monitoring of uses and users.

The role of research-based information in assisting management decisions can be appreciated through the research effort of GBRMPA both in terms of expenditure and research output since its creation. However, while management has been primarily concerned with acquiring biophysical knowledge of the Reef, the integration of social knowledge into decision-making processes has taken place primarily through public consultation. Public participation, while being a forum for managing social and cultural impacts, does not replace the systematic collection of critical social, cultural and economic information which should be the basis for informed decisions.

What can the social sciences contribute to better planning and management of the Great Barrier Reef?

The 'social sciences' refer to a range of disciplines which have methods, processes, and theories pertinent to environmental management. These include economics, politics, history, geography, anthropology, archaeology, psychology, sociology, cultural studies, media and communications. For example, recreational management draws upon social and environmental psychology theory and practice, cultural heritage management from archaeology and anthropology and environmental decision making from politics, law and sociology. Public participation, mediation and conflict resolutions derive from sociology, psychology and communication studies, whereas the study of cultural and social values and attitudes towards the environment derive from environmental psychology, sociology, cultural studies and history.

The social sciences have traditionally been concerned with the study of socio-political, cultural and economic systems with minimum reference to the interface with natural systems, except for geography, which is about 'people and places'. Likewise, physical and biological sciences have been mainly concerned with developing an understanding of natural systems with little reference to human systems. Environmental management has emerged from the latter tradition and has focused on managing the impacts of human activities on natural systems rather than managing the activities themselves. The integration of social, cultural, ecological and economic values into resource management is the challenge facing environmental organisations if they are to achieve the internationally and nationally set objectives of Ecologically Sustainable Use. The 25 Year Strategic Plan for the Great Barrier Reef World Heritage Area and the Great Barrier Reef Marine Park Authority Corporate Plan reflect the commitment of the Authority to those goals.

Strategic and corporate objectives

GBRMPA is a vital participant in the implementation of the 25 year Strategic Plan for the Great Barrier Reef World Heritage Area. The GBRMPA Social, Cultural and Economic Research Program will contribute to the 25 year vision through the implementation of specific objectives

and strategies in the areas of research and monitoring, recognition of Aboriginal and Torres Strait Islander interests, resource management, education, communication, consultation and commitment, and conservation.

The Strategic Plan 5-year objectives provide broad directions for social research:

- 'To improve the capacity to determine ecologically sustainable levels of tourism and recreation and their effects on visitor experiences and attitudes.' (Strategic Plan 4.8)
- 'To provide additional information on the socio-economic characteristics and impacts of major human activities affecting the Area.' (Strategic Plan 4.9)
- 'To develop, in conjunction with Aboriginals and Torres Strait Islanders, an understanding of their marine resource use, management practices and maritime knowledge.' (Strategic Plan 4.10)
- 'To improve the capacity to determine the economic values of selected major biological communities and uses of the Area.' (Strategic Plan 4.14)
- 'To ensure that projects related to the social, cultural and economic interests of Aboriginals and Torres Strait Islanders are included in research and monitoring programs.' (Strategic Plan 6.5).

The Corporate Plan sets 1994-1995 objectives for the development of a social, cultural and economic program:

- 'To have research programs which are integrated and coordinated with those of the CRC Reef Research Centre and other organisations.' (Corporate Plan 1994-1999, 1.10.2)
- 'To have completed investigations, relevant to the Far Northern Section, into:
  - the types of Reef experiences desired by users;
  - the types of Reef experiences presently available to Reef users; and
  - social and economic impacts of use, and
  - subsistence values.' (Corporate Plan 1994-1999, 2.1.1)
- 'To have the information required to review the Far Northern Section collated in an accessible form.' (Corporate Plan 1994-1999, 2.6.1)
- 'To have an improved understanding of Aboriginal and Torres Strait Islander maritime practices in the Far Northern Section.' (Corporate Plan 1994-1999, 2.14.1)
- 'To have enhanced mechanisms for communicating information needs and priorities.' (Corporate Plan 1994-1999, 3.9.1)
- 'To have regular in-house seminars to address key management issues and related research and monitoring information.' (Corporate Plan 1994-1999, 3.10.2)
- 'To have developed and implemented a socio-economic research program.' (Corporate Plan 1994-1999, 3.10.5)
- 'To have enhanced understanding by staff and the public of decision making processes, and the role of science in decision making.' (Corporate Plan 1994-1999, 4.3.5)

Approach to program development

The Social, Cultural and Economic Program has been active since April 1994. During that period, efforts have been made to integrate and focus various initiatives of the Authority and associated organisations to address issues relating to uses and users of the Marine Park. The program was developed through consultation with GBRMPA staff, the Great Barrier Reef Consultative Committee and the CRC Reef Research Centre. Planning and management issues were identified, analysed and prioritised taking into account corporate goals, the nature and importance of issues, long-term information needs, current planning and management, existing projects and social data collection.

The objectives of the Program are:

- to collect information on social, cultural and economic information of relevance to the planning and management of the Great Barrier Reef;
- to actively promote the integration of social, cultural and economic information into decision making and policy development;
- to review the effectiveness of educational, public participation and social impact assessment procedures and programs for planning and management;
- to produce an inventory of uses and a profile of users in a format that is useful for planning and management;
- to develop programs for the monitoring of social, cultural and economic impacts of uses for planning and management;
- to develop a strategy for social information management in collaboration with the CRC Reef Research Centre and GBRMPA sections; and
- to liaise with and inform users (including GBRMPA) of the results of the program in a suitable format and to be receptive to user needs.

The strategies to achieve those broad objectives are to develop a program which:

- reflects strategic and corporate directions, planning and management needs and which is sensitive to stakeholders' views;
- integrates social science research with existing and future research programs and promotes multi-

disciplinary projects within GBRMPA and with the CRC Reef Research Centre and other institutions;

• involves stakeholders (users, planners and managers) in research projects, as appropriate, in a way that promotes ownership; and

• provides avenues for information flow to, and discussion with, a range of audiences about social, cultural and economic issues of relevance to the planning and management of the Great Barrier Reef.

An integrated information management strategy for the long-term collection of social, cultural and economic information will be developed. It will consider protocols for information collection, storage and access and procedures for integration of a range of information types into the GBRMPA Geographic Information System.

1994-1995 program

A number of projects are currently under way. They focus on:

- the current review of the Far Northern Section Zoning Plan;
- developing an approach for long-term data collection and monitoring;
- developing links between research, planning and management and the CRC Reef Research Centre and
- workshops and discussion papers which explore, document and propose options for addressing some of the planning and management issues identified early in the process.

The projects will provide a sound basis for future research and a number are summarised below.

Projects relating to the review of the Far North Section

The 'Far Northern Section Attitude Survey' seeks information on community support (nationwide) for actively managing undeveloped settings for primitive recreational opportunities in the Far Northern Section.

The 'Ecotourism Opportunities in the Far Northern Section' project consists of developing an inventory of marine and coastal ecotourism opportunities and evaluating and integrating planning mechanisms for maintaining those opportunities. This project is complementary to a CRC Reef Research Centre project on wildlife ecotourism being undertaken by Peter Valentine and Dr Alistair Birtles.

The uses of community based information, specifically from Aboriginal and Torres Strait Islander people, are being discussed within the context of planning. These include a consideration of protocols, collection, storage, access, and integration into the GBRMPA Geographic Information System.

A discussion paper on public participation strategies is being prepared jointly with Planning and Management Section staff to assist with the review of the Far Northern Section.

The use allocation project

The development of an action plan for the coordination and facilitation of a range of actions to address issues of resource allocation in the GBRMP has been initiated. It will include a case study on the Bramble Reef Replenishment Area (see below), workshops and the writing of issues and options papers. The integration of the range of outputs will be used for policy development. Important outputs will be the development of social impact assessment guidelines.

The Bramble Reef Replenishment Area will be reopened to fishing in July 1995. The project seeks to explore the effectiveness of management tools for resource allocation. It will identify and monitor socio-economic as well as environmental indicators of change, assess the relative value of social and environmental indicators for management and develop a process of negotiation for use allocation decisions based on the best combination of indicators of change.

Economics

A discussion paper on the role of economics in decision making has been prepared. It documents available economic models relevant to the management of the Great Barrier Reef World Heritage Area and Great Barrier Reef Marine Park and identifies and evaluates the range and appropriateness of economic instruments for informed decision making.

The visitor statistics strategy

This project seeks to assess existing data collection instruments and their relevance to management needs and will propose a framework for the long-term collection of relevant user statistics. This project is complementary to two CRC Reef Research Centre projects: the 'Analysis of Great Barrier Reef Visitors' undertaken by Professor Philip Pearce and the 'Visitor Use Patterns' project by Mr Peter Valentine.

The findings of various projects will be presented in later issues of *Reef Research*.

Coral Reefs and Scuba Divers

IDENTIFYING AND ASSESSING THE EFFECTS OF SCUBA DIVERS ON HARD CORAL ASSEMBLAGES

*Tony B. Rouphael**

With the growth in popularity of SCUBA diving in the last two decades, resource management agencies, reef tourist operators and environmentalists are beginning to express concern at the potential for increased coral damage at some of the more popular dive sites. In response to this concern, the Pacific Asia Travel Association Foundation and Dive Queensland have instigated a study to investigate the potential impact on hard coral assemblages associated with recreational SCUBA diving. This study is currently being carried out by researchers from James Cook University of North Queensland and the CRC Reef Research Centre, Townsville. Quicksilver Connections and Quicksilver Diving Services (both of Port Douglas) are providing the logistical support needed to undertake this project.

A primary objective of this study will be to develop a 'standardised' technique with which to identify and assess damage to corals by SCUBA divers at established dive sites. This will be of particular importance for both coral reef management agencies and tourist operators who must ensure that use of individual sites does not compromise their ecological or aesthetic values. The focus of this study will not be confined simply to assessing symptoms associated with this recreational activity on coral assemblages. It will also identify and suggest management strategies that may minimise or prevent future impact.

To achieve these objectives we need to learn more about the ways SCUBA divers interact with coral assemblages and identify the short-term and long-term consequences of these interactions. One way of doing this is to describe the behaviour of recreational SCUBA divers underwater and make observations on the type and severity of interactions between divers and corals. Such a behavioural study has been instigated under the present research program and is now providing valuable information on the ways SCUBA divers affect specific coral assemblages. The aim of this paper is to present a brief summary of this study, identifying the methodology used, and some preliminary findings.

Methodology

Between February and May 1994, 179 SCUBA divers were observed at a range of dive sites on Agincourt reef in the Cairns Section of the Great Barrier Reef. All divers were qualified and ranged in experience from having completed one open water dive since certification through to having completed 100 or more logged dives. Approximately 70% of these divers had completed 60 or less dives since certification.

Divers were observed over six separate sites. These sites were selected to represent three common reef habitat types. Two sites each were characteristic of: shoulder dives - the corals occurred on a sloping bottom; pinnacle dives - the dive was centred around a pinnacle with a near vertical face; and garden dives - the corals occurred on a flat or horizontal bottom. At each site, individual divers were selected at random from the dive party and were observed for 10 minutes during a 30-minute dive. This time interval allowed at least three divers to be observed on most dives. Partitioning each dive into three separate time periods (for example, the first 10 minutes of a dive or the second 10 minutes) allowed the research team to identify whether

more damage occurred at the beginning, middle or end of a dive.

Results

Of the 179 divers observed, most divers (84%) did not damage corals. The remaining proportion (16%) were responsible for a number of coral breakages (figure 1). Usually, only small fragments were broken from the tips of branching corals. A total of 144 coral fragments were generated in this way. Fragmentation (asexual reproduction) is a 'natural' propagation mechanism for many hard corals, however, the survivorship of individual fragments is dependent on a number of factors including fragment length, species and on the physical environment in which they reside.

Seven divers were responsible for 101 fragments, or 71% of the total. Further, five of these divers were underwater photographers, while another was unable to control his buoyancy (he possessed an old fashion horse-collar vest). Future studies will be done to determine more conclusively if underwater photographers are more likely to damage corals than non-photographers.

All hard coral breakages were restricted to those with branching growth forms. Two individual soft corals were also observed to lose single fragments on separate occasions. The flexible body of soft corals greatly minimises the risk of these organisms being damaged.

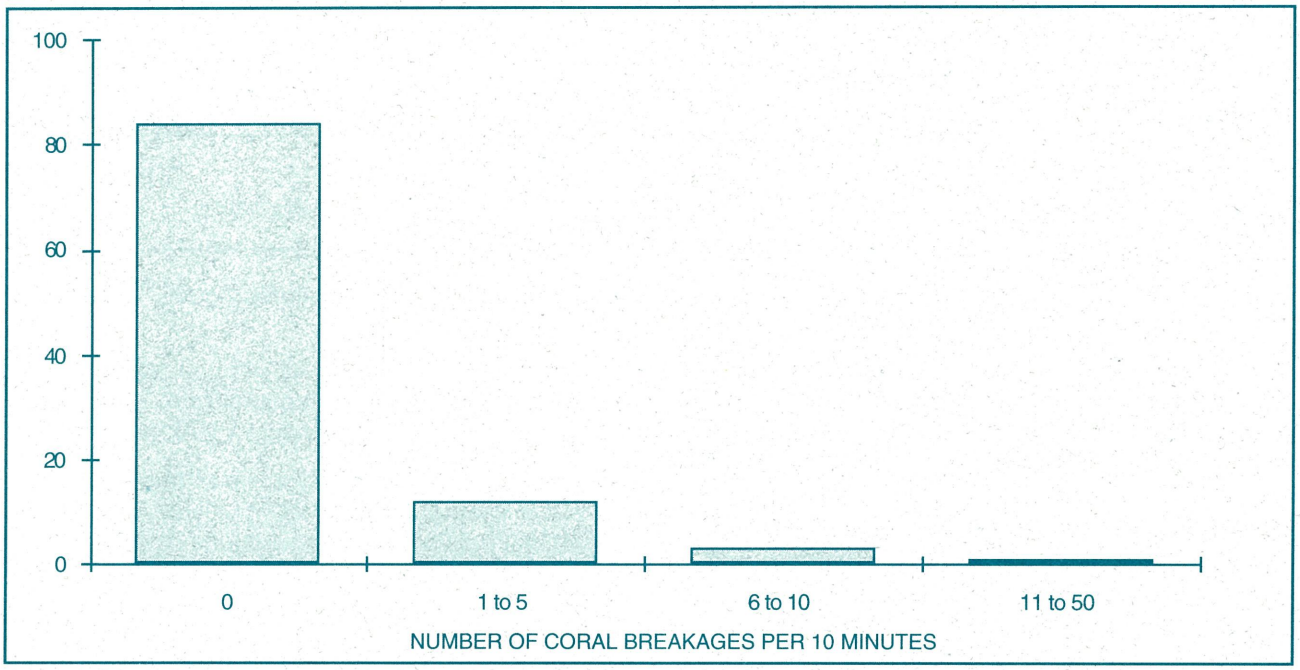
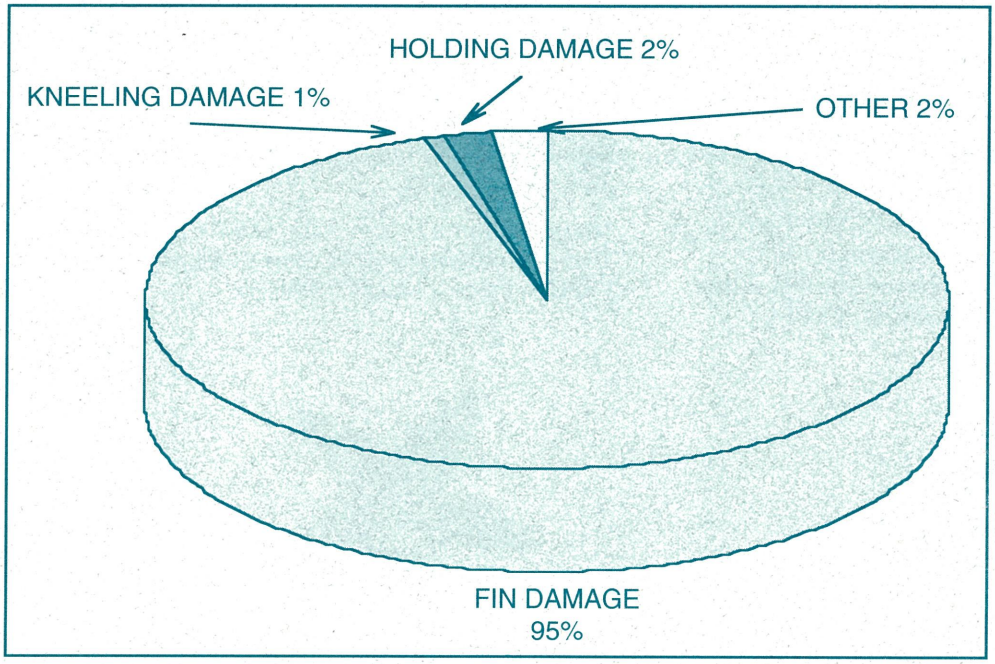


Figure 1. *The number of coral breakages per 10-minute interval*



By far the largest cause of coral breakage by divers was through contact with their fins (figure 2). In comparison, contact by consoles (depth gauges), holding or kneeling on corals resulted in considerably fewer breakages. Such a high proportion of the damage attributable to contact by fins suggest poor buoyancy control is a major contributing factor.

Figure 2. *Causes of coral damage by SCUBA divers*

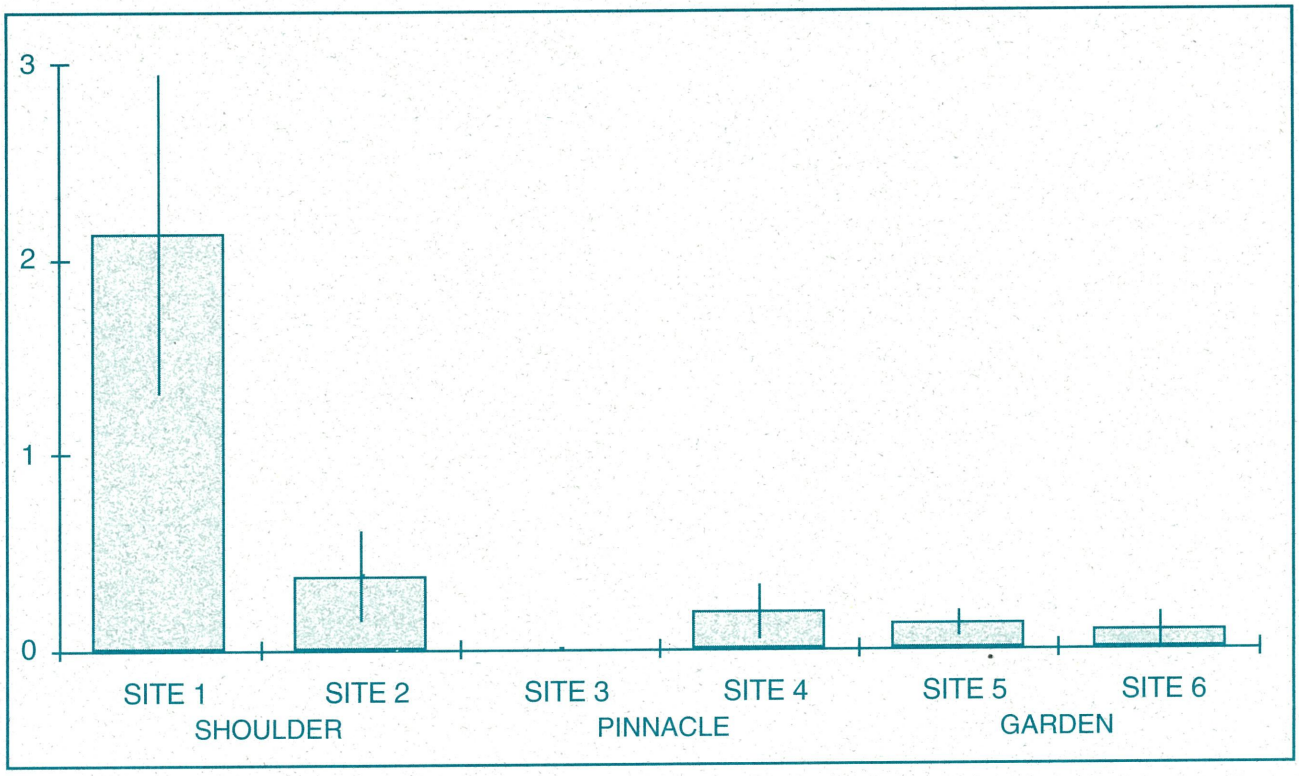


Figure 3. *The mean rate of breakage per diver per site per 10-minute time interval (mean standard error)*

Figure 3 illustrates the mean number of breakages recorded for the six study sites. Preliminary findings suggest that the incidence of breakages is not related to the general topography of the dive site, but is strongly related to the characteristics of the individual sites. For example, site 1, which recorded the highest mean breakage rate also had the highest coverage of branching coral colonies. Conversely, sites with low branching coral cover also recorded the lowest breakage rates.

Conclusion

These preliminary results are already providing important insights into the ways SCUBA divers affect coral assemblages in specific coral reef environments. For example, some dive sites are likely to be more susceptible to impacts by divers than other sites because of greater fragile branching coral cover. The findings also suggest that specific activities associated with SCUBA diving, such as underwater photography, may increase the likelihood that divers will break corals. Perhaps the most significant finding of this study is that the majority of certified SCUBA divers observed did not cause any physical damage to corals. Most damage (70%) recorded were attributable to fewer than 4% of the divers.

The next step will be a long-term monitoring study to examine the effects of SCUBA divers on coral reef benthos at newly established dive sites. The aim of this study is to identify whether signs of physical damage, such as recently broken coral colonies or abnormally high rates of fragmentation, increase at these sites in response to visitation by high numbers of SCUBA divers. Knowledge gained from both the behavioural study and the monitoring program should greatly improve our understanding of the ways SCUBA divers can affect tropical benthic assemblages. This, in turn, will lead to the better management and use of SCUBA diving sites within the Great Barrier Reef and in other coral reef environments around the world.

**Tony is a Masters Degree student with the Department of Tropical Environmental Studies and Geography at James Cook University of North Queensland.*

Much is happening around Australia in relation to marine oil spill activities at present, with the State of Queensland arguably leading the way. In this edition of Slick Talk we provide an update on a number of initiatives that the Queensland Government is undertaking.

Queensland Government Takes Spill Responsibilities Seriously

One outcome of the 1993 review of the National Plan to Combat Pollution of the Sea by Oil (the National Plan) was a transfer of lead agency responsibilities for responding to oil spills within the Great Barrier Reef region from the Australian Maritime Safety Authority (AMSA) to the Marine and Ports Division of the Queensland Department of Transport (QDoT). The QDoT Regional Harbour Masters are now designated as the On Scene Coordinators (OSCs) for spills within the Reef Region. Previously, QDoT had lead agency responsibility for State waters out to three nautical miles and AMSA took over beyond three nautical miles. Obviously, oil spills do not respect lines on maps and the new arrangement ensures that a more practical, rational and streamlined response structure is in place. A remaining anomaly is that within designated port limits, the relevant port authority is the lead agency for responding to oil spills. If this responsibility was also transferred to QDoT there would be a single lead agency for all marine waters adjacent to Queensland, which could only result in a more efficient and effective oil spill response capability.

In line with its inheritance of lead agency responsibility for Great Barrier Reef spills, QDoT has embarked on a program of procuring additional oil spill response equipment to bolster what is already stockpiled in the State under National Plan funding arrangements and by the oil industry.

Major items of equipment recently purchased or on order by QDoT include:

- Eight Porta-Tanks, each with a storage capacity of 10 000 litres and which can be erected by two people, without tools, in under ten minutes. Temporary storage of recovered oil can pose a significant problem during an oil spill clean up, especially in sensitive coastal areas where acceptable disposal sites are limited. The availability of these Porta Tanks in Queensland, which as their name suggests are highly portable, will help to ease this problem until supplementary resources arrive and more permanent solutions are identified.
- Eight Pacific Alpha skimmers; a simple suction/weir design manufactured from stainless steel and intended for use in calm harbour conditions. This skimmer can be connected directly to a vacuum truck and has an oil recovery capacity of 3000 litres of light to medium viscosity oil per hour.
- Five Pacific Boat Spray Units; consisting of a pump and spray booms, designed for the application of modern third generation oil spill dispersants from small to medium sized work boats. The pump can double as an oil transfer pump to remove oil from damaged tanks and minimise further spillage.
- Two Marco Class 1 Oil Recovery Vessels (one currently under sea trials and the second to be purchased during 1995); for use within ports and coastal waters.

The Porta-Tanks and Marco Oil Recovery Vessels are built in Queensland, and the Alpha Skimmers and Boat Spray Units are built in Australia, in line with QDoT's preference for purchasing oil spill equipment locally, wherever possible.

When combined with current additional purchases of equipment by the National Plan, including additional offshore boom, the QDoT contribution marks a reasonable improvement in operational capability to deal with oil spills in Queensland. QDoT should be applauded for this initiative since most other State Governments in Australia rely on the oil industry and the National Plan to provide oil spill response equipment in their States.

New Marine Pollution Act for Queensland

Another significant initiative of QDoT in recent months is the completion of drafting of the Queensland Transport Operations (Marine Pollution) Bill, which at the time of writing (October 1994) was before the State Parliament. The Bill proposes to implement the MARPOL Convention in State waters, bringing Queensland into line with Federal legislation. As such the proposed legislation will not only apply to oil but also other ship-sourced pollutants covered by the MARPOL Annexes, namely Garbage, Noxious Liquid Substances and Harmful Packaged Substances. The Bill has provision for regulation of ship sourced sewage, including requirements for holding tanks and pump-out facilities, and can be amended to incorporate any new Annexes of MARPOL that might be developed to control ship sourced air pollution and ballast water. This is a significant improvement on the preceding Queensland *Pollution of Waters by Oil Act 1973* which regulated discharges of oil only.

The Transport Operations (Marine Pollution) Bill will also give the Queensland Government the power to require the provision of waste reception facilities in ports, and gives legislative backing to oil spill response plans and operations. Fines for offences under the new Act may exceed $1 million. The Act will be administered by the Marine and Ports Division of QDoT.

Southern Surveillance Sorties

Legislation such as the new Transport Operations (Marine Pollution) Act can only be effective if there is an appropriate level of surveillance and enforcement capability to support the legislation.

Much of the eastern and northern coast of Queensland is currently well-covered by both Great Barrier Reef Marine Park and Coastwatch surveillance flights, which, among other tasks, maintain a watch for oil spill incidents and illegal discharges. However, the south-east coast of Queensland, which receives a lot of shipping traffic servicing Brisbane, Bundaberg and Gladstone, is largely unprotected by aerial surveillance.

QDoT has identified this 'gap' in the system and conducted some trial surveillance flights over the area from the New South Wales border to Gladstone in early 1994. These trials proved useful and at the time of writing QDoT were finalising contractual details for the commencement of regular aerial surveillance over this area.

In addition to improving oil spill detection and enforcement capabilities, such an aerial presence also provides an important deterrent factor, and will hopefully reduce the regular 'operational discharges' which have frequently impacted on southern Queensland beaches in recent years.

Surveillance flights can also be useful for collecting data on shipping movements, frequency of discharges and identifying particular problem areas and shipping types. This can then be used to support contingency planning and targeting particular problem areas and shipping types for education or perhaps more intensive surveillance and enforcement effort. It is important that all data collected by the QDoT flights in southern Queensland are statistically meaningful, compatible with the data collected by the Marine Parks and Coastwatch flights in the north and made available for inclusion in the OILSPILL database maintained by AMSA in Canberra. It is not clear whether this has been provided for by QDoT.

An area of Queensland that remains largely 'unprotected' is the Gulf of Carpentaria. There is some Coastwatch activity here and the Queensland Boating and Fisheries Patrol conducts occasional surveillance flights in relation to fisheries enforcement. The AMSA OILSPILL database has indicated that of all vessel types, fishing vessels are the most frequent dischargers of oil. Given the intensity of commercial fishing activity in the Gulf of Carpentaria, the sensitivity of environmental resources (including fisheries resources) in this area and the increase in other shipping types using the Port of Karumba (including livestock carriers with additional pollution concerns under MARPOL), there appears to be a need for a more regular marine pollution aerial surveillance presence in the Gulf.

(Steve Raaymakers is currently Manager, Environment and Communication with the Ports Corporation of Queensland. The views expressed through his continued authorship of 'Slick Talk' are not necessarily those of the Ports Corporation nor GBRMPA).

What's out there

SICK SOFT CORAL SYNDROME - SUBTERFUGE OR CAUSE FOR CONCERN?

Ray Berkelmans and Hamish Malcolm

The Sunlover pontoon site at Arlington Reef is different from other pontoon sites in that the hard substratum is dominated by soft corals. During a site visit in December 1993, a large proportion of the soft corals appeared to be dead or dying. Colonies were contracted and covered with mucus and sediment. Many colonies also had turf algae growing on them. The apparent health of the colonies was so poor that it was difficult to identify the species affected.

Concern turned into mild alarm when video footage taken during the site visit was viewed by several coral ecologists - nobody had seen these symptoms before. The extent and cause of these apparently sick corals were cause for concern to both the Great Barrier Reef Marine Park Authority (GBRMPA) and the operator. From Sunlover's perspective, the death of a large number of soft corals would almost certainly have meant a reduction in the aesthetic appeal of this site, which in turn may have reduced the tourism potential and economic viability of this operation. From a management perspective, GBRMPA was keen to know if the problem was unique to this pontoon site (suggesting anthropogenic causes), or if it was more widespread.

The plot thickens ...

To our surprise, when we returned to survey the pontoon site and surrounding bommies three weeks later (January 1994), most of the soft corals appeared to be healthy. There were no direct signs of mass mortality (bare substratum with presence of spicules) or indirect signs of mortality (fresh, bare hard substratum). If it were not for the video proof of condition of the site during the first visit, our sanity might have been seriously questioned.

To quantify the change in the proportion of soft corals affected between the two surveys, five 50 m transects were videoed and the number of affected colonies and the number in good apparent health were counted. The results confirmed the reduction in the number of affected colonies at the pontoon site over this three-week period; on average, 13% of all soft corals were affected in December 1993 compared to about 2% in January 1994 (figure1).

To assess whether affected soft corals were restricted to the Sunlover pontoon site or were distributed equally over the whole area, percentage cover and condition of soft corals were determined using line intercepts from five transects (each of 50 m length) at the pontoon snorkelling area and at each of two spatial control sites - one 300 m east of the pontoon (Site 1) and one 500 m west of the pontoon (Site 3).

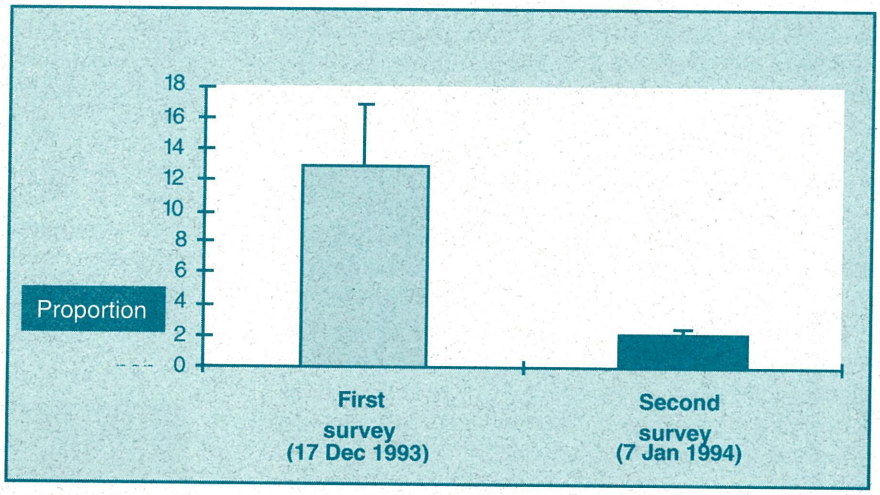


Figure 1. Proportion of soft coral colonies affected (+/- standard error) at the Sunlover snorkelling pontoon

Although only a small proportion of corals appeared affected during the second survey, the results show that corals in this condition were not restricted to the pontoon site. In fact, more corals were affected at Site 1 (about 7% of all soft corals) compared with the pontoon site and Site 3 (less

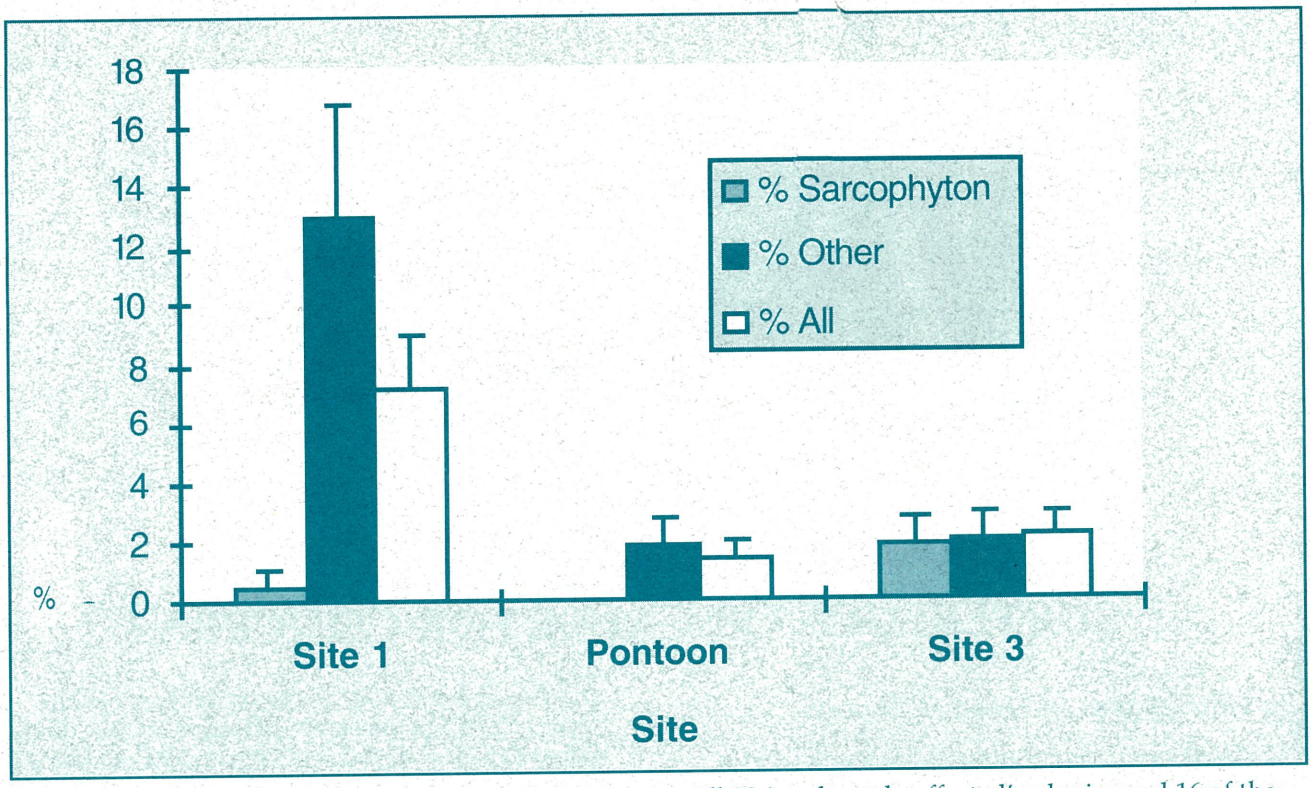


Figure 2. Percentage of soft coral cover affected (+/- standard error). Site 1 = 300 m E of Sunlover pontoon, Site 2 = Sunlover snorkelling pontoon, Site 3 = 500 m W of pontoon, (n = 5 x 50 m line intercept transects per Site)

than 3% of all soft corals) (figure 2). Soft coral cover was highest at the pontoon site at around 42% and lowest at Site 1 at around 30%. This infers that the condition of the soft corals was probably not a result of the pontoon operation.

One mystery solved ...

So how did the soft corals manage such a miraculous recovery? The answer to this question became clear towards the end of our surveys when we came across a *Sinularia* colony which was half way through shedding a thick mucus layer. Half of the colony was expanded and in apparently good health while the other half was still contracted and covered in turfing algae and sediment. Pieces of mucus, still containing sediment and algae, were lifting off at the interface between the two halves of the colony, revealing healthy soft coral tissue underneath (figure 3).

In order to determine the recovery rate of affected corals, forty soft corals were tagged during the January survey and reassessed one month later in mid- February. Twenty of the tagged colonies were moderately affected (colonies contracted and covered with mucus and sediment) and another twenty colonies were badly affected (contracted, mucus and sediment covered and covered in turf algae). Tags were nailed into the limestone substratum adjacent to soft corals to avoid stressing corals or contributing to any existing stress. Tissue samples were taken from affected colonies for identification; the majority of the tagged soft corals were *Sinularia polydactyla*, however three *Isus hippurus* and one *Sarcophyton* sp. were also included in the sample.

All 20 'moderately affected' colonies and 16 of the 'badly affected' colonies were found in the resurvey. Overall, 91% of all the tagged colonies had either recovered or were in the process of recovery after 29 days (figure 4). Of the 'moderately affected' colonies, 60% had already recovered while the rest were in the process of shedding their mucus layer. Fewer 'badly affected' colonies had recovered at this time (30% completely, 50% partially). Two colonies in the 'badly affected' category had died, while one colony showed no signs of recovery. These last three colonies were all *S. Polydactyla*.

More questions raised ...

Although the formation of mucus sheets on certain hard corals (such as *Porites*) and soft corals has been documented in the scientific literature (e.g. Coffroth 1984, 1985, 1988; Coll et al. 1987), this phenomenon is not well known to tourist operators, environmental managers and also many coral ecologists we spoke to in making our enquiries. This may in part be due to the fact that much of the scientific literature deals with biochemical aspects of mucus sheets and their value as a food source to bacteria and higher trophic animals. Few papers actually convey a

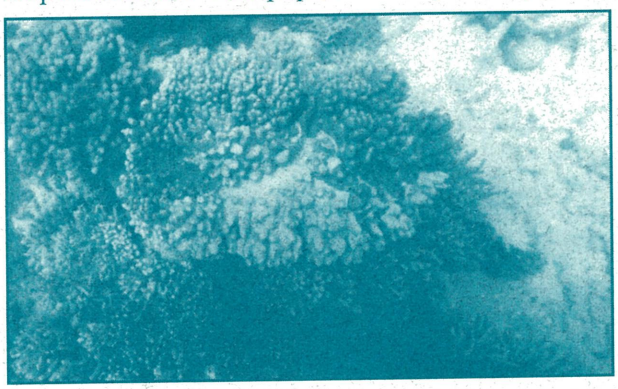


Figure 3. *Sinularia polydactyla* in the process of shedding its mucus layer

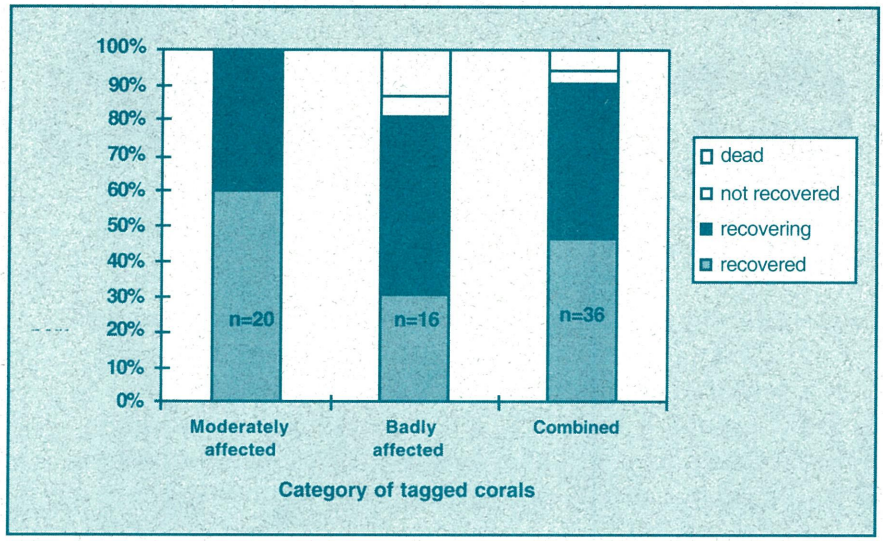


Figure 4. Status of tagged colonies on 14 February 1994; 'Moderately affected' = soft corals covered in mucus and sediment on 7 Jan 94 (n=20); 'Badly affected' = soft corals covered in mucus, sediment and algae on 7 Jan 94 (n=16)

good description of how strikingly ominous the condition of soft corals can appear to the ignorant observer when soft corals are contracted and fouled with sediment and algae.

The role and significance of mucus sheets is not well understood. Corals (both hard and soft) are known to secrete large amounts of mucus more or less continually, but this mucus is fairly watery and is moved over the surface of the coral by cilliary currents. Coffroth (1988) suggests that when corals are under stress, mucus production and cilliary movement slows down or stops and the mucus transforms into a transparent film which quickly becomes fouled with sediment and algae. These transformed mucus films (or sheets) have been speculated to function as a protective covering during adverse environmental conditions and also as food for bacteria, detritus and filter feeders. However, field observations have so far failed to correlate mucus sheet formation in the soft coral, *Briareum asbestinum*, with any environmental conditions, including sediment, temperature, salinity and particulate matter (Coffroth 1988). *In situ* experiments simulating stressful environmental conditions have also failed to increase rates of mucus sheet formation in treatment corals over control corals (Coffroth 1988). While such environmental conditions have been shown to induce mucus sheet formation in hard corals in the genus *Porites*, these corals have also been shown to form mucus sheets on lunar cycles (Coffroth 1985). In our study, two weeks of persistent 20-25 knot south-easterly winds preceded our observations of mucosed soft corals in the first survey. Whether the environmental conditions associated with these winds caused the mucus sheets to form is not known. However, some colonies which were definitely not mucosed in January were mucosed in February. No obvious bad weather occurred during this time, supporting the notion of a cyclic pattern.

The periodicity of mucus sheet formation in *B. asbestinum* has been found to average 10-11 days (Rublee et al. 1980; Coffroth 1988), but in the soft coral, *Lobophytum pauciflorum*, mucus sheets have been recorded to last up to 7 weeks (Coles et al. 1987) and in another soft coral, *Alcyonium digitatum*, up to 5 months (Hartnoll 1975).

No mortality rates of mucus covered soft corals are reported by these authors. We found that two out of sixteen colonies in our sample died in the 29 days between surveys. Although no firm conclusions can be drawn from these few data, it is tempting to think that there is more to mucus sheet formation than simple routine cleaning - it could well be a sign of stress from which corals may or may not recover.

In conclusion, the unhealthy appearance of many of the soft corals at Arlington Reef was due to the soft corals being contracted and covered in a tight mucus layer which had become fouled with sediment and filamentous algae. Most regained their normal healthy appearance when the mucus layer was shed after a month or so. The extended area (up to 500 m from the pontoon) over which these corals were found, indicates that this phenomenon is probably a natural one, unrelated to the tourist pontoon. This is supported by similar observations on other soft coral dominated reefs (pers. observ.), and by other published studies. However, the significance and role of these mucus sheets, especially in relation to environmental stress, is still not well understood. In addition, what these symptoms mean in terms of potential death of soft corals remains to be studied.

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COTS COMMS

Dr Brian Lassig and Udo Engelhardt

In his review of the Authority's crown-of-thorns starfish program in 1991, Dr Robert Johannes recommended the development of contingency plans identifying research and management actions to be activated in the event of a new crown-of-thorns starfish (COTS) outbreak. Dr Johannes noted that the response to previous outbreaks had been slow and that because of the delays some valuable opportunities for research were lost. For example, investigations into the initial causes of outbreaks can only be carried out in the very early stages of an outbreak.

Great Barrier Reef Marine Park Authority (GBRMPA) and Australian Institute of Marine Science (AIMS) staff developed the framework of a COTS contingency plan and presented it at the 7th International Coral Reef Symposium in Guam in 1992. The plan concentrates on the vital step of detecting any COTS population increases and quickly establishing the scale of those increases. Since 1992 there has been a concerted effort to refine the plans and to supplement them with practical tools for responding appropriately to any future increases in COTS numbers on the Great Barrier Reef (GBR). The contingency plan has withstood the test of time. Although there have been a few unanticipated changes (all improvements), the principles of the plan have been followed.

Monitoring is the lynch-pin of the contingency plan. With collaborative monitoring arrangements involving GBRMPA, AIMS and Reef-User groups we are now in a unique position to record changes in COTS populations on the GBR. The fact that relatively minor increases in COTS numbers on a number of northern GBR reefs have been detected is testimony to the effectiveness of this monitoring. Additional fine-scale surveys were implemented this year. Although the project has just started it is already providing detailed information on COTS populations from a good sample of reefs between Innisfail and Lizard Island (see *Current COTS*).

During the last outbreak GBRMPA was strongly criticised by a few scientists and some journalists for its policy of limited intervention (i.e. not attempting to kill all of the starfish on the Reef). Accusations were also made that GBRMPA and AIMS were concealing the truth about the seriousness of damage to the GBR. While we can never avoid accusations being made, we have devoted a considerable amount of our time and program resources to ensure that information on the program and its results have been widely and frankly disseminated. We have produced booklets and a video giving details of the results of the research and monitoring and most readers would be familiar with the frequent appearance of COTS in the media. A detailed scientific review of the last five years of the program is nearly completed. We have actively pursued opportunities to promote the COTS program, its achievements and the uncertainties of the phenomenon, in the hope that informed opinions are likely to be more rational. This proactive approach will hopefully mean we can spend more time trying to advance the state of our knowledge about COTS and less time on fire-fighting.

Recognising the importance of COTS to the north Queensland reef-based tourism industry, we are working closely with the industry on a number of issues. This financial year the CRC Reef Research Centre (which has strong industry representation) established a COTS program and is funding five projects of immediate benefit to both the tourist industry and GBR management. A number of Cairns and Port Douglas based operators, as well as the Queensland Department of Environment and Heritage (QDEH) and GBRMPA staff, donated substantial amounts of their time to work with us earlier in the year to develop some practical guidelines for responding to reports of increasing COTS numbers on reefs in that area. The workshops resulted in a booklet *Planning for COTS Population Increases: Management and Industry Roles & Responsibilities*. Copies of the booklet should be available early in 1995.

Finally, we have investigated new techniques that could be used to control local COTS populations. We are now in a position to recommend an environmentally friendly alternative to copper sulphate (see *COTS Controls*). Again, members of the tourist industry provided considerable assistance in making this achievement possible.

The take home message from this introduction is that we've come a long way in the last couple of years. While we don't know whether or not the currently observed increase in COTS numbers is the early stage of another outbreak, we are in the best ever position to respond in an appropriate manner and to respond in a record-breaking time. We're in this unique position because of the dedication, commitment and concern of a very large number of people from all sectors of the community.

CURRENT COTS

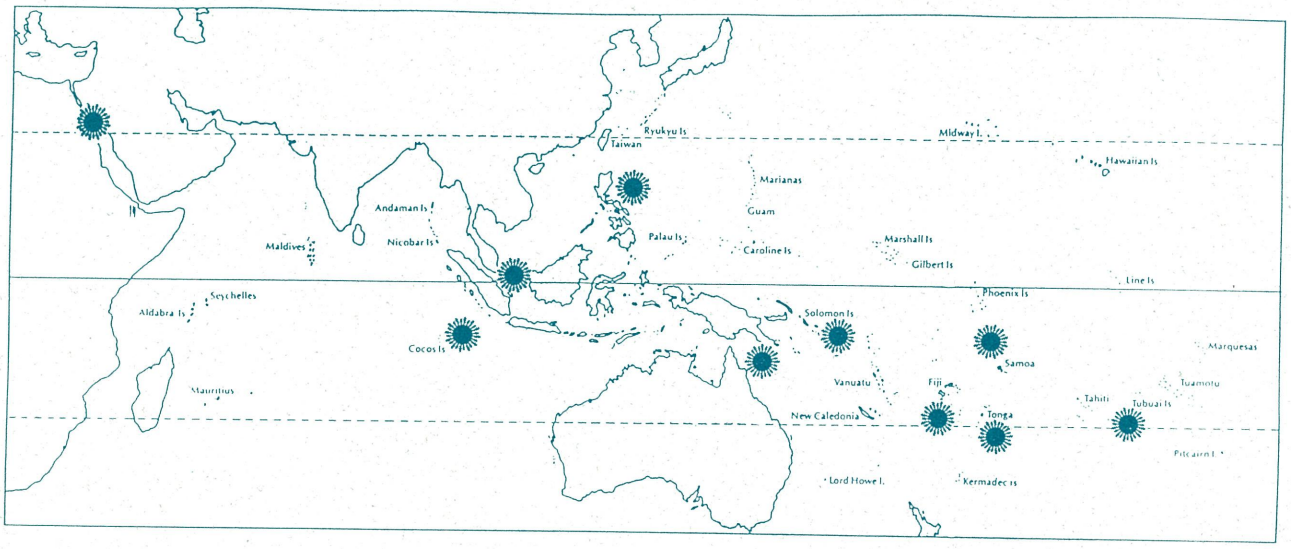
Global COTS

While COTS COMMS usually reports only on the local COTS scene, this parochial view has been imposed by our general lack of knowledge on the status of COTS elsewhere. We rarely receive information on the international COTS situation. This has changed over the last 12 months with reports from a number of reefs across the Indo-Pacific Region. The bottom line is that the recent increase in COTS numbers on some reefs in the northern GBR is far from unique. Reports of increasing COTS populations have come from the Cook Islands, Tonga, Western and American Samoa, Fiji, the Solomon Islands, the Philippines, Malaysia, Indonesia, the Great Barrier Reef, the Cocos (Keeling) Islands and the Red Sea.

Although there are few details on the scale of these increases, most seem to be relatively minor localised increases of hundreds to a few thousand starfish. Local controls have been implemented in a number of the areas.

The apparently pan-tropical synchrony in COTS populations raises a number of interesting questions. How? and why? immediately spring to mind. Are the COTS populations across the oceans responding to the same cue? Is the trigger or cause of these increases the same in each case or are populations on individual reefs or geographic areas controlled by different factors? Are all of these reefs connected?

These, and many more questions, are well worth exploring (but we're not going to monopolise *Reef Research* to do it). More information on COTS populations on reefs throughout the Indo-Pacific Region is needed before any of the questions can be resolved.



To our overseas readers, or indeed the local globetrotters: reports of current and historical COTS densities from across *Acanthaster planci*'s range would help enormously with unravelling the puzzle.

Meanwhile, on the GBR, reports of increasing numbers of COTS continue to come in from AIMS, Reef-Users and the GBRMPA fine-scale surveys. To date, 30 reefs (of about 300 in the 300 km stretch of reef between Innisfail and Lizard Island) have been reported to have increasing COTS populations. QDEH staff have also reported relatively high numbers of COTS on a few reefs north of this area.

AIMS Surveys

We recently received a report from AIMS describing the results of manta tow surveys in the Cairns, Cooktown/Lizard Island, Princess Charlotte Bay and Cape Grenville sectors. Very few COTS were recorded on the six reefs surveyed in both the Princess Charlotte Bay and Cape Grenville sectors. Only one of the twelve reefs (Davie Reef in the Princess Charlotte Bay sector) showed an appreciable change from previous surveys. Coral cover on this reef had declined from 30-50% in 1989-90 when it was last surveyed to less than 10% this year. Cyclone Ivor passed through the area in March 1990 and it may be that Davie Reef has not had sufficient time to recover from that event.

Six reefs in the Cairns sector and 12 reefs in the Cooktown/Lizard Island sector were surveyed. COTS numbers on a number of reefs in both of these sectors were higher than in previous years. The COTS populations on Evening Reef (in the Cairns sector) and on Swinger, Startle (east), Lizard Island, MacGillivray, North Direction and Mackay Reefs (in the Cooktown/Lizard Island sector) were considered to be at the upper limits of non-outbreak densities or at the early stages of outbreaking. Additional SCUBA searches on Startle (east) Reef recorded a range of starfish sizes and probably ages (new recruits, juveniles and adults).

Reef-User Reports (COTSWATCH)

It's been a year since the successful relaunch of the Authority's Reef-User reporting scheme now called COTSWATCH. Public support for the scheme has exceeded all our expectations, with a steady flow of completed sighting forms landing on our desks. Quite a number of contributors have become regulars, providing us with updates on the COTS situation at some of their more frequently visited reef sites. For all the statistics buffs amongst you, here are a few 'vital stats' on the past twelve months of the scheme:

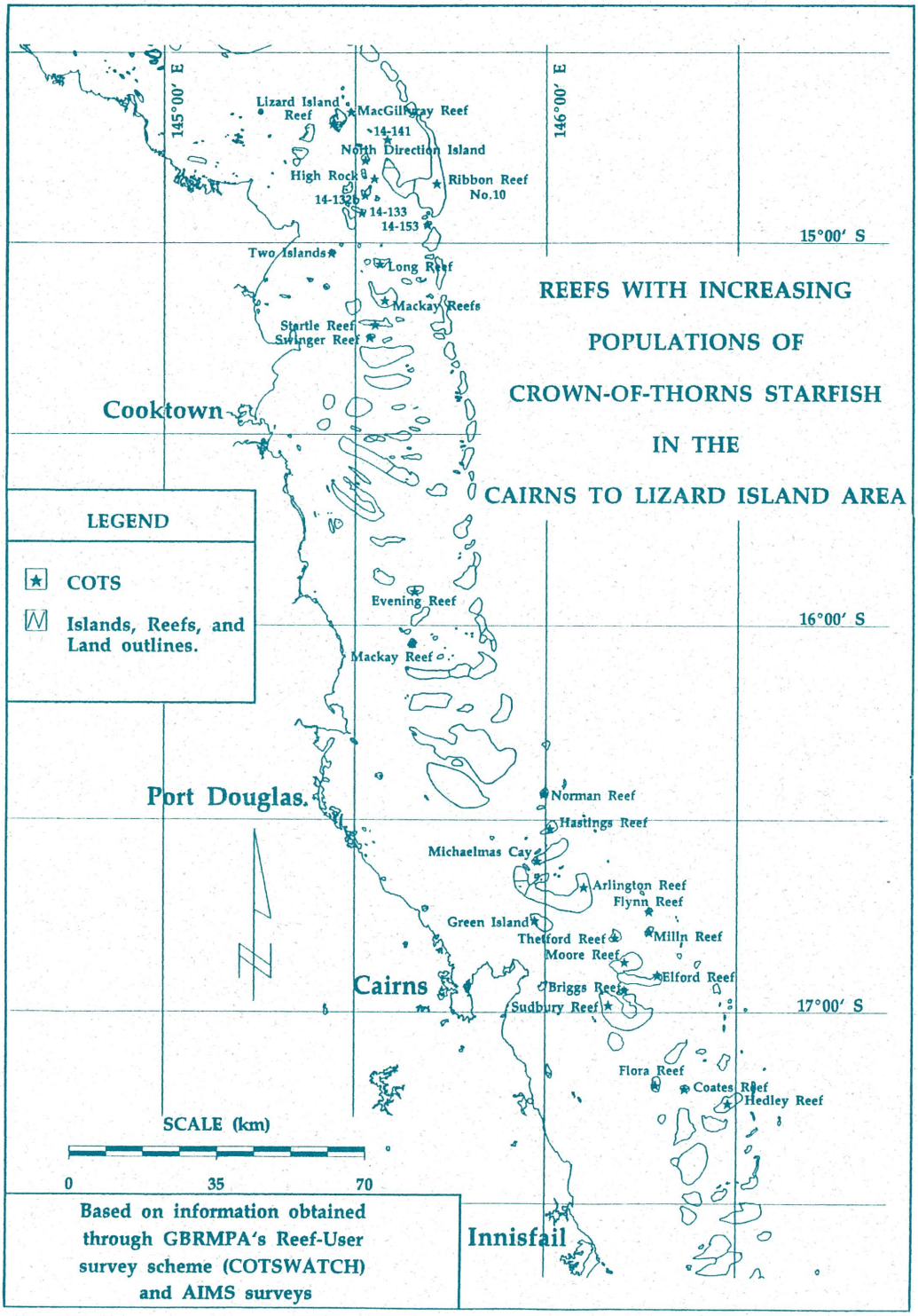
In total, we received 314 reports from Reef-Users, presenting information collected at 508 sites at 74 different reefs. The ratio of zeros to actual sightings of COTS remains at approximately 50:50, an important figure given that it is just as beneficial to know where COTS aren't found. A total of 1552 COTS were observed, with more than 30% of actual sightings reporting on the presence of at least some juveniles (<15 cm). Assuming that these smaller starfish make it to adulthood, the starfish should become a lot more conspicuous over the next 6-12 months - so keep an eye on them.

The COTSWATCH reports have been instrumental in providing an early warning of locally increasing numbers of starfish. Both the GBRMPA fine-scale and the AIMS broad-scale surveys are now attempting to quantify these increases. The combination of the three independent, yet collaborative survey schemes will allow us to get a detailed understanding of the current situation on the GBR.

Clearly, the scheme is working much better than any previous versions of it. However, there may still be some room for improvement. If you have any ideas on how to make things work even better, please let us know. In the meantime, we will continue to provide feedback to all contributors on a regular basis. 'COTS COMMS' will remain the principal means of getting information back to interested Reef-Users.

As always, many thanks for all your efforts. We would like to acknowledge the recent contributions to the scheme for the period from September to November 1994:

S Svensson / Townsville, **M Cunningham** / Mission Beach, **S Wood** / Mission Beach, **H Sweatman** / JCU, **S Simpson** / Port Douglas, **K Burns** / Sunlover Cruises, **K Jesienowski** / Port Douglas, **R Schutte & W Kibble** / Great Adventures, **J Anderson** / Great Adventures, **I Gengenbach** / Townsville, **G Connett** / Port Douglas Dive Centre, **J Purcell** / Great Adventures, **A Van Welderen** / Cairns, **C Hopkins** / Deep Sea Divers Den, **R Moran** / Mike Ball Dive Expeditions, **G McGarry** / Sunlover Cruises, **A Marshall** / Port Douglas, **G LaPraik** / QDEH Cairns, **J Low** / QDEH Cairns, **A Saunders** / Cairns, **Aquamarine Industries** / Cairns, **J Cruise** / QDEH Airlie Beach, **G Manahan** / Cairns, **K Roach** / Cairns, **S Richards** / Cairns, **A Baliss** / Port Douglas, **G Leeon** /



Cairns, **S Moon** / Ocean Spirit Cruises, **M Schaer** / Pro Dive Cairns, **M Short** / QDEH Cairns, **C Williams** / QDEH Cairns, **P Koloi** / Coral Princess Cruises, **I Stapleton** / Port Douglas, **J Green** / Captain Cook Cruises, **W Legg** / Rockhampton

Fine-Scale Surveys

This project is being funded through the CRC Reef Research Centre and is being conducted by GBRMPA staff with the assistance of volunteers. The project is intended to quantify the recent increases in COTS numbers on some reefs in the Cairns Section of the Great Barrier Reef Marine Park. Surveys of 24 mid-shelf reefs between Lizard Island and Innisfail (a distance of about 300 km) will be conducted. In contrast to the AIMS broad-scale surveys that use the manta tow technique, the fine-scale surveys use a transect based method. Transects have the potential to provide good estimates of not just the densities of starfish but also the sizes present as well as their frequency. This information can assist in understanding the mechanics of population changes (e.g. are the starfish the result of successful recruitment in one or several years?). It may also help with making predictions about future changes in the COTS populations.

Specific objectives of this study are:

- to assess the current status of COTS populations on mid-shelf reefs in the suspected source area of previous outbreaks, and to identify possible geographic (latitudinal) differences between populations;
- to identify a possible future outbreak during its early stages so that appropriate management strategies can be implemented in a timely manner;
- to assess whether or not pre-outbreaking populations of COTS exhibit characteristic habitat preferences that may assist in improving the cost-effectiveness of fine-scale surveys in the future; and
- to conduct a preliminary assessment of possible relationships between COTS abundance and (*i*) the incidence of coral scarring as well as (*ii*) the amount of live coral available.

To date, we have surveyed six of the twenty-four reefs selected. Preliminary results confirm earlier observations by Reef-Users, in that relatively high numbers of starfish are being recorded on all reefs surveyed. Interestingly, there are some locations that support high numbers of rarely observed juveniles (up to 30% of local populations). It is likely that these aggregations (and the coral damage that will result from their feeding) will become much more obvious in the next year to two.

The remaining reefs will be surveyed over the next four months and reported on in the next issue of COTS COMMS.

PROGRAM OVERVIEW

This section continues the serialisation of the COTS Program review that was started in the last issue of *Reef Research*. It's perhaps surprising to many readers that there are still many aspects of the biology of the crown-of-thorns starfish that remain to be studied. Knowing the animal's basic biology is a vital and fundamental step towards understanding the causes of starfish outbreaks. In this issue we very briefly describe the results of the last five years of research into the biology of larval and adult COTS.

Larval and Adult Starfish Biology

Aspects of the reproductive biology of COTS have significant implications for the numbers of starfish and the changes in these over time. A number of hypotheses on the causes of outbreaks relate to the high potential of COTS to produce massive numbers of offspring if the conditions are right.

A major study of the reproductive biology of COTS was conducted by Dr Russ Babcock and Mr Craig Mundy of AIMS. While COTS were observed spawning at Davies Reef off Townsville between December and January, gonads were largest early in the spawning season indicating that this is the peak time for breeding. Measurements of fertilisation rates under controlled laboratory conditions also suggested that the fertility of COTS was high early in the spawning season and then declined gradually. Because this research looked at COTS in the Central Section of the GBR we're not sure whether or not the same pattern occurs in other areas of the Reef. In particular, it would be useful to understand the breeding patterns of starfish in the Cairns Section, where primary COTS outbreaks have occurred in the past and may do so again in the future. Dr Kerry Black of the Victorian Institute of Marine Sciences has shown that temperature variations in this Section are different from those in the central GBR. This might mean that the breeding cycles are different on the northern GBR.

Fertilisation success depends not only on the synchrony in spawning times, but also on the spatial distribution of COTS within reef habitats. Babcock and Mundy reported that a large number of COTS (129 individuals counted) appeared in a relatively small area and the majority (68%) spawned during a period of only a few hours. They also observed COTS and a diverse range of reef animals spawning at the same time. Although little is known about cues that trigger the mass spawning of COTS as well as other reef animals, these results indicate that COTS outbreaks may be initiated from a relatively small population of COTS through spawning synchrony and aggregation. Fertilisation rates for COTS in the field were the highest measured for any invertebrate. Even when starfish were separated by distances of over 30 m, about half of the eggs were fertilised. Dr John Benzie of AIMS investigated some aspects of the fertilisation process and found that the gametes of COTS aged more slowly and sperm maintained a higher fertilising capacity when diluted compared to sea urchins.

All of these results highlight the innate ability of COTS to produce large numbers of offspring if environmental conditions are favourable. With each mature female starfish producing up to 100 million eggs in a spawning season it is quite likely that outbreaks can be initiated under natural conditions provided there isn't major mortality in the next critical phases of life - the larval and early juvenile stages.

Over 10 years ago Dr Charles Birkeland of the University of Guam proposed that primary COTS outbreaks were caused by particularly successful settlement of larvae in years with heavy rainfall. He suggested that monsoonal rain following a couple of dry years results in increased nutrient inputs from the land and this generates unusually large amounts of food (microscopic plants called phytoplankton) for the COTS larvae just as fertilisers encourage garden plant growth. Greater amounts of food mean higher survival of larvae.

The hypothesis hinges on the normal diet of COTS larvae. A series of laboratory experiments were conducted by Dr Tenshi Ayukai of AIMS and Dr Ove Hoegh-Guldberg of the University of Sydney to investigate the likelihood of COTS larvae deriving their nutrition from sources other than microscopic plants - bacteria and dissolved organic matter. The results suggested that these alternative food sources could be used by COTS larvae but they are likely to be relatively insignificant to the nutritional requirements of larvae compared to phytoplankton.

The importance of relatively large phytoplankton (>2 µm) as a food source for COTS larvae has been confirmed by this research and the PhD research by Mr Ken Okaji of AIMS. Okaji has shown that both the growth and development rates of COTS larvae in experimental conditions are limited by food availability. Seawater enriched with additional nutrients resulted in faster growth and shorter times to settlement compared with natural seawater. This result lends further support to Birkeland's hypothesis and suggests

that human activities that contribute to nutrient enrichment of GBR waters may increase larval COTS survival. Further monitoring of the concentrations of phytoplankton and non-phytoplankton food sources is needed to establish the relative importance of these in the field and to clarify the role food limitation may play in controlling starfish numbers.

Very little research into the early post-settlement stages of COTS has been possible because of the difficulty in finding small COTS juveniles in the field. There are, however, a few exceptional places, where a large number of COTS juveniles have been found. A study in Fiji, by Dr Leon Zann of GBRMPA, reported that the growth of COTS juveniles on Suva Reef was relatively slow during an algal feeding period (2.6 mm/month between 7-13 months), but was accelerated following the switch in diet from algae to coral (16.7 mm/month between 13-16 months). Sexual maturity was reached two years after settlement. The longevity of one generation of COTS was estimated at 7-8 years, whereas another generation collapsed in 2-3 years, because of disease associated with an undescribed sporozoan.

On the GBR, COTS recruitment has been studied indirectly by determining the size frequency distribution of outbreak populations and defining year classes based on peaks in size frequencies. This method is not always reliable, because the size (body diameter) of COTS varies depending on the quantity and quality of food available. Starfish size has been shown to decrease under poor food conditions. An alternative reliable method for age determination of COTS was developed by Mr Richard Stump of James Cook University. The technique involves measuring growth bands in skeletal elements (aboral spine ossicles) which appear to grow constantly, regardless of food conditions and somatic growth. Although the method developed has successfully resolved the age structure of COTS populations on some GBR reefs, further work is required to validate the technique in other places. One other limiting factor is that the first band is laid down when starfish are three years of age. Size remains the only means of estimating age in younger starfish.

One of the major problems with studying the changes in COTS populations on the GBR (and the factors affecting them) has been the difficulty of finding small juvenile starfish. To solve this problem COTS juveniles have been raised under laboratory conditions and used for different types of field experiments. Although this approach has been successful in the past, the method for mass rearing of COTS juveniles itself is still incomplete and does not guarantee reproducible yields. Reasons for this inconsistency are unknown at this stage, although there are a number of possibilities, including senility of starfish, a narrow optimal spawning window, and inter-annual variability in reproductive success (as noted by several researchers for a variety of coral reef organisms). While an effort is currently being made to improve the rearing technique, precautionary measures are also being taken to avoid the total loss of reared COTS juveniles by having a back-up rearing facility at the Great Barrier Reef Aquarium.

COTS CONTROLS

Well, the good news is - copper sulphate is out, sodium bisulphate is in! Our research into alternative, environmentally acceptable controls of COTS has produced the desired result. Sodium bisulphate, which sells under the trade name *Dry Acid* has been shown to be an effective chemical agent for locally controlling starfish numbers. The compound is readily available in most hardware and swimming pool supply stores. A manual detailing the 'acid treatment' should be available by January 1995. This outcome marks the successful conclusion of our research at Bait Reef off the Whitsunday Islands. A number of dedicated people have greatly assisted in achieving this breakthrough. However, particular mention has to be made of Kate and Dale Westwood, the owners of the research vessel *Banjora*. Their tireless efforts in getting the job done made all the difference. Many thanks for your terrific support (and substantial meals)!