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REEF RESEARCH

GREAT BARRIER REEF MARINE PARK AUTHORITY

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NEWSLETTER OF THE RESEARCH AND MONITORING SECTION

Editorial

As promised, this issue of *Reef Research* contains a 'bumper' article of COTS COMMS. In response to reports received about renewed outbreaks of crown-of-thorns starfish in both the Indian and Pacific Oceans, the Great Barrier Reef Marine Park Authority is taking its very successful COTSWATCH scheme to the international community. 'COTSWATCH – International' was recently launched by the Authority and is being promoted by both the Authority and the CRC Reef Research Centre. If you have any sightings of the starfish to report (and remember, zero sightings are also useful) please contact Udo Engelhardt at the Authority on +61 77 500 812.

Martin Russell reports on the management implications learnt from closing and re-opening a reef to fishing. He draws his conclusions from a study at Bramble Reef which was closed to fishing in 1992. Following the re-opening of the reef in 1995 researchers have found that the population of coral trout on Bramble Reef is now at the same level as it was before the closure. However, a great deal of new information was gained from this study and it is this information that will enable management agencies to ascertain what management actions to take in the future.

Steve Raaymakers discusses the threat of the introduction of foreign species through ships' ballast water and the international response to this issue. In *What's Out There?* Jamie Oliver writes on the damage caused to the Great Barrier Reef by cyclone Justin in March 1997.

Finally, a synopsis of the Augmentative Grants awarded to post-graduate students in 1997 is included.

In the December issue I promised to keep you up-to-date with the review of the marine tourism industry in the Great Barrier Reef World Heritage Area. The review was ▶

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WHAT'S IN THIS ISSUE

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Editorial

continued from front page

jointly funded by the Authority and the Department of Industry, Science and Tourism's Office of National Tourism.

I last reported that the terms of reference were being finalised. The review is now finished and a report was submitted to the Great Barrier Reef Ministerial Council in July 1997. The report makes a number of recommendations for planning and management of tourism use within the Great Barrier Reef World Heritage Area. The Ministerial Council endorsed the report subject to some minor changes and further consultation. If you are interested in obtaining a copy of the report, *Review of the Marine Tourism Industry in the Great Barrier Reef World Heritage Area*, contact Karen Robinson at the Authority on +61 77 500 759.

The Authority also recently released, for comment, a management plan for the Cairns area of the Great Barrier Reef Marine Park. For further information on the plan please contact Carol Honchin on +61 77 500 753.

Ed.

Slick Talk 21

with Steve Raaymakers

Since its first appearance in *Reef Research* in June 1992, Slick Talk has traditionally presented news and views relating to ship-sourced *oil* pollution. Since I am currently (March–July 1997) on an extended overseas study tour, I have not been able to set my hands on any current affairs relating to this issue in Australia. Instead, this appearance of Slick Talk presents news on another ship-sourced ecological concern: the translocation of marine species through environmental barriers via ships' ballast water. The international response to this issue constitutes the subject of my overseas study tour, and a summary of the project is presented here.

Since the days of sail, ships have carried ballast, originally in the form of rocks, to balance the ship correctly. Often cargo ships would take on ballast when empty of cargo and remove the ballast when cargo was loaded. Modern ships, especially bulk carriers and tankers, continue this practice, except now sea water is used instead of rocks.

Most marine organisms have planktonic egg or larval stages and it is possible for these to be drawn into a ship's ballast tanks when ballast water is taken on. When the ballast water is eventually discharged, often at a port in another country, any organisms discharged with the ballast may survive and even establish viable populations.

The introduction of marine pests via this vector is a major concern for Australia which is a net exporter of bulk cargo (e.g. coal, iron ore, bauxite, silica sand, sugar and grain) and therefore a major importer of ballast water.

The Commonwealth Scientific and Industrial Research Organisation's Centre for Research on Introduced Marine Pests (CRIMP) estimates that up to 75 species have been introduced to Australian marine environments, with possibly many others not yet known. Some of these are causing measurable ecological impacts and/or are of significant concern to commercial fisheries and even human health.

Such introductions have significant implications for the Great Barrier Reef. Some ports in this region are amongst the largest and most frequent importers of ballast in the country.

Australia has been extremely active in attempting to address this serious concern. The Commonwealth Government has designated the Australian Quarantine and Inspection Service (AQIS) as the lead agency for this issue. The Australian Maritime Safety Authority (AMSA) with support from AQIS has been leading efforts within the International Maritime Organization (IMO) to develop an international regulatory regime for ballast management. A national advisory council with high-level, cross-sectoral representation has been formed. A national ballast water management strategy including voluntary guidelines for shipping and a strategic research program has been developed.

The Commonwealth Scientific and Industrial Research Organisation's CRIMP has been formed and is actively surveying ports around the country for the presence of foreign marine species. It is also undertaking research into possible biological controls and other subjects.

Many state agencies are also active in this area. For example, the Queensland Ports Corporation is funding research and development of ballast water treatment technology, is commissioning CRIMP to conduct surveys within its ports, and together with some individual Queensland ports authorities, is about to complete a major ballast water risk assessment for 12 Queensland ports.

Finally, industry is also becoming involved. In particular, the Australian mining and energy industries have a keen interest in this subject. Approximately 80% of ballast water introduced to Australia is a direct result of the bulk export of minerals and energy products (e.g. iron ore, coal, oil and gas).

In recognition of this, in 1996–97, the Australian Minerals and Energy Environment Foundation (AMEEF) awarded a travelling scholarship. It was for the study of international responses to the ballast water issue and to benchmark ballast water management at Australian bulk mineral and energy export ports against the world's best practice.

This is the first time that an AMEEF travelling scholarship has been awarded for a subject not directly related to on-mine activities. It demonstrates the mining industry's recognition that its environmental issues extend beyond the mining lease. I was lucky enough to be the recipient of this scholarship.

At the time of writing my study tour has taken me to various ports, government agencies, institutions and non-government organisations in England, France, Switzerland, Holland, Denmark, Sweden and North America.

The objectives of the study tour are to:

- assess the international research, regulatory and management responses to the ballast water issue, and their implications for bulk mineral and energy exports from Australia; and
- assess the world's best practice in ballast water management and benchmark against the situation at Australian bulk mineral and energy export ports.

Findings so far are that Australia appears to be far more active in responding to this issue than the European countries, while the Americans are more pro-active in the regulatory area, with specific legislation addressing non-indigenous marine species having been passed and recently strengthened.

A comprehensive report will be presented to, and published by, AMEEF at the end of the project (late 1997). A summary of the findings will be reported in a future issue of *Reef Research* once the AMEEF report is finalised.

(Steve Raaymakers is currently the Environment Manager with the Queensland Ports Corporation. Opinions expressed through his authorship of 'Slick Talk' are not necessarily those of the Ports Corporation nor the Great Barrier Reef Marine Park Authority.)

What's out there?

Cyclone Justin

Jamie Oliver

Background

Cyclones are one of the most important natural phenomena affecting reefs in non-equatorial regions. The severity and extent of the damage which they cause can substantially alter the physical structure, biological composition and ecological relationships within reefs. In addition, cyclones can play havoc with man-made structures. This can result in further ecological damage depending on the fate of these structures and will have an important economic effect on reef tourism. This article provides a brief synopsis of the available information on the effects of cyclone Justin on the Great Barrier Reef. The information was obtained from a variety of sources. Further detailed information can be obtained from Marji Puotinen at the Cooperative Research Centre for Ecologically Sustainable Development of the Great Barrier Reef (CRC Reef Research Centre), Terry Done and Lyndon DeVantier at the Australian Institute of Marine Science (AIMS), Jenny Baer in the Impact Assessment Unit of the Great Barrier Reef Marine Park Authority (GBRMPA), and David Haynes, Water Quality Coordinator at GBRMPA. I am grateful to these individuals for providing me with much of the information presented in this summary.

Cyclone Justin was an extremely large but generally weak cyclone which occurred off the Queensland coast from 7–24 March 1997. Its movement was unusual. The cyclone spent the first five days almost stationary well off the Queensland coast before moving north-east towards New Guinea. It then moved back towards Queensland, crossing the reef near Cooktown and then headed along the coast, finally weakening into a rain depression south of Townsville. Although a simple interpretation of the path of the cyclone (figure 1) might suggest that the most substantial damage would have occurred between Cairns and Townsville, a more sophisticated analysis of predicted wind energy, carried out by CRC Reef researcher Marji Puotinen, resulted in a more complicated pattern of potentially destructive effects along the Queensland coast and the Great Barrier Reef.

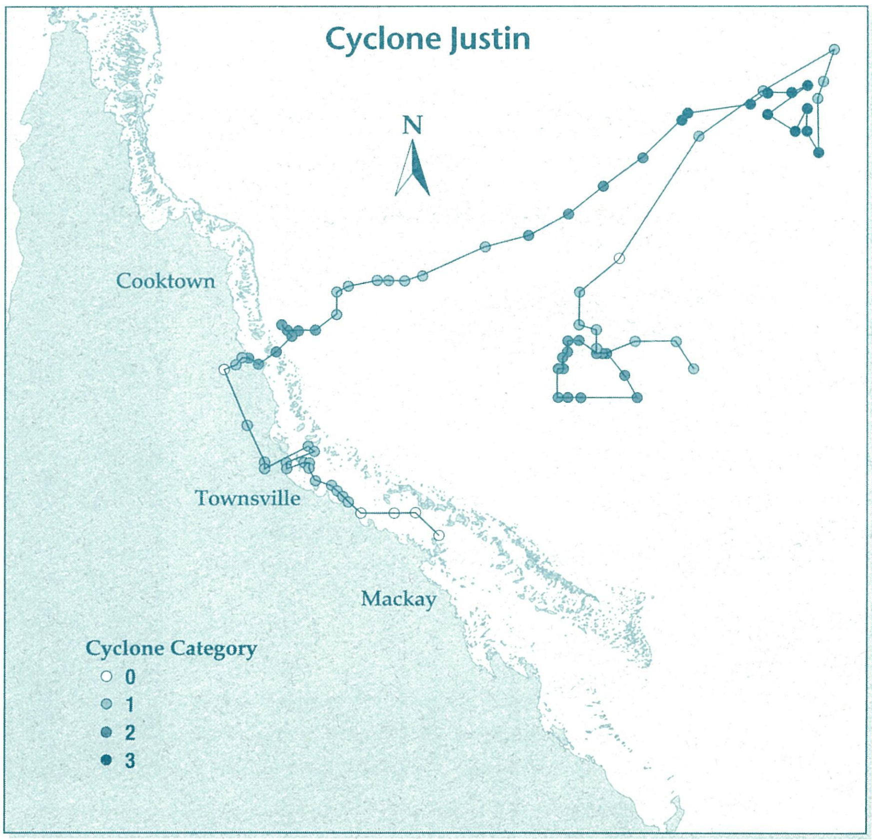


Figure 1. Path of cyclone Justin

During its initial stationary stage, the size of the cyclone and the period of its influence caused very large waves to be generated along the middle of the reef south of Townsville even though, at this stage, the cyclone was quite some distance offshore. During the second phase, when it returned from New Guinea, its influence was more direct and caused by waves and wind near the centre of the cyclone. Its path in this instance created a zone of high wind energy across the reef near Cairns. This was followed by a less destructive zone from Townsville to the Whitsundays as the cyclone weakened after moving back offshore. Thus there were two principal areas of destructive effects: the reefs offshore from Cairns–Cooktown, and the reefs between Townsville and Mackay. While the northern area was affected by relatively severe winds on one occasion, the southern area was actually affected twice: first by the waves generated while the cyclone was offshore, and then again when the cyclone passed directly through the area as it weakened into a tropical depression.

Damage caused by cyclone-induced waves

Reports from divers indicate that some reefs off Cairns, Townsville and the Whitsunday Islands have been damaged to a moderate degree. Generally the damage appears to be less severe than that caused by some other recent cyclones (Ivor, Joy, Winifred). The Australian Institute of Marine Science, GBRMPA and the CRC Reef Research Centre carried out a joint survey in the Whitsunday Islands region. Lyndon DeVantier of AIMS collected additional data. The data from this survey are not yet completely analysed, but preliminary results indicate that damage to coral communities has been very high in some discrete locations, but almost unnoticeable in many other spots. Approximately 58% of the 72 reefs surveyed had some degree of coral breakage, but only two of those reefs (~3%) exhibited severe levels of coral breakage when compared to the damage recorded from cyclone Ivor (a severe cyclone which caused extensive recorded damage on northern reefs). This high degree of spatial variation in coral damage is due to a number of factors including small-scale variation in the speed and direction of the wind; variation in wave height and direction; and the sheltering effect provided by other reefs and other parts of the same reef. The AIMS Long-term Monitoring Program has also detected damage at two out of the five reefs that were recently surveyed off Townsville. Damage was not severe and consisted mainly of overturned table corals. The cyclone also modified some small sand cays and spits by shifting sand and altering their overall shape. At Michaelmas Cay, off Cairns, approximately 50% of the low vegetation in the middle of the cay was buried by shifting sand. This caused a reduction in the seabird populations which breed and roost on the cay. Both the vegetation and seabird numbers are now recovering. The cay, which was closed to tourists for two weeks, has been re-opened. In the Whitsunday region, there was little evidence of sand movement on most reefs, although the two reefs which exhibited severe coral damage also had areas where scouring at the edge of the reef-flat in the back reef area had created erosion channels about 0.5–1 m deep. This erosion may have also facilitated eventual recovery of the area by exposing new areas of previously buried hard, bare substrate for new coral colonies to settle and grow on.

Damage caused by structures on the reef

As a result of the winds and waves generated by the cyclone whilst it was offshore from Cairns, tourist pontoons at Low Isles, owned by Quicksilver Connections Ltd, and Norman Reef (figure 2), owned by Great Adventures, broke free from their moorings and were washed onto the adjacent reef-flat. Both pontoons have been subsequently towed off the reef-flat. Preliminary assessments of the damage caused during both the grounding of the pontoons and their subsequent removal

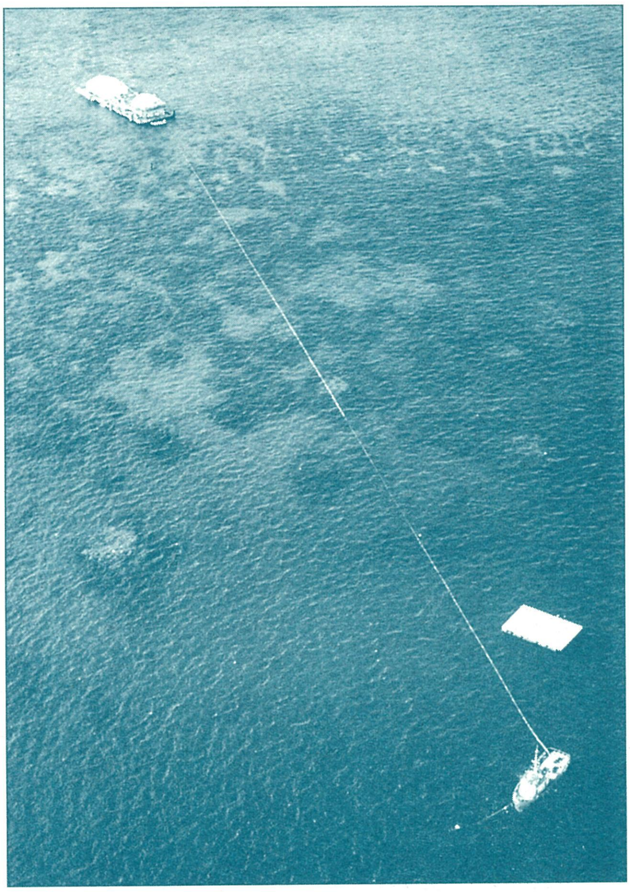


Figure 2. The pontoon at Norman Reef being towed off the reef-flat. The white rectangle is the helicopter pontoon.

have been carried out by Mike Short from the Queensland Department of Environment. At Low Isles a total area of 0.2 ha was damaged, in an area of coral and seagrass. At Norman Reef an area of about 0.25 ha was damaged on a coral dominated reef-flat. Although the damage was quite severe in spots (total removal of all corals and/or seagrass), at the scale of the entire reef, the damage caused by both groundings cannot be considered to be a major ecological impact. A more detailed survey of the scars caused by the grounding and removal of the Norman Reef pontoon has been conducted by a consultant marine biologist, but the results have not yet been analysed. Recovery of the Norman Reef scar will be monitored over the next two years.

Although some other tourist pontoons suffered damage to the superstructure, the pontoons at Norman Reef and Low Isles were the only ones to break free of their moorings. Investigations are currently being conducted to determine what caused the moorings to fail during the cyclonic conditions – which they were designed to withstand – and what steps are required to ensure that such failures do not recur.

Other smaller structures were also damaged at various locations. For instance, a large section of the pontoons of a floating marina in Cairns Harbour was destroyed, while at Hinchinbrook Island resort a walkway to a pontoon was removed from its supports. At Hardy Reef, a helicopter pontoon broke free, while a swim pontoon at Hamilton Island suffered a similar fate. Both were retrieved relatively undamaged. No reports of any ecological damage arising from these incidents have been received.

Effects on water quality

Cyclones can have a major influence on the water quality of the Great Barrier Reef lagoon, through the effects of turbid, sediment-laden water coming from adjacent rivers in flood (figure 3). The Great Barrier Reef Marine Park Authority and AIMS sampled river flood plumes resulting from cyclone Justin rainfalls in March 1997. Floodwater samples were collected at approximately 70 nearshore sites located between Trinity Inlet (near Cairns) and Lucinda (near Ingham) and these will be analysed for chlorophyll a, phaeophytin, suspended solids, particulate and dissolved nutrients and pesticides. The extent of the flood plumes was also surveyed from a light aircraft and the plume mapped into a Geographic Information System. Water samples were also collected during the flood event from the Russell River. Samples were collected from below a pristine rainforest site, from a site below banana growing areas and from a site below cane growing areas in order to compare the impact of a variety of land uses on floodwater quality. Offshore coral communities were also surveyed before and after the flood event to investigate the impact of freshwater plumes on coral communities.

Figure 3. Flood plume from the Herbert River after cyclone Justin

Ongoing research and monitoring

Although cyclones are a natural source of disturbance, it is important that management agencies such as GBRMPA support and encourage ongoing research into the patterns of cyclone activity on the Great Barrier Reef and their effects on reef biota. This knowledge is important in understanding both the ability of reefs to recover from different patterns of physical disturbance, and the patterns of natural stress which reef communities experience even in the absence of human activities.

There are a number of research programs which are investigating aspects of cyclone damage on the Great Barrier Reef. Long-term monitoring at specific sites, led by Terry Hughes at James Cook University and Terry Done at AIMS, is building up a detailed picture of the dynamics of coral communities and their responses to cyclonic disturbances. The CRC Reef Research Centre is supporting Terry Done's and Marji Puotinen's work on the development of models of wind and wave patterns which can predict the spatially variable damage to reefs caused by cyclones. An important by-product of this research is the publication of an atlas of cyclones in the Great Barrier Reef. The AIMS Long-term Monitoring Program continues to survey reefs in all sections of the Great Barrier Reef on an annual basis. This work will enable the detection of damage and subsequent recovery at a regional scale. Finally, GBRMPA will commission additional surveys and monitoring projects to fill in information gaps as required or to document damage at particular reefs of management significance.

1997 AUGMENTATIVE RESEARCH GRANTS SCHEME

The Great Barrier Reef Marine Park Authority awarded eleven grants this year to students undertaking research relevant to the management of the Great Barrier Reef Marine Park. All students are working towards a Doctorate or Masters degree. Kim Davis reports.

KEY: **Researcher** / Supervisor,
Project title ($ awarded) Description of project

JAMES COOK UNIVERSITY OF NORTH QUEENSLAND

Naniel Aragones / Dr G Inglis,
Restoration ecology of seagrass beds: improving the efficiency of seagrass transplantation ($800) The general objective of this project is to examine the biological and methodological factors that affect the success of attempts to restore seagrass beds through active transplantation. Naniel was awarded a grant for this project in 1996 and has carried out short-term pilot experiments in areas near Townsville. Preliminary results imply that fast-growing seagrass species, such as *Halodule uninervis* and *Cymodocea serrulata* are suitable for transplanting and that transplanting efforts as part of on-site or off-site mitigation for developmental projects which are impacting seagrasses, should be conducted in autumn or early winter when daytime low tides and bed exposure occur.

Andrew Baird / Dr B Willis & Dr T Hughes,
The length of the larval phase in corals: new insights into patterns of reef connectivity ($1300) Some controversy exists among reef ecologists as to whether or not coral larvae are mostly retained on their reef of origin or are dispersed among reefs. Andrew aims to determine the likelihood of localised recruitment by quantifying the number of larvae settling over time from single cohorts from a range of coral species. He also hopes to establish the potential of coral larvae for long distance dispersal by quantifying the capacity of coral larvae to delay metamorphosis. This project will address a major gap in our knowledge of the larval phase of reef corals. It will enable managers to identify reefs, isolated by distance or lack of connecting currents, which require higher levels of protection.

Michaela Dommisse / Dr C Alexander & Dr M Furnas,
Characterising detritus of the Great Barrier Reef: quantity and quality over space and time ($1124) Detritus has been recognised as a significant component of marine food webs such as those in coral reef ecosystems. However, the nutritional value of detritus is not well known. The objectives of this study are to assess the potential nutritional value of detritus on reef communities and to determine whether significant spatial and temporal variability exists in the nutritional value and quantity of detritus delivered to reef communities of the Great Barrier Reef. This project will provide information on the contribution of detritus to nutrient stocks within the Great Barrier Reef. Such information is particularly relevant for management of near-shore reefs exposed to terrigenous detritus containing elevated levels of nutrients.

Michael Pido / P Valentine,
Evaluation of resource management in small-scale tropical marine fisheries: a comparison of marine reserves/parks in the Philippines and Australia ($1000) This research is aimed at evaluating the performance and outcomes of resource management in small-scale tropical marine fisheries. Michael will develop performance and outcome indicators that cover the relevant facets of management of small-scale fisheries. He will carry out a between-country evaluation of selected marine parks/reserves in the Philippines and Australia via a survey questionnaire distributed to users groups engaged in small-scale fisheries. This study will generate information on people–resource interactions as they relate to the management of inshore fisheries under marine parks/reserves.

Michael Rasheed / Dr G Inglis & Dr R Coles,
Investigations of recovery and succession in north Queensland tropical seagrass communities ($1200) This research is aimed at establishing and comparing some of the mechanisms of recovery

for tropical seagrass communities following loss, at an inshore intertidal and an offshore subtidal site in the Great Barrier Reef region. Michael received funding from the Authority in 1996 for this project and has reported that preliminary results indicate that sexual reproduction plays a minor role in the recovery of experimentally cleared areas with the majority of recolonisation due to vegetative growth. Further field work is required to complete this project which will provide managers and planners with some of the basic knowledge of the natural recovery process. This knowledge is essential in developing strategies to deal with potential seagrass loss.

Janine Sheaves / Associate Professor C Alexander, Dr J Collins & Dr B Molony,

The trophic role of alpheid shrimps ($1000) Alpheid shrimps are common inhabitants of tropical mangrove forests and seagrass beds. Both habitats are important nursery areas for many species. Alpheid shrimps are believed to eat fallen mangrove leaves and seagrasses. Janine aims to determine the importance of mangrove leaves and seagrasses in the diet of alpheid shrimps and their trophic role within these areas. She states that an understanding of the role of alpheids and their role in nutrient recycling and consequent enhancement of primary productivity may lead to more informed planning and management decisions regarding these important nursery grounds.

James True / Dr B Willis,

Massive* Porites *corals as indicators of environmental changes ($700) In order to develop a technique for monitoring coral health, James will examine short-term acclimation and survivorship of scleractinian corals exposed to environmental stress. By improving our understanding of how environmental factors influence the growth and health of scleractinian corals, this study will also validate current assumptions which underlie models of coral growth. During this study James will document natural variation in tissue thickness of *Porites* corals and investigate the mechanisms which control the timing of tissue uplift. Results will provide new insights into extracting long-term records from coral skeletons.

THE UNIVERSITY OF QUEENSLAND

Ingo Ernst / Dr I Whittington & Dr M Jones,

Gyrodactylidae (Monogenea) of the Great Barrier Reef ($1360) Gyrodactylidae are viviparous flatworms which parasitise the fins and gills of teleost fishes. There are no published records or descriptions of gyrodactylid species from Australia yet preliminary investigations have revealed several species of *Gyrodactylus* from Heron Island. Ingo will describe these and other species found in a comprehensive survey of fish from Heron and Lizards Islands. He states that gaining basic information on the gyrodactylid fauna of Australian marine fishes is essential if we are to identify our natural parasitic fauna, potential threats to/of future fish culture ventures and understand the role of these organisms in the coral reef community.

Michelle Heupel / Dr M Bennett,

***Biology of two reef-living sharks: the blacktip reef shark,* Carcharhinus melanopterus, *and the epaulette shark,* Hemiscyllium ocellatum** ($612) Michelle was awarded a grant in 1996 for this project to examine various aspects of the biology and behaviour of two species of reef-dwelling sharks at Heron Island Reef. She reported that the main focus of her research, to date, has concerned *H. ocellatum* and that substantial progress has been made in relation to population sizes and tagging effort, prey selection and growth rates, activity programs and habitat use, reproductive biology and host-parasite interactions. Future work on this project will include tag/recapture studies for both species but the overall focus of her research will be on the blacktip reef shark, *C. melanopterus*. Michelle believes this study, in addition to studies on other species, will assist future management decisions regarding elasmobranch fishes.

THE UNIVERSITY OF SYDNEY

Misaki Takabayashi / Dr O Hoegh-Guldberg,

Intra-specific variability in reef corals ($1610) This project will investigate intra-specific variability in corals with respect to their tissue colours. Whether or not different coral colour morphs differ in ecology, physiology and skeletal morphology will be determined. The project will also explore the potential use of coral colour as an indicator of the health and genetic origin of colonies, physical changes in habitat and water clarity. Misaki believes that the genetic techniques established in this project, to determine the clonal genetic variability of corals, will provide insight into the gene flows among and within Pacific reefs.

AUSTRALIAN INSTITUTE OF MARINE SCIENCE/ UNIVERSITY OF HAMBURG, GERMANY

Sven Uthicke / Dr D Klump & Professor H Thiel,

The role of sediment feeding holothurians in nutrient cycles of coral reef ecosystems ($1200) Sven seeks to enhance our understanding of material fluxes on coral reefs in the Great Barrier Reef by quantifying different components of the sediment/water column interface nutrient cycle, such as grazing and excretion by sediment feeders. Information on the biology and ecology of commercially harvested holothurian species will be obtained as Sven also plans to study whether sediment-feeding holothurians can be regarded as herbivores as they feed on fresh autotrophic material.

MANAGEMENT IMPLICATIONS LEARNT FROM CLOSING AND RE-OPENING A CORAL REEF TO FISHING

Martin Russell

The primary aim of the Research and Monitoring Section's Effects of Fishing Program is to ensure that fishing activity in the Great Barrier Reef Marine Park is consistent with nature conservation and World Heritage values. The Great Barrier Reef supports a widespread commercial and recreational reef-line fishery that is of great economic and social importance to the people of Queensland. It is a multi-species fishery, with most fishers targeting around 10–20 species of the coral reef fish found on the Great Barrier Reef. The major species targeted by the fishery is the common coral trout *(Plectropomus leopardus)*.

Reef closures in the Great Barrier Reef Marine Park are seen as a management strategy that can effectively lead to the rehabilitation of reef fish stocks. One of the Effects of Fishing Program's projects is titled *Bramble Reef Replenishment Area*. The research is being carried out by Sea Research who is studying fish population density changes resulting from closing and re-opening a reef to reef-line fishing. From this research the Program is looking at the management implications and effectiveness of reef closures.

Bramble Reef, in the northern Central Section of the Great Barrier Reef Marine Park, was designated a Replenishment Area and closed to fishing in January 1992 (see *Fishing: The effects on the Great Barrier Reef?*, *Reef Research*, December 1996). The objective of the closure was to replenish commercially and recreationally targeted fish stocks, particularly coral trout *(Plectropomus leopardus)*. A monitoring program was set up to collect data on coral trout density concurrently with estimates of chaetodon, lethrinid and lutjanid populations and measures of coral cover. The research was designed to detect temporal changes in the density of these reef fish populations and the coral cover on Bramble Reef in contrast to the control reefs (John Brewer, Lodestone and Davies Reefs). A baseline study prior to the closure showed that the mean coral trout density was lowest on Bramble Reef relative to the control reefs, and that the mean density of coral trout on all reefs in the study area was at a low level. It was perceived that a reduction of this species on these reefs was due to fishing pressure. After one year of closure, a further three control reefs (Britomart, Little Trunk and Trunk Reefs) were included in the study as these reefs adjacent to Bramble Reef were subject to effort displacement from the closure.

Annual underwater visual surveys carried out during the 3.5 years of closure (January 1992 to July 1995) found more than 300% increase in the density of legal size coral trout (greater than 38 cm total length) on Bramble Reef. Three of the control reefs (John Brewer, Lodestone and Davies), however, also had similar increases in legal size coral trout density (figures 1 and 2).

The surveys indicated that there was a highly successful pulse in coral trout recruitment on Bramble, John Brewer and Lodestone Reefs the year Bramble Reef was closed, i.e. 1992 (figure 3). The resulting cohort was instrumental in increasing the density of coral trout on these reefs. This 1992 cohort was protected on Bramble Reef by the closure, as indicated by the significantly higher coral trout

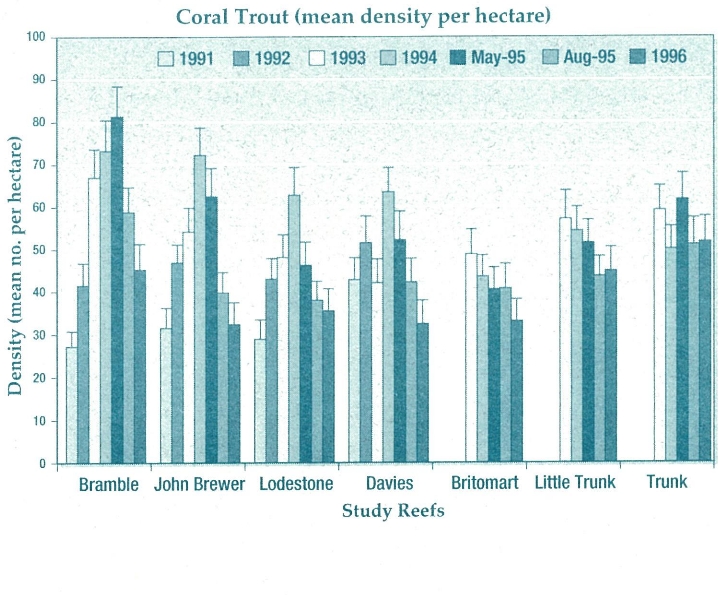


Figure 1. Coral trout mean density per hectare for all reefs in the study. An increase in coral trout density occurred on Bramble, John Brewer, Lodestone and Davies Reefs since 1991 until the re-opening of Bramble Reef in July 1995. There was a decrease in density on Britomart, Little Trunk and Trunk Reefs after Bramble Reef was closed. The coral trout density decreased on Bramble Reef after the re-opening with similar decreases on all of the control reefs.

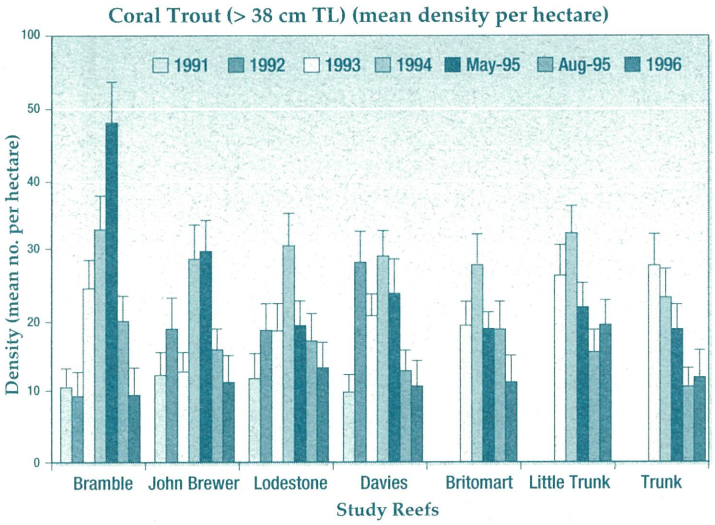


Figure 2. **Legal size (> 38 cm total length) coral trout mean density per hectare for all reefs in the study. An increase in legal size coral trout density occurred on Bramble, John Brewer, Lodestone and Davies Reefs since 1991 until the re-opening of Bramble Reef in July 1995. The legal size coral trout density on Bramble Reef was protected by the closure, but was quickly reduced to pre-closure levels soon after the re-opening.**

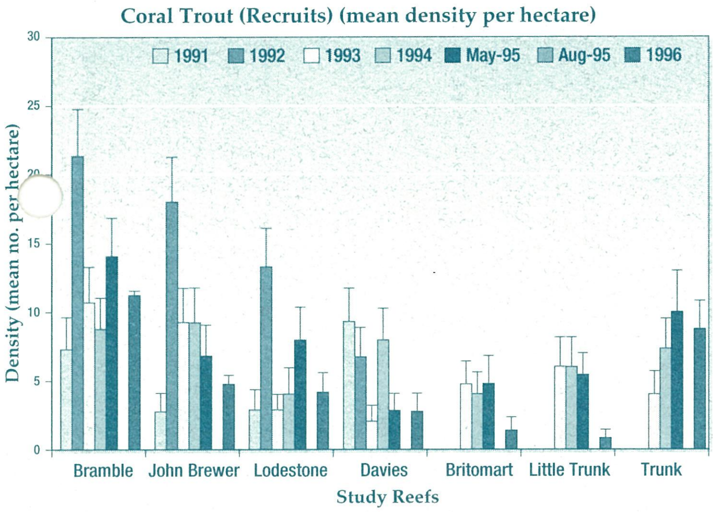


Figure 3. **Coral trout recruits mean density per hectare for all reefs in the study. There was a highly successful recruitment pulse on Bramble, John Brewer and Lodestone Reefs in 1992, the same year Bramble Reef was closed to fishing. After the closure of Bramble Reef the recruitment levels on Bramble, John Brewer, Lodestone and Davies Reefs were not as high.**

density on Bramble Reef in 1995. In contrast, the control reefs, which were open to fishing, had lower densities of coral trout (figure 2). This was most likely attributable to fishing effort.

Bramble Reef was re-opened to fishing in July 1995 and the first post-opening survey was carried out 8 weeks later to assess the impact of fishing on fish stocks following the re-opening. This survey showed that following the re-opening coral trout density on Bramble Reef decreased by approximately 30% and the legal size coral trout density had been reduced by approximately 60% (figures 1 and 2). There were also similar density decreases on all of the control reefs after the re-opening of Bramble Reef.

A second post-opening survey was carried out twelve months after the re-opening and showed that the coral trout density on Bramble Reef had decreased by approximately 50% and that the legal size coral trout density had decreased by approximately 80%. There were also further decreases in coral trout densities on all of the control reefs (figures 1 and 2).

These post-opening surveys suggest that there have been continuing high levels of fishing effort on Bramble Reef and all the control reefs since the re-opening of Bramble Reef. The density of legal size coral trout on Bramble Reef is now at the same level as before the closure and at similar levels of surrounding control reefs. There are low numbers of juvenile fish on most of the reefs in the study area due to decreased recruitment levels since the high recruitment pulse that occurred in 1992.

The results of this study illustrate that if the fish population densities of a replenishment reef are assessed in isolation to recruitment surveys and control reefs, an incorrect picture of the success of the reef closure would be given. This study showed that success of annual juvenile recruitment will dramatically increase stock size on closed and open reefs. Also, once a closed or replenished area is re-opened to fishing, fish stocks can be quickly reduced to levels found on surrounding open reefs. Naive populations of coral trout, i.e. those that are not often fished, are far more susceptible to capture than exploited populations. Therefore a reef should not be re-opened to full exploitation after a closure. Rather a staged temporal and/or spatial opening strategy should be used. Long-term recruitment data should be used in determining the duration of the closure and the timing of the re-opening to take advantage of successful recruitment pulses and subsequent strong cohorts. The study points out that unless the intended objective for the reef closure is well defined and the appropriate management strategies for re-opening the reef are decided, the benefits of the closure will diminish in a relatively short time.

The *Bramble Reef Replenishment Area* study is an ongoing research project with annual coral trout population density surveys. The information gained from these surveys is crucial for determining the appropriate management strategies for Bramble Reef and other reefs in the Great Barrier Reef Marine Park.

Udo Engelhardt

Fine-scale surveys (Cairns Section)

Well, the third year of sampling of the CRC Reef Research Centre / Great Barrier Reef Marine Park Authority / Department of Environment Cairns fine-scale survey program has now been finalised, with 27 mid-shelf reefs having been surveyed this summer season. Unfortunately, every single sampling trip early this year was to some degree affected by cyclones and very strong winds. Needless to say we missed out on surveying a number of exposed reef fronts. Strangely, I could not convince any members of my dive teams to give it a go. I guess the 30+ knot winds and 2–3 metre waves breaking at the reef fronts could have had something to do with it.

As predicted following last year's fine-scale surveys, both the number of reefs affected and the intensity of local outbreaks in this section have increased. Active reef-wide and/or spot outbreaks of crown-of-thorns starfish (COTS) were found throughout the survey area (see figure 1). Localised COTS densities of between 3 and 40 times sustainable levels (= 30 COTS per hectare) were detected. As expected, the proportion of mature starfish in outbreaking populations has also increased significantly since last year.

Seven (25.9%) of the 27 reefs surveyed were classified as Active reef-wide Outbreaks (AO), with a further 13 reefs (48.2%) supporting Active Spot Outbreaks (ASO). Seven reefs (25.9%) were classified as non-outbreaking. Recently observed population trends in this area are summarised in table 1.

This survey season also saw a record number of COTS spines being collected for ageing of individual animals. At last count, some 1500+ sets of spine samples had been collected. At 10 spines per sample, processing and analysis of the 15 000 spines will certainly take a bit of time. However, work is already well under way and will be completed over the next few months.

As reported last year, the great majority of outbreaking populations of COTS are made up of several year classes, with at least 2–3 strong cohorts making up the bulk of the populations. Size–frequency distributions recorded throughout the survey area provide a clear description of the widespread nature of these multiple, intensive recruitment events that have led to the current outbreaks. The COTS population observed at Coates Reef (17-011) (see figure 2) illustrates the typical size distribution seen on many reefs in this area. Starfish ranging from 2 to 62 cm in diameter were recorded on this reef. Ageing analysis will no doubt confirm the existence of several year classes in this population.

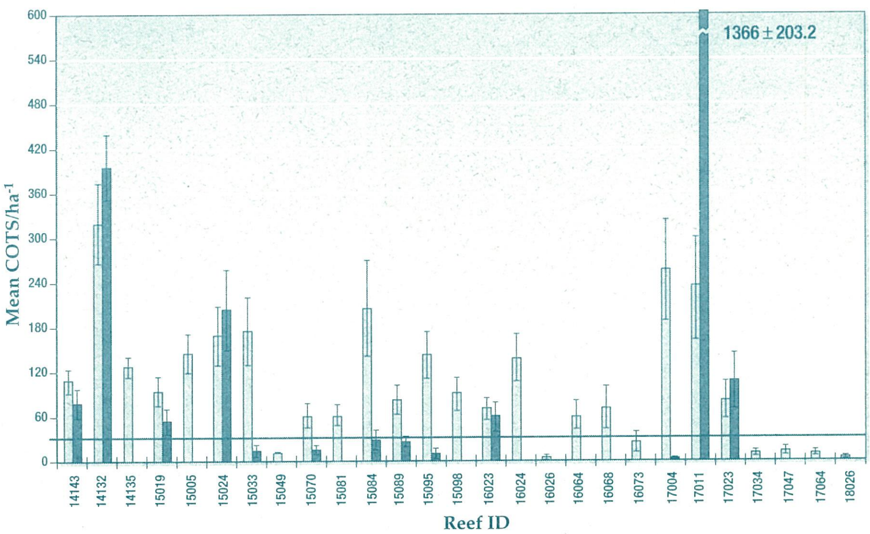


Figure 1. Estimated mean densities of crown-of-thorns starfish (COTS) on mid-shelf reefs surveyed in 1996–97. The line at 30 COTS per hectare represents the upper limit of a sustainable population of starfish. Error bars show standard errors (± 1 SE). Light grey bars show density estimates for back reef zones, while dark bars show those for front reef zones.

Following the completion of other types of analyses, further updates on the outcomes of the surveys will be presented in future issues of COTS COMMS. So stay tuned for more.

This intensive sampling program could not have been completed without the invaluable assistance provided by a dedicated bunch of field assistants who toughed it out during last summer's cyclone-affected surveys. My sincere thanks to: Mickaela Bergenius, Jens Bjelvenmark, Jim Cruise, Noreen and Dave Downs, Doris Engelhardt, Michael Hartcher, David Haynes, Selma Klanten, Marie Puotinen, Martin Russell, Marie-Lise Schlaeppy, Niklaus Taylor, Steve Wilkinson.

Reef ID	Reef Name	Status 94–95	Status 95–96	Status 96–97
14-116	Lizard Island Reef	AO	NS	NS
14-143	North Direction Reef	ASO / IO	AO	AO
14-132b	Rocky Islets Reef (b)	ASO / IO	AO	AO
14-133	U/N	IO	AO	NS
14-135	Helsdon Reef	NS	NS	ASO*
15-019	Long Reef	ASO / IO	AO	AO
15-005	Three Isles Reef	NS	NS	ASO*
15-024	Mackay Reefs	ASO / IO	AO	AO
15-033	Lark Reef (East)	NO	ASO / IO	ASO
15-043	U/N	IO	IO	NS
15-049	U/N	NS	NS	NO*
15-070	U/N	NO	ASO / IO	ASO
15-084	Irene Reef	ASO / IO	ASO / IO	ASO
15-089	Endeavour Reef (East)	ASO / IO	ASO / IO	ASO
15-095	Evening Reef	AO	ASO / IO	ASO
15-098	Morning Reef	NS	NS	ASO*
16-015	Mackay Reef	ASO	NS	NS
16-023	Rudder Reef (East)	NO	IO	AO
16-024	U/N	NO	IO	ASO*
16-026a	Tongue Reef (West)	NO	NS	NS
16-026b	Tongue Reef (East)	NS	ASO	NS
16-026c	Tongue Reef (North)	NS	NS	NO*
16-057	Hastings Reef	NO	NO	NS
16-064	Arlington Reef (West)	ASO	NS	NS
16-064	Arlington Reef (East)	NS	ASO / IO	ASO*
16-049	Green Island Reef	NO	IO	NS
16-068	Thetford Reef	NO	NO	ASO*
16-073	Elford Reef (East)	NO	NO	NO*
17-001	Sudbury Reef	NO	NS	NO*
17-006	Maori Reef	NO	NS	NS
17-016	McCulloch Reef	NO	NS	NS
17-004	Scott Reef	NS	ISO	ASO
17-011	Coates Reef	NS	AO	AO
17-023	Cayley Reef	NS	NS	AO
17-034	Feather Reef	NS	NO	NO
17-047	Eddy Reef	NS	NS	NO*
17-064	Taylor Reef	NS	NS	NO*
18-026	U/N	NS	NS	NO*

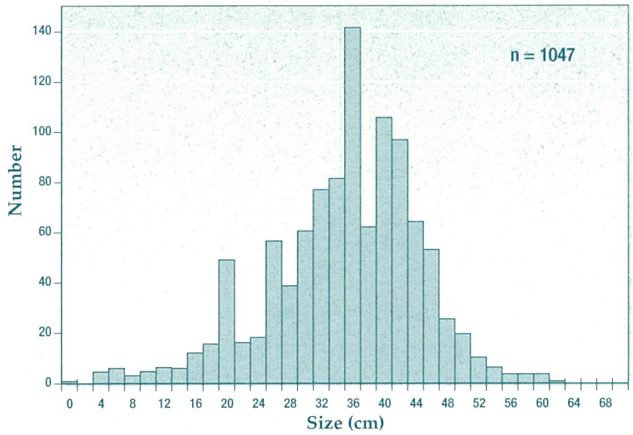


Figure 2. **Size–frequency distribution of COTS recorded at Coates Reef (17-011) in 1996–97**

A special thanks goes to the staff of the Far Northern Region of the Queensland Department of Environment, and in particular Mike Short, Frazer Muir and their field staff who have now been supporting the fine-scale surveys for three years running. Their efforts have greatly assisted in getting a far more comprehensive understanding of recent developments on reefs in the Cairns Section, a task that would have been significantly more difficult without their commitment and support. Again, many thanks to everyone involved.

COTSWATCH Reef-user monitoring scheme

Thanks to the efforts of our dedicated volunteer COTSWATCHERS, the COTS program continues to receive valuable information on the whereabouts of the starfish across the reefs of the Great Barrier Reef. The 'vital statistics' for the period from 7 January to 29 April 1997 read as follows – 216 completed reports were received, providing details on 425 individual sites from 73 different reefs.

Table 1. **Status of mid-shelf reefs surveyed using the CRC Reef Research Centre / Great Barrier Reef Marine Park Authority / Department of Environment fine-scale technique. Reefs are listed in order from north to south.** *(AO = Active reef-wide Outbreak, ASO = Active Spot Outbreak, IO = Incipient Outbreak, ISO = Incipient Spot Outbreak, NO = Non-Outbreaking, NS = Not Surveyed, * = front reef zone not surveyed in 1996–97; U/N = unnamed reef)*

As usual, my sincere thanks to all contributors for continuing to support this valuable scheme.

Our most recent COTSWATCHERS are:

A Lloyd / Ingham; **A Ballard** / Townsville; **A Knight** / Quicksilver Connections; **C Coxon** / Port Douglas; **C Piper** / Lane Cove; **C Purdon and H Malcolm** / DoE Townsville; **D Conwell** / North Epping; **D Schapendonk, I Davis, T Lace, A Kelly and P Paxton** / Great Diving Adventures; **D Wachenfeld** / Hermit Park; **D Wiseman and W Mahon** / Sunlover Cruises; **D Anderson, S Wilson, D Kusnezow, W Pearce, Brian X and S Payne** / Great Adventures, Cairns; **F Helligman** / Lady Elliot Island Resort; **F Muir and S Martin** / DoE Cairns; **Friendship Cruises** / Mission Beach; **G Conwell** / North Epping; **G Burns** / Roseville; **G Smith** / Townsville; **I Stapleton** / Nimrod Cruises; **J Purcell** / Great Adventures; **J McKenzie-Smith** / Cooktown; **K Wallis** / DoE Magnetic Island; **K Hoppe** / Kiel; **L Bright** / Townsville; **M Watterson** / Innisfail; **M Greet** / Port Douglas Dive Centre; **M Allen** / F.V. Seafari, Cairns; **M Mathews** / Undersea Explorer; **N Munro** / Sixteen South Charters, Port Douglas; **N Heath** / Aspley; **Navy Divers** / HMAS Cairns Dive Store; **Ocean Spirit Cruises** / Cairns; **P Heatherwick** / Port Douglas; **R Avery** / Menai; **R Taube** / Brisbane; **S Balson** / DoE Cardwell; **S Zannino** / Gladstone; **T Kong** / Hong Kong.

New updated brochure

'Crown-of-thorns starfish on the Great Barrier Reef: the facts (Update March '97)' has now been published. Based on the latest survey results, this popular-style fold-out brochure presents an overview of the current COTS situation on the Great Barrier Reef as well as overseas. While the update closely resembles last year's original publication of the same title, there are some significant changes. The brochure not only reports on the latest population trends observed on the Reef, but also summarises some of the more recent findings of our ongoing research program. Copies are available free of charge from the CRC Reef Research Centre, the Great Barrier Reef Marine Park Authority and many regional offices of the Department of Environment in Queensland.

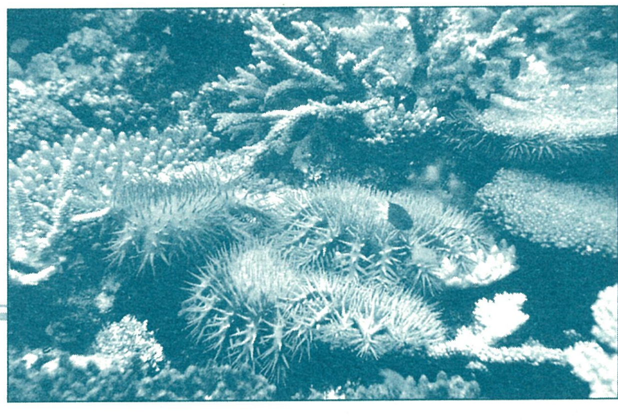
'COTSWATCH – International'

Over the last few months, I have received an increasing number of reports of renewed outbreaks of COTS on reef systems in both the Indian and Pacific Oceans. Some of these reports talk about massive outbreaks with many thousands of starfish being seen, and in some cases removed as part of local attempts to control the outbreaks and minimise the loss of live coral cover.

What is particularly interesting about these reports is that they coincide with the latest outbreak event in the central parts of the Great Barrier Reef (see above). The apparent synchrony and geographically widespread nature of these latest outbreaks is intriguing in that they suggest that a truly large-scale phenomenon (?) may be affecting reefs in two of the world's great oceans at roughly the same time.

Given that these somewhat disturbing trends now being reported from widely separated reefs worldwide, the time has come to step up our efforts aimed at understanding why the outbreaks are happening over such a large area and what the long-term effects on Indo-Pacific reefs really are. As a first step, I would like to ask divers, dive industry staff, other scientists and anyone with an interest in coral reefs to support the new 'COTSWATCH – International' reef monitoring scheme. Identifying currently unaffected as well as outbreaking areas alike has to be a priority at this stage. Furthermore, if new and developing outbreaks can be detected early, appropriate local response measures may be initiated.

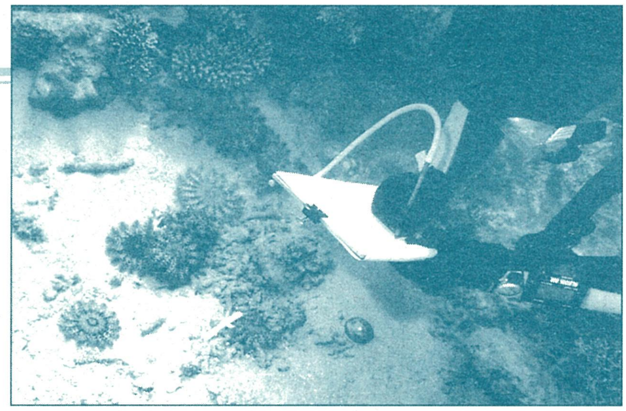
The editor of 'Asian Diver', a popular dive magazine published in Singapore and distributed throughout most of the Indo-Pacific region has kindly agreed to publish a short 'promotional' article on the proposed 'COTSWATCH – International' monitoring scheme in the next issue of the magazine. Initially, the scheme will use the original 'COTSWATCH' form in circulation here



Active outbreak of COTS

in Queensland. However, depending on the success (or failure!) of the launch, a modified, international version may soon be created.

In the meantime, I would very much appreciate getting any relevant information on the worldwide distribution of COTS, in particular, over the last decade. New, intending contributors should please remember that 'zero-sightings' are actually just as useful as actual sightings of the starfish. Dive log book entries may prove an extremely valuable source of relevant information. Upon request, I will be able to provide new contributors with plenty of 'COTSWATCH' forms, background material on the latest research findings and, if required, a copy of the COTS controls manual. Please get in touch.


Monitoring of juvenile populations of COTS

New Research Reports

Last but not least, a couple of CRC Reef Research Centre-funded projects have been completed, resulting in two Technical Reports. Below, you'll find the executive summaries of Dr John Benzie's report on COTS genetics and Mr Dave Fisk's report on the COTS controls strategy project (phase 1). Both of these reports are available through the CRC Reef Research Centre, telephone +61 77 81 4976. Happy reading.

Benzie, J.A.H. and Wakeford, M. 1997, Genetic determination of sources of *Acanthaster planci* recruitment, Technical Report No. 17, CRC Reef Research Centre, Townsville, 31 pp.

The precise origins of outbreak populations of crown-of-thorns starfish *(Acanthaster planci)* are still unknown. Modelling studies, and inferences from known aspects of *A. planci* biology, suggest outbreaks first occur in the region of latitudes 14–16°S. Early genetic studies indicated that outbreak populations sampled from Townsville to the Swains region all came from one genetic source, presumably within this region.

The present study provides detailed information for the first time on the genetic structure of populations close to the beginning of an outbreak phase, sampling several populations from the presumed region of outbreak origin. The principal objective of the study was to determine sources of recruits to *A. planci* populations in an attempt to better define the nature of the origin of outbreak populations in the region of 14–16°S. This was to be achieved through interpretation of the genetic structure of those populations by specifically addressing the following questions: 1) Are recruits to those *A. planci* populations showing a recent increase in population size different in genetic composition, and hence derived from different sources? 2) Is the genetic composition of the present 'outbreaks' the same as those described from the 1980s, implying both present and past outbreaks were derived from the same source area? 3) Are there differences in the genetic constitution of different age classes in the same population suggesting temporal variation in the source of recruits, and is this variation the same order of magnitude as any spatial variation observed?

Six populations of the crown-of-thorns starfish, *A. planci*, showing large increases in population size in 1994–95 were examined using 100–300 individuals collected from each population in Nov. 1995 – Feb. 1996. Nine allozyme loci used previously to determine population structure in the 1980s outbreak populations were analysed. The results showed: 1) no significant genetic differentiation among the recent outbreak populations for any age class (2–6 years old), consistent with the recruits to each population being derived from the same source in each year, 2) the 1996 samples clustered with the eight 1986 outbreak populations in a small part of the genetic space spanned by the 1986 non-outbreak populations, suggesting that the outbreak populations were derived from the same source in both 1986 and 1996 and, 3) no significant variation between age classes in each of the six populations suggesting that no change in the source of recruits to these reefs has occurred over the last 5–6 years.

The data showed no significant genetic differences between populations and indicated that all populations have derived their recruits from the same gene pool for the last five years. This does not necessarily mean that all populations arose from larvae from one source reef. In combination with data showing simultaneous increases in population size at several reefs (Engelhardt and Lassig in press) and hydrodynamic models indicating much of the region between 14°S and 16°S is highly connected, the genetic data indicate that *A. planci* found on several reefs in the region act as one panmictic population. The data are consistent with any one or more of a number of reef populations in this region contributing to the production of a pool of recruits that might build up over time until they contribute significantly to colonisation of reefs downstream and give rise to outbreaks in the central and southern Great Barrier Reef. The considerable similarity in the genetic constitution of the 1986 and 1996 sets of outbreak populations is consistent with both being derived from the same source area.

Reference: Engelhardt, U. and Lassig, B.R. in press, Crown-of-thorns starfish (*Acanthaster planci*) outbreaks in the northern Great Barrier Reef, Proc. 8th Int. Coral Reef Symp., Panama City, Panama.

Fisk, D.A., Vail, L. and Hoggett, A. in press, Development of cost-effective control strategies for crown-of-thorns starfish, Technical Report No. 19, CRC Reef Research Centre, Townsville, 36 pp.

An investigation was undertaken to determine the most effective method of controlling the crown-of-thorns starfish (COTS) on small patch reefs. The effect of the manipulation of COTS densities on the coral community was also an important component of the study.

Two injection regimes using dry acid (sodium bisulphate) were trialled over a 10-month period and both significantly reduced the densities and mean size of COTS on isolated patch reefs. The frequent injection regime (approximately 2 person hours effort per week) was more effective at reducing COTS numbers than the infrequent regime of 15–20 person hours intensive effort every 4 months. A visit interval of 2–3 days was tested in the latter study period and was found to be most effective at maintaining the relatively lowest numbers of COTS on two of the reefs. However, migration of individuals into the treated reefs was probably occurring at a rate that quickly offset the effect of protective measures. COTS numbers increased at a rate which was related to the interval between injection visits. Both regimes of injection effort reduced the mean size of COTS on a patch reef as well. Initial COTS density was probably the most important factor affecting the efficiency of control measures in the short term. Diver experience was also found to be very important. Efficient search methods should include a diver adopting an oblique observation position and a circular swimming motion around a feeding scar. Overhangs and cavities are favoured resting places for COTS, and these require inspections at a number of different angles to detect the starfish.

It is recommended that an intensive eradication effort in the initial phases of a control program should be followed by frequent less intensive effort. This is particularly the case where COTS are already on a site and are deemed to be causing noticeable damage to coral.

Feeding observations of populations of COTS on the study reefs indicate that few species or growth forms of corals are immune from some damage due to starfish feeding behaviour, especially when a number of COTS size classes are present. This also is the case when a reef is at an infestation stage and there is high coral cover of *Acropora* available, which is the preferred food of COTS.

Over the eight-month and ten-month study periods, most of the coral community parameters thought to be sensitive to the impact of COTS aggregations showed no significant change when compared to sites where no COTS injections took place. Indices included live and dead coral cover as well as an index of mortality, fragmentation rates, and relative abundance of coral species. Hard coral cover generally decreased over the first eight months but there was no difference between any of the treatments in this trend. The cover of *Acropora* spp. decreased over the eight months but this decrease was lower in the untreated sites compared to all the treated sites. As the numbers of COTS did not decrease at the non-manipulated sites, the likely explanation for this result is the relatively higher initial cover of *Acropora* spp. at these sites.

A significant increase in the mortality index (ratio of dead to live coral cover) at the unmanipulated sites compared to the treated sites occurred at the same time as a significant decrease over time in the mean index value. This may indicate that the period of the injection regimes was not sufficient to significantly alter the expected changes in community structure under the prevailing circumstances of COTS densities and migration rates. Also, it is most likely that the differences between treatment sites in coral cover (particularly *Acropora* spp.) was too large for an effect of treatment regimes to be detected over the period of the study. Alternatively, the period prior to the commencement of the study when COTS were present in large numbers may have been too long as they may have changed prior to the start of this study.