RESULTS OF MANAGEMENT-RELATED PROJECTS

This section provides a summary of the main results of management-related projects funded under the COTSAC program and coordinated by the GRMPA. The results are presented in the categories of research as recommended by the COTSAC, rather than by individual projects. For some of the very broad categories, e.g. "human factors", related studies are grouped into subcategories. Summaries provided by researchers (in reports or publications) have been used where possible. The author accepts responsibility for any interpretation and for summaries when not provided by researchers.

This review is intended as a report of work done and not as a critical analysis. No attempt has been made to interpret results or question the validity of researchers' methodologies and constructions. Where relevant, and to help with understanding, notes on actual work done have been included with results. Details can be obtained by reference to the publications and reports listed at the back of this review.

Background

Management-related studies were primarily intended to investigate the role of human activities in outbreaks and to provide options for controlling them should they be found to be triggered or exacerbated by human activity. "Conclusive evidence of major populations prior to major human impact or involvement with the Great Barrier Reef would alleviate concern that they represent a totally new, man-induced alteration to the ecological dynamics of the system" (COTSAC, 1985). To this end, oral history studies were intended to research evidence of outbreaks on an historic timescale (200 years) while examination of reefal sediments for COTS skeletal elements was to find evidence of outbreaks on a geologic timescale (15,000 years).

A variety of projects focussed on the possibility of human activities causing outbreaks, viz. over-fishing of COTS predators and enhanced larval survival through altered environmental conditions, e.g. increased nutrient input from agricultural activities. In this regard, a suite of studies focussed on Green Island reef - an area of intensive usage, close to the coast, offshore from the Barron River catchment, and site of massive COTS outbreaks in 1962 and 1979.

Socio-economic implications of COTS outbreaks (e.g. effects on intrinsic and economic values) have an important bearing on management strategies. Studies in this area were intended to assess such aspects as the cost to the tourist and fishing industries, and research programs.

In parallel, the COTSAC recommended studies into testing control measures. These were designed and implemented to assess the effectiveness of existing methods and to develop potentially more efficient techniques, including biological control. Assessment of the need to control COTS outbreaks was to be elucidated by a risk analysis study.

In addition to these research projects, the GBRMPA initiated two projects consistent with COTSAC recommendations to keep the public and media informed on the situation regarding distribution and research relating to COTS. A special edition of the Australian Science Magazine and a 25 minute video on COTS and current research were produced in 1987. Both have proved immensely popular.

Results

GEOLOGICAL STUDIES

(a) Surface sediments from Green Island and John Brewer Reefs contain nearly two orders of magnitude more COTS skeletal elements than Heron Island Reef. This finding reflects the known recent history of COTS outbreaks on these reefs. While Green Island

and John Brewer Reefs are known to have been seriously affected by COTS outbreaks in the last 30 years, no large COTS populations have been recorded from Heron Reef.

(b) Radiocarbon dating of groups of COTS skeletal elements has confirmed that elements present in surface sediments generally represent the remains of contemporary *A. planci.*

(c) The number of *A. planci* skeletal elements in ancient, subsurface sediment obtained from Green Island and John Brewer Reefs is comparable with numbers recovered from surface sediment at these localities.

(d) Detailed stratigraphic interpretation of the *A. planci* record within subsurface cores is complicated by biogenic sediment recycling, primarily by callianassid shrimp. Although carbon dating of bulk sediment from cores shows an ordered age structure with depth, accelerator mass spectrometer ages for individual COTS skeletal elements show little relation to bulk dates.

(e) Because of this bioturbation individual outbreaks or short-term cycles in COTS abundance cannot be identified, however, the density and distribution of subsurface elements suggest that large populations of *A. planci* are not a recent phenomenon, but have been an integral part of the GBR ecosystem for at least 7,000 years on John Brewer Reef and 3,000 years on Green Island Reef.

(f) Analysis of surface and subsurface sediments from Capricorn-Bunker reefs (Heron, Fitzroy, Wreck, Wistari and Lady Musgrave Reefs) failed to find any COTS skeletal elements, suggesting these reefs have not supported large numbers of COTS in the past.

(g) Surface and subsurface sediments collected from reefs off Innisfail contained COTS skeletal elements of similar densities to those recorded from Green Island Reef. The density of elements in subsurface samples from these reefs is consistent with a prolonged period of relatively high COTS population densities.

(h) There was a decrease in the density of COTS skeletal fragments moving south from the Innisfail sector.

(i) South of 20° there is no record of COTS skeletal elements in surface or subsurface sediments, suggesting a southern limit to large populations of COTS at this latitude.

HUMAN FACTORS POTENTIALLY CAUSING OUTBREAKS

(i) Predator Removal Hypothesis

(a) The following predators on COTS were identified from field observations and feeding trials:

* *Charonia tritonis* (giant triton)
* *Thalassoma lunare* (moon wrasse)
* *Lethrinus nebulosus* (spangled emperor)
* *Chaetodon aureofasciatus* (butterflyfish)
* *Abudefduf* sp. [?*melas*] (damselfish)
* *Dischistodus perspicillatus* (damselfish)

(b) Of 267 COTS examined at Holbourne Island (off Bowen) during an outbreak, 40% had missing or regenerating limbs. This sublethal damage was construed as an index of predation pressure.

(c) A literature survey of carnivorous reef fishes of the families Serranidae, Labridae, Lutjanidae and Lethrinidae identified species of these families as potential predators on *A. planci*, although COTS were not specifically reported as a prey item.

(d) *A. planci* fragments were found in the alimentary tract of a spangled emperor (*Lethrinus nebulosus*); one in a sample of 238 benthic invertebrate feeding fishes (including 30 *L. nebulosus*, 23 *L. chrysostomus* [red-throat emperor] and 5 *L. sebae* [red emperor]) collected from GBR reefs affected by COTS.

(e) Although the predator was of a size capable of consuming a living adult starfish, it was unknown whether the prey had been consumed whole or as fragments ingested from bottom sediments.

(f) Available data on fishing on the GBR is inconsistent and incomplete.

(g) Because of these inadequacies, especially the lack of fishing effort statistics, it is not possible to gather any evidence to support or refute the hypothesis that over-fishing of COTS predators has been responsible for observed recent increases in starfish populations. [Major research projects investigating the "predator removal hypothesis" are being funded through the COTSREC program]

(ii) Terrestrial Runoff Hypothesis

(a) Lignin phenolic acids and triterpenoid alcohols are particularly strong markers of terrigenous input sources.

(b) Benthic sediment sampling across a transect from Cairns to Arlington Reef (approx 35km offshore) demonstrated that terrigenously derived organic material reaches mid-shelf reefs of the GBR.

(c) Taraxerol, a pentacyclic triterpenoid alcohol of exclusive higher plant origin was isolated and identified in sediments from Arlington Reef.

(d) There is some evidence for anthropogenically derived hydrocarbons, probably of petroliferous origin, near Cairns Harbour. They do not appear to extend to 20kms from the shore.

(e) Increased levels of phosphate in the water column are responsible for chemical and morphological alterations of the coral skeleton.

(f) Nutrients in the oceanic waters are being transported from terrigenous sources both in solution and adsorbed on to the sides of clay and iron oxyhydroxide particles.

(g) Increased levels of nutrients in the marine environment are closely related to land management practices on the nearby mainland.

(h) The distribution and deposition of anthropogenically-derived influences on coral reefs is more widely spread than previously anticipated.

(i) Non-anthropogenic influences such as El Nino Southern Oscillation events are also being recorded in the coral skeleton.

(j) During the year of this study (1986/87) a total of 2,056 tonnes of elemental nitrogen, 734 tonnes of phosphorus and 971 tonnes of potassium was applied to the Barron River catchment.

(k) Major land uses contributing to fertiliser application were the following:

Phosphorus - dairying, beef, maize, peanuts, tobacco and sugar
Nitrogen - dairying, maize, sugar and tobacco
Potassium - tobacco, sugar and potatoes

(l) While agriculture chemicals (fertilizer) applied to farms above the Tinaroo Dam account for almost half of the total catchment application (farms below the dam accounted for the other half), the presence of the dam provides a potential short and long term storage for nutrients and an opportunity to accumulate very high quantities of some chemicals. These may subsequently be exported to the sea.

(m) Historical data from annual ABS surveys show a dramatic increase in the use of fertilisers within the Atherton Shire (part of the Barron River catchment) beginning in the decade of the 1960s and peaking in 1974.

(n) Controlled releases from the Tinaroo Dam (first filled in 1963) mean some water flows down the Barron River from the dam each year, but overflow conditions are irregular.

(l) An estimated 10% (base value) of applied nutrients is exported from the catchment annually. The infrequent "pulses" caused by overflow of the dam might be highly significant in downstream marine receiving waters.

(iii) Green Island - A Case Study

Hydrology & Sedimentology

(a) The currents around Green Island and surrounding reef are mainly forced by wind. Their velocity and direction are dependent on wind intensity and direction.

(b) During north-east winds, the predominant currents spiral, in an anticlockwise direction, around the island onto the southern reef flat, creating an eddy effect in the lee of the island. This area is consequently an area of high retention.

(c) During south-east winds, predominant currents flow to the north west. High retention areas are located in the lee of the island. Double vortices were recorded on the flooding tide.

(d) There was a minimal treatment-response-discharge time for sewage. Dye released into the island's toilets was detected in the sea within one hour of release.

(e) The reef flat and slope up to approximately 700m to the north of the sewage discharge point (located on the reef crest to the south west of the island) are usually exposed to the discharged sewage plume.

(f) The major concentration of dye representing effluent consistently passed 50m from the end of the jetty at a bearing of 330 degrees. However, significant concentrations of dye are retained in the lee of the island for a period up to 18 hours.

(g) Effluent escaping from holes in the discharge pipe has the potential for considerable impact on the reef environment and on reef users as compared to discharge from the outlet proper. Discharge waters from holes in the pipe are more likely to be retained in leeward eddies.

(h) Bioturbation appears to make sediment coring an ineffective index of the suspected contemporary appearance of seagrass as the amount of bioturbation alters the stratification considerably.

Fishes (effects of COTS, sessile fauna and seagrass beds)

(i) The seagrass bed has a marked effect on the relative abundance of some species within the reef fish community. Large numbers of juvenile snapper, emperor, parrotfish, goatfish and rabbitfish were found around the base of bommies within the seagrass bed. Rare species of parrotfishes were also associated with the seagrass bed.

(j) There was no difference in the total number of fish species recorded in seagrass and non-seagrass areas at Green Island. Furthermore, the presence of a seagrass bed did not appear to affect the distribution patterns of highly mobile schooling species (e.g. adult snapper) or more site attached species such as damselfishes.

(k) Fish distributions did not appear to be strongly related to the sessile fauna on the bommies which they inhabit. The only exception to this was the density of parrotfish juveniles, which was found to be related to the abundance of rubble substratum.

(l) Adult and juvenile snappers, parrotfish and goatfish were found to be absent at nearby Arlington Reef (no seagrass beds, no history of COTS outbreaks). However, no differences were found in the density of the six most common species of reef fish between Green Island and Arlington Reef study sites.

(m) The Green Island seagrass bed is important for the recruitment of reef fishes, especially the commercially important snappers. Up to 40 juvenile snappers (mainly *Lethrinus nebulosus*) were found on bommies within the seagrass beds at Green Island while none were recorded in non-seagrass areas at Arlington Reef.

Juvenile COTS

(n) Substrate searches (10 stations, 2 sites at each, and 4 replicate quadrats 0.5m x 0.5m at each site) and belt transect surveys (10 stations, 2 sites, 20m x 4m transects searching for feeding scars) located only two juveniles in 1989 - a 0+ and a 1+.

(o) Most feeding scars found were caused by the corallivorous gastropod *Drupella*. *Drupella* were present in 12 of the 20 sites searched.

[Studies on coral recovery on Green Island Reef have been funded by the GBRMPA's Research & Monitoring Section and more recently with COTSREC funds]

(iv) Pacific Reefs

Fiji

(a) According to Fijian reef fishermen,COTS in the Suva area were low to moderate in abundance from the 1930s to the 1960s. A progressive build up occurred on some reefs in 1963-67 leading to a major outbreak episode from 1967-71.

(b) A chronic phase between 1977-89 consisted of three intensive, macroscale recruitment events (1977, 1984 & 1987), and at least two localised but intensive recruitment events.

(c) Outbreaks were the result of high juvenile recruitment.

(d) Annual recruitment was very patchy in time and space. The macroscale recruitment events resulted in outbreaks over thousands of hectares, whereas the localised but intensive events resulted in small concentrated outbreaks over only tens of hectares.

(e) Although growth rates within monitored cohorts were highly variable, mean growth rates of two cohorts (1984 & 1987) were similar.

(f) Longevity of the 1977 cohort was 7-8 years; that of the 1984 cohort was 2-3 years. The latter was affected by two mass mortalities that have been attributed to a sporozoan pathogen.

(g) Annual recruitment between 1975-89 had no overt relationship with rainfall events as proposed in the terrestrial runoff hypothesis.

Vanuatu

(h) The distribution and abundance of COTS and the living and dead coral cover were investigated at 29 sites on 13 islands of Vanuatu, South Western Pacific, using spot dives, manta tows and belt transects in March/April 1988. About 31% of sites surveyed had been affected to varying degrees (active outbreaks: 10%; recently affected: 6%; probable past outbreaks: 14%). Reefs over a distance of 500km of the archipelago had been affected.

(i) Reefs around the capital, Port Vila on Efate Island, were seriously affected by COTS outbreaks and despite small scale control programs in 1986, coral cover became insufficient in many tourist sites for coral viewing. Anecdotal reports indicate that the outbreak episode was probably the first in at least 20 years.

(j) COTS outbreaks apparently began almost simultaneously in much of the group (almost 5° of latitude or 500km) around the same time (1985/86).

(k) No direct correlation with human activities was evident. Rural islands are undeveloped, light to moderately populated, and fishing pressure is relatively light. The outbreaks are considered to result from a widespread and highly successful recruitment from a primary outbreak rather than from a series of virtually simultaneous, independent, widely scattered primary outbreaks along the archipelago.

NON-BIOLOGICAL CONTROL

(a) Small, isolated COTS outbreaks may be successfully eradicated and limited areas (several hectares) of coral may be preserved during a major outbreak by a prolonged program of hand control.

(b) Total costs of eradication programs (excluding labour) on the GBR, using the most efficient and effective technique available (injection of copper sulphate) were in the order of $6 to $17 per starfish. Inclusion of labour doubled the cost.

(c) Control of COTS outbreaks on the macroscale (many reefs) is not possible using currently available methods.

(d) Quicklime has limited potential for mass eradication. Large quantities are required, uniform dispersal would be extremely difficult, a large portion of starfish are hidden and would escape injury, and coral and some sessile benthos would be seriously affected.

(e) Fences constructed with 12mm mesh, 1m in height with a 0.6m wide overturned top are effective barriers to starfish movement. These fences could be used to prevent reinfestation of cleared areas by migrating adult COTS, thereby avoiding the necessity of a sustained eradication operation.

BIOLOGICAL CONTROL

(a) *A. planci* have specific symbiotic bacteria associated with tissues of healthy specimens.

(b) Diseases of COTS do occur in both wild populations and in aquarium-held specimens.

(c) Symptoms of disease initially include declining activity of the starfish and subtle changes in physical characteristics. These initial symptoms are followed by necrosis and lesion formation, usually resulting in death within 1-2 days. Dead COTS in the field are decomposed or fragmented beyond recognition in 3-5 days.

(d) Marine bacteria are involved in mortality of starfish. This has been demonstrated by recovery of severely affected starfish following treatment with antibiotics.

(e) Bacteria associated with lesion formation and necrosis have not been shown to be able to initiate disease in healthy adult COTS.

(f) A range of marine bacteria can act as facultative pathogens of adult COTS but none were identified as primary pathogens applicable to development as potential biological control agents.

(g) Pig gastric mucin was found to be toxic to COTS, indicating that chemicals, probably less environmentally damaging than copper sulphate, can be found for small scale control of COTS populations.

(h) Intracellular parasites resembling the vegetative (asexual) stage of sporozoans were found associated with pathological change primarily in the stomach and pyloric caecae of diseased COTS collected in Fiji.

(i) Juvenile COTS showed changes ranging from increased transparency of the aboral disc to complete erosion of the cardiac and pyloric stomachs and eventual perforation. Adult COTS had deep ulcerative lesions covering more than 50% of the body and erosion of the central disc area which exposed the pyloric caecae, gonads and skeletal elements.

(j) Four microscopic changes were recognised in the stomachs and pyloric caecae of diseased COTS, viz. oedema, inflammation, necrosis and fibrosis.

(k) A mass mortality (>99%) which occurred amongst juveniles 8-23 months old on Suva Reef, Fiji, was attributed to the disease.

(l) Of the 90 COTS examined from the GBR, 10% showed some sign of the disease, but pathological effects were minor compared to specimens from Fiji.

SOCIO-ECONOMIC RESEARCH

(a) COTS outbreaks have not decreased overall visitation to the GBR in gross terms as visitation is currently increasing each year. At the current time, COTS do not appear to be a serious factor influencing decisions on whether or not to visit the Reef. However, reduced visitation may result in the future should the COTS seriously affect the coral sections (areas where coral can be viewed) of the GBR.

(b) The financial value of the Reef region to tourism was derived as $653,700,000 per annum (1987 figure). This included expenditure on travel to the region, travel within the region, accommodation, food and sightseeing trips to the coral sections of the Reef. Associated with this expenditure would be flow-on expenditure resulting from the multiplier effect.

(c) Over and above this financial figure an economic value of the GBR exists as a result of it being a "public good". For visitors to coral sections of the Reef, this was estimated to have an economic value of $105,623,627 per annum.

(d) In net present value terms, the Reef region was valued, over and above current financial expenditure values, at more than one billion dollars.

(e) In order to specifically evaluate the economic value of the coral sections of reef a contingent valuation approach, based upon a hypothetical entry fee to the coral sections of reef was conducted. This analysis derived a value of $5,652,056 as the consumer surplus, or economic value of the coral sections of the reef. For vicarious users (persons not currently on a trip to the GBR, but gaining some benefit from either having the option in the future, knowing of its existence or knowing it will exist for future generations), the economic value of coral sections of the GBR was estimated at $45,386,664 per annum.

(f) The determination of these financial and economic values provided a baseline for analysing the economic effects of COTS on coral sections of the Reef. The contingent valuation approach was again implemented through the form of an additional entry fee to that contributed for the management of the Reef. In this situation a hypothetical trust fund was set up from which the entry fee contributions would be expended on the research and control of COTS. The aggregate consumer surplus for visitors to coral sections of the Reef and visitors intending to visit a coral section of reef was calculated as $1,317,078 per annum. Vicarious users were willing to pay $15,633,926 per annum to a trust fund that would research and control COTS.

(g) The proportion of willingness to pay for the research and control of the starfish was considered to be considerable in comparison to the overall willingness to pay for the management of the reef (approx $17 million for COTS research and $68 million for total management; a ratio of about 25%).

(h) No particular group of users indicated they had sustained a significantly stronger impact from COTS.

(i) As a result of there currently being very little decision making effect on visitors to the region the financial impact sustained by the local economy was also considered not to be significant. However, in temporal terms, the financial and subsequent employment impacts with the regional economy may significantly increase if visitors' utility is diminished through increased damage by COTS.

(j) The economic values accruing to vicarious users should be considered very carefully with respect to future impacts to the region. Should the GBR deteriorate through increased damage by COTS then the overall value of the Reef to Australia will decrease significantly through the loss of utility held by this group.

(k) None of fourteen commercial GBR fishermen interviewed had seen COTS spines in fish stomach contents.

(l) Many fishermen spoke of "dead reefs" and reefs that used to be good, but there is no evidence to suggest that this is due to COTS infestations. There is no evidence that COTS outbreaks have affected reef fishing.

RISK ANALYSIS

(i) Tourism

(a) In 1985 an estimated 200 crewed charter boats operated in GBR waters. These vessels had a market value of over $50 million and carried an estimated 1 million passengers.

(b) In 1985 the number of bare-boats was estimated at 85 (market value $9 million), increasing to 130 (market value over $10 million) in 1986.

(c) By 1987 the total value of the fleet (crewed and bare-boats) probably increased to $70 million, carrying 1.1 million passengers.

(d) The regional spread of passenger numbers was:

- Central Area (Whitsunday Islands and adjacent outer reef, and waters adjacent to the ports of Mackay, Shute Harbour and Bowen) - 37%
- Northern Area (outer reefs adjacent to Townsville and as far north as Mission Beach) - 29.5%
- Far Northern Area (Green Island and adjacent reefs as well as those out from Port Douglas and Lizard Island) - 19.5%
- Southern Area (Capricorn and Bunker Groups, the Keppel Isles, the Swain Reefs, as well as the inshore waters adjacent to the ports of Bundaberg, Gladstone and Rosslyn Bay) - 14%.

(e) Activities of passengers were as follows:

- Sightseeing and [continental] island day trips (34%)
- General reef trips (29%)
- Ferry trips (26%)
- Other (11%)

(f) In 1987 there were in the order of 2,000 rooms/units in the island resorts (excluding Magnetic Island) with a guest capacity of approximately 5,000 persons. These were serviced by 2,500 - 3,000 employees.

(ii) Fisheries

(g) The total Reef Region commercial fleet was estimated at 1,075 boats in 1981, having a market value in that year of $56.3 million. The otter trawl fleet comprised 485 vessels, valued at $44.6 million. Operating these boats were 2,000 skippers and crew (including part-time fishers).

(h) The conservative value of the commercial catch was estimated to have averaged at least $27.8 million for each year from 1977/78 to 1979/80, in 1979/80 prices. In terms of volume, the Reef Region commercial catch of all species was estimated at 7,600 - 8,700 tonnes (live weight) of which the prawn catch was in the order of 4,500 - 5,000 tonnes.

(i) **For the en**tire Reef Region, the value of the capital invested was $180 million (in 1986 values). The otter trawl component was approximately $150 million. The value of the catch was approximately $156.5 million (including $127.5 million for the otter trawl catch).

(iii) Economic Analysis

(j) The consumers' surplus resulting from visits to coral sites by Reef region visitors was estimated to be $5,650,000 per annum, or over $8 per adult visitor. This is the annual sum of money visitors would be willing to pay over and above their fares and other costs incurred in seeing coral sites in their present condition. The value of coral sites to vicarious users was estimated at $45 million per annum. The total economic value of coral sites was thus estimated to be over $51 million per annum. (Other statistics presented in summary of Socio-economic Research).

(k) Visitors to the reef expressed a willingness to pay an average of $3.00 per visit to coral sites for the purpose of research and control of COTS, yielding a total of $1.3 million per annum. The Australian Public (vicarious users) expressed a willingness to pay a total of $15.6 million per annum for this purpose. The net present value for all coral

sites on the GBR for both of these groups of users was estimated to range from $317 million to $615 million.

(iv) **Controls and Rehabilitation**

(l) Using the willingness of visitors and vicarious users to pay for COTS control, visitation rates, results and costs of attempted controls on the GBR (Zann & Weaver, 1988), it is concluded that local control programs at popular tourist sites are economic propositions. In the cases of Green Island, John Brewer Reef and Beaver Cay, funds collected from visitors would cover protection of limited coral-viewing areas by manual COTS controls.

(m) Estimates of costs to rehabilitate areas devastated by COTS range from $25 to $600 per square metre (depending on coral cover required, techniques employed and distance from coral sources). The cost of rehabilitation is much higher than COTS control.

ORAL HISTORY

(a) Australian reef users (especially trochus divers) expressed high awareness of COTS prior to 1960 with personal recollections dating back to the 1930s.

(b) Of the Australian indigenous groups, Eastern Torres Strait Islanders (from Murray, Darnley and Stephen Islands) were most familiar with COTS.

(c) COTS abundances often led trochus divers to abandon a reef because they made swimming and diving impossible. COTS injuries ranked below coral abrasions and eel-bites as work-related injuries.

(d) Eleven of the 92 respondents indicated major populations of COTS prior to 1960, with several describing outbreaks in the 1930s and 1940s.

(e) The (sometimes contradictory) evidence for the occurrence of previous aggregations of COTS is not sufficiently conclusive to rule out the possibility that outbreaks of the scale observed since the 1960s represent a recent phenomenon.

SURVEYS

(i) **Near Infra-red Aerial Photography**

(a) Although mapping of reef flat ecology can be carried out by normal ground methods and true colour aerial photography can greatly aid in this mapping process, the differentiation of living corals and other organisms such as algae is greatly enhanced by using near infra-red aerial photography.

(b) Testing of the methodology to date has indicated that it has a high potential for monitoring changes to reef top communities.

(c) Evaluation of the effectiveness of images obtained from different flying heights suggests that a flying height of 3000 feet (914m) is optimal. Smaller scale images appear incapable of differentiating coral heads and signals from living coral and macroalgae are very similar. Larger scales provide enormous detail with even small coral heads less than 20cm in diameter being identifiable. However, cost effectiveness is reduced by the large number of photographs required to cover individual reefs or transects and associated digitising costs.

(d) Greatest potential lies in the digitised imagery with a wide range of manipulative and quantitative procedures available. Indicative of the power of the method is the size of

individual pixels resulting from scanning. On the 4000 feet photography this is 50cm x 50cm and on the 500 feet photography 7cm x 7cm.

(ii) Capricorn and Capricornia Sections

(e) COTS abundances (using 50m x 20m transects) and coral cover (using 10m intersect transects) were estimated on 30 reefs in the Capricorn Section and on 11 reefs in the Capricornia Section of the GBRMP during December 1985 and January 1986. Ten reefs in the Swain Group (Capricorn Section) were surveyed previously in January 1984.

(f) On Sanctuary Reef in the main body of the Swain Group there were moderate numbers of COTS on the back reef slope and in the shallow lagoon. Hard coral cover was locally reduced on the back reef slope and was less than 10% in one site.

(g) There were small localised aggregations on three other reefs in the main body of the Swain Group: on the west tip of Horseshoe Reef, on the west face of Gannett Cay Reef, and on the north-west side of Recreation Reef. There were also small numbers (between 10 and 50) on seven other reefs in the Swain Group.

(h) During the survey in January 1984 the small active aggregation was present on Gannett Cay Reef, but only 2 individuals were seen on the back reef slope at Sanctuary Reef (compared to 160 in 1985).

(i) COTS were observed on 3 of 11 reefs surveyed in the Capricornia Section. Mean numbers were 4 per hectare on Fitzroy Reef and one per hectare on the other two reefs (Lamont and Llewellyn Reefs). Coral cover was high on reefs were no COTS were recorded (34% - 60%) and lowest (17.4%) at Fitzroy Reef.

(iii) Whitsunday Region

(i) The distribution, abundance and impact of COTS were assessed on 29 fringing reefs and on 8 continental islands in the Whitsunday region in December 1988 and on 4 adjacent midshelf reefs in January 1989. When logistically feasible, COTS were eradicated by injection with saturated copper sulphate solution.

(j) Aggregated populations were found on the following reefs:

* Hayman Island between Rescue and Tower Points (estimated over 1,000 COTS: 250 injected);
* Hook Island- Maureen's Cove (estimated 1,000 COTS: 112 injected)
  - Luncheon Bay (estimated COTS several hundred: 72 injected)
  - Pinnacle Point (estimated COTS several hundred: 29 injected)
  - Butterfly Bay (estimated COTS 1,000: 72 injected)

(k) COTS were were found on Langford Island reef and Bait Reef, mainly at depths ranging from 8-14m.

(l) Scarring of hard corals consistent with recent COTS predation (or other corallivores) was found on White Bay reef (Haslewood Island), Catseye Bay reef (Hamilton Island), Mantaray Bay reef, Mackerel Bay reef and Saba Bay reef (Hook Island), Langford Island reef, Blue Pearl Bay reef (Hayman Island), Black Island reef, Lagoon Rocks reef (Whitsunday Island) and Hook reef.

(m) No indication of coral predation was evident at Anchor Point, Cockatoo Point, Hook Passage (Hook Island), Whitsunday Island, Peter Bay reef, Chance Bay, reef at eastern end of Whitehaven Beach, Chalkie's Beach reef and Pallion Point reef (Haslewood Island), Driftwood Bay (Hamilton Island), Henning Island reef, Hardy Reef and Line Reef.