

THE CROWN OF THORNS STARFISH RESEARCH PROGRAM
1986/87

A SUMMARY OF PROJECTS CURRENTLY UNDERWAY FOR THE MEMBERS OF THE
CROWN OF THORNS STARFISH ADVISORY REVIEW COMMITTEE

PREPARED BY GBRMPA ACTING COORDINATOR AND AIMS CROWN OF THORNS
STARFISH STUDY LEADER.

PROJECTS RECOMMENDED BY CROWN OF THORNS STARFISH
ADVISORY REVIEW COMMITTEE, 17 FEBRUARY 1986

(A) MANAGEMENT-RELATED PROJECTS TO BE CO-ORDINATED BY GREAT
BARRIER REEF MARINE PARK AUTHORITY (Grants 1985/86)

GBRMPA PROGRAM AREA (1) HUMAN FACTORS AFFECTING CROWN OF THORNS
STARFISH

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| (a) "Survey of crown of thorns predators at infested and non-infested reefs on the Great Barrier Reef" | A.Prof.R.Endean
Uni.Queensland | \$50,000 |
| (b) "The relationships between crown of thorns starfish outbreaks and water mass characteristics in the Great Barrier Reef Region" | Mr D. Claasen,
Dr L. Zann and
Mr I. Dutton,
GBRMPA and
consultants | \$42,000 |
| (c) "Potential human causes of crown of thorns starfish in the South Pacific" | Dr L. Zann
GBRMPA,
Mr J. Brodie
Uni. S.Pacific,
Fiji: | \$12,000 |
| (2) <u>SOCIO-ECONOMIC RESEARCH.</u> | | |
| "Socio-economic consequences of major populations of crown of thorns starfish" | Mr T. Hundloe,
Griffith Uni.
Qld | \$39,800. |

(3) RISK ANALYSIS

"Biological and economic risk analysis study to contribute to assessment of the need for control of crown of thorns starfish"	Mr T. Hundloe, Dr J. Parslow, Griffith Uni. Qld	\$33,000.
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(4) ORAL HISTORY

"Oral history of human use and experience of crown of thorns starfish on the Great Barrier Reef"	Dr D. Trigger, Dr L. Ryan, Dr A. Chase, Griffith Uni. Qld	\$10,000
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(5) BIOLOGICAL CONTROL

(a) "Studies on diseases of the crown of thorns starfish"	Prof.R.Campbell, James Cook Uni. Qld	23,389
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(b) "Identification of bacterial populations associated with crown of thorns starfish and assessment of their role in the ecology of the starfish"	Dr D. Sutton, James Cook University, Qld	\$18,737
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(6) GEOLOGICAL SEDIMENTS

"Role of Acanthaster in reef degradation processes: historical perspective and current influence"	A.Prof.R.Henderson James Cook Uni. Qld.	\$79,540
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B) ECOLOGICAL RESEARCH (CO-ORDINATED BY AUSTRALIAN INSTITUTE OF MARINE SCIENCE) (1986)

(1): POPULATION DYNAMICS OF PREDATOR

(a)	"Geographic patterns in genetic variation of <i>Acanthaster planci</i> populations"	Dr. J. Stoddart, AIMS	\$22,736
(b)	"Inheritance patterns of isoenzymes in <i>A.planci</i> "	Drs J.Stoddart and R.Olson AIMS	\$1,300
(c)	"A field test of the larval starvation hypothesis for <i>A.planci</i> "	Dr.R.Olson,	\$42,509
(d)	"Fertilization rates of <i>A.planci</i> in the field"	Dr.R.Olson, AIMS	\$18,500
(e)	"Substrate selection by larvae of <i>A.planci</i> "	Dr.R.Olson, AIMS	\$5,000
(f)	"Development of techniques for the production of large numbers of larvae and juveniles of <i>A.planci</i> "	Dr.R.Olson,	\$20,500

(g)	"Feeding rate of A.planci in the field"	Dr.P.Moran, AIMS	\$4334
(h)	"Feeding preferences of A.planci in the field"	Dr.P.Moran, AIMS	\$4,200
(i)	Rate of decomposition of adults in the field"	Dr.P.Moran, AIMS	(no cost)
(j)	"Ephemeral patches of phytoplankton in the central GBR as a potential food source for larvae of A.planci".	Dr.M.Furnas, AIMS	\$10,834
(2): DYNAMICS OF PREY AND ECOSYSTEM CONTEXT			
(a)	"Recolonization and recovery of coral communities"	Dr.T.Done, AIMS	\$12,706
(b)	"Interpretation of the history of disturbance to coral communities through analysis of morphology and population structure in massive <u>Porites</u> spp."	Dr.T.Done, AIMS	\$2,200
(c)	"Genetics of population fluctuations of corals"	Dr.J.Stoddart, AIMS	\$5,700

(d)	"Growth and survivorship of coral remnants following outbreaks of <u>A. planci</u> "	Dr.T.Done, AIMS	(no cost)
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(e)	"Effects of outbreaks of <u>A. planci</u> on fish communities"	Dr.D.Williams AIMS	\$763
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(f)	"Effects of outbreaks of <u>A. planci</u> on the interaction between corals and algae: trophodynamic implications"	Dr.D.Klumpp, AIMS	\$5,404
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(g)	"Effects of outbreak of <u>A. planci</u> on the interaction between scleractinian and alcyonarian corals"	Dr.T.Done, AIMS	\$13,394
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(3) INTERACTION OF PREDATOR AND PREY

(a)	"Macro-scale studies of the distribution and abundance of <u>A. planci</u> and corals on the Great Barrier Reef"	Dr.P.Moran, AIMS	\$34,172
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(b)	"Meso-scale studies of the distribution and abundance of <u>A. planci</u> and corals on selected reefs"	Dr.P.Moran, AIMS	
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(4) TECHNOLOGICAL AND ANALYTICAL METHODOLOGY

(a)	Enhancement of substrate	Dr.R.Reichelt.	\$14,844
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reflectance in Landsat
imagery with special
attention to reef damage
by A. planci AIMS

(b) "Evaluating procedures
for the verification of
Landsat images with
reference to the effect
of A. planci" Dr.R.Reichelt \$500
AIMS

(c) "Numerical models of the
hydrodynamic regime
around schematized and
actual reefs" AIMS \$6,000

(d) "Numerical models of the
hydrodynamic regime at
John Brewer Reef" Dr.J.C.Andrews \$11,144
AIMS

(e) "Dispersal of A. planci
outbreaks on the Great
Barrier Reef a simulation
study" Dr.R.Reichelt \$2,000
AIMS

(f) "Analyses and models of
existing data" Dr.R.Bradbury \$13,894
and others

(g) "Tagging of A. planci
using micro-injectable
transponders" Dr.P.Moran, \$12,050
AIMS

OTHER INSTITUTIONS

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- (a) "Determination of Acanthaster reef flat infestation patterns by low level aerial photography" Assoc.Prof.D.Hopley \$2,000 James Cook Uni.
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- (b) "The dynamics of physiological parameters of high density crown of thorns starfish populations" Dr.J.Lucas, \$19,352 James Cook Uni.
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- (c) "A study of the temporal and spatial distributions of Acanthaster larvae in relation to survival and dispersal" Drs.R.F.Hartwick, \$5,000 and N.E.Milward, James Cook Uni.
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- (d) "Simulation of large-scale population dynamics of crown of thorns starfish in the Great Barrier Reef system" Dr M.K.James, \$32,697 Dr.L.Bode, Prof.K.P.Stark James Cook Uni.
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- (e) "Development of monoclonal antibodies against larvae of A. planci: a pilot study to detect and characterise larval membrane marker(s) for this species" Dr.P.Hanna \$16,078 Dr.V.Lee, Dr.B.Richardson, Deakin Uni.
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(f)	"Dynamics of recruitment and the densities of juvenile crown of thorns starfish between 15°s and 20°s on the Great Barrier Reef"	Dr.P.Doherty, Griffith Uni.	\$49,797
(g)	"Analysis of physical mechanisms controlling plankton patchiness on the Great Barrier Reef"	Dr.J.Parslow and Dr.A.Gabric, Griffith Uni.	\$4,000
(h)	"Field studies on the ecology of adult and juvenile <u>A. planci</u> "	Assoc.Prof R.Endean Dr.A.Cameron, Uni.of Qld	\$22,000
(i)	"Dynamics of the <u>Acanthaster</u> /hard coral interaction":	Dr.V.Harriott and Mr D.Fisk, Kuranda,Qld	\$12,000

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THE ROLE OF ACANTHASTER PLANCI IN REEF DEGRADATION PROCESSES:
HISTORICAL PERSPECTIVE & CURRENT INFLUENCE

Outline of Progress to November 30th 1986

Chief Investigator: Assoc. Prof. R. Henderson
Geology Department, James Cook University

The study is based on inspection of reefal sediment to identify Acanthaster skeletal remains. The plan was to inspect contemporary (surface) sediment from two locations with known outbreak histories (John Brewer and Green Island Reefs) and one location which has long history of investigation and no recorded Acanthaster outbreaks (Heron Island Reef). It was hoped that this work would show that contemporary outbreaks have left a clear record within surface sediment. It was then intended to use conclusions based on contemporary sediment to evaluate the prehistoric record of Acanthaster in subsurface sediment sampled at Green Island and John Brew Reefs.

Atlas of Skeletal Elements:

The initial task was to prepare a comprehensive atlas of Acanthaster skeletal elements to use as a reference for identifying individual spicules in sediment. Acanthaster spicules possess a distinctive pigmentation but all we have recorded from sediment have had their morphology checked to guarantee their authenticity.

Surface Sediment Study:

The principal sedimentary environments of all three reefs have widely sampled. Our procedure has been to take 1 kg sediment samples, sieve these to obtain the size fraction > 0.5 mm. This fraction has then been totally picked for Acanthaster skeletal elements. We have processed 159 samples in this way, 45 from Green Island, 59 from John Brewer, and 55 from Heron Island.

Our results show that Acanthaster remains are commonplace in surface sediment on John Brewer and Green Island Reefs, with counts as high as 135 being recorded. In contrast spicules are very rare on Heron Island, with only two elements represented in the entire sample suite. For John Brewer Reef and to some extent Green Island, we have found that the skeletal record of Acanthaster is enhanced in sedimentary environments adjacent to areas of dense coral cover where the biomass of Acanthaster would have been concentrated during outbreaks. This relationship implies that the mortality pattern of Acanthaster, as recorded by its skeletal debris, replicates its life distribution. It further indicates that post-mortem hydrodynamic transport of Acanthaster skeletal debris is limited.

Subsurface Sediment Study:

Sampling was accomplished by vibracoring, using equipment loaned to us by the Bureau of Mineral Resources. Sampling programmes both on John Brewer Reef and Green Island proved to be difficult to execute because of repeated equipment failure and unfavourable weather conditions culminating in loss of the pontoon sampling platform and vibracorer during cyclone Winifred.

Cores were obtained from eight sites on John Brewer Reef and six sites on Green Island Reef. In each case four replicate cores were obtained. Initially it was hoped to process all four cores from each site to check comparability of results.

Our procedure was to split each core and to divide half the core into 250 g samples, each of which was sieved and the > 0.5 mm fraction totally picked for Acanthaster skeletal elements. Cores ranged from 2-4.5 mm in length and yielded up to 51 samples. Our experience showed that processing of all four cores was impractical due to the cost in labour. Accordingly, we generally processed only two cores from each site. Our results are as follows:

1. The density of Acanthaster spicules in subsurface sediment is generally compatible with that seen at the surface. Sites which showed an abundance of spicules in surface sediment generally also show an enhanced spicular content in the subsurface.
2. The down-core distribution of Acanthaster remains is almost continuous in several cores but subject to fluctuations. A tendency for deeper core intervals to have an enhanced spicule content is apparent for both John Brewer Reef and Green Island.

We conclude that the tenure of Acanthaster, in considerable numbers, on both Green Island and John Brewer Reef has been enduring and extends to well before European settlement.

The present phase of the project is concerned with obtaining an age structure for cores by C14 dating. This is not a simple matter because reefal sediment is subject to bioturbation and the degree to which an age structure within it is preserved is unknown. Our approach involves both bulk sediment dated (at ANU), and the dating of individual spicules by accelerator-based techniques (at the Institute of Nuclear Science, NZ).

Future Work:

We are confident that the work completed and presently in train will unequivocally demonstrate that Acanthaster has had a long history of high population densities in parts of the GBR. However, we doubt that the temporal quality of the sediment record is sufficient to record specific outbreak episodes which have a duration of only a few years.

A matter of considerable interest to us is the influence of Acanthaster production on reef destruction, and sedimentation rates and styles. It may be that this animal has had a much greater hand in shaping the GBR as we know it today, than any of us currently recognise. We would like to see our study advance in this direction and may seek support from the GBRMPA in due course.

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"IDENTIFICATION OF BACTERIAL POPULATIONS ASSOCIATED WITH
CROWN-OF-THORNS AND ASSESSMENT OF THEIR ROLE IN THE
ECOLOGY OF THE STARFISH"

Chief Investigator: Dr D. Sutton
Sir George Fisher Centre for Tropical Marine Studies
James Cook University

Introduction

The major objectives of this project have been to study the interaction between marine bacteria and Crown-of-thorns, specifically to:-

- (1) identify the bacteria associated with field and aquarium populations of Crown-of-thorns starfish;
- (2) devise diagnostic procedures for detection of these bacteria;
- (3) examine the relationship between bacteria and disease in Crown-of-thorns starfish.

This project, funded both by the Marine Science and Technologies Grants Scheme and by the Great Barrier Reef Marine Park Authority, was initiated as a result of observations made by John Lucas of disease in aquarium specimens at James Cook University. Subsequently, Leon Zann made observations of disease in a juvenile population of starfish in Fiji and in both cases the role of microorganisms was implicated. Epidemics in other invertebrates and in asteroids in particular, from other parts of the world have also indicated that microorganisms are able to initiate epidemic diseases in these animals.

As a result of our study we have substantially completed objectives (1) and (2), and will be addressing objective (3) during 1987. Crown-of-thorns from diverse locations have been found to possess large populations of bacteria, at least one of which seems to be a specific symbiont. This species possesses some unusual characteristics in having a vitamin requirement and being unable to produce catalase. The close association of these bacteria in symbiont association with the Crown-of-thorns could account for these characteristics as Crown-of-thorns tissues would provide both the catalase and vitamins. These bacteria have not been found to be present in other starfish and have only rarely been detected in the water column.

Diagnostic tests have been devised to allow rapid confirmation of the presence of the symbiotic bacteria in Crown-of-thorns. The usefulness of these tests has recently been confirmed under field conditions and has also been shown to be useful for detecting bacteria other than the symbiotic type. Tests will require refinement to allow accurate delineation of all types commonly found on Crown-of-thorns.

The taxonomic characterisation of the symbiotic bacteria is substantially complete and requires only DNA analysis before

publication. This should be completed early in 1987, although some problems related to the development of appropriate HPLC techniques have been encountered.

In summary therefore, the results of the study to date are that:-

- a) Crown-of-thorns starfish have a large characteristic populations of bacteria associated with their tissues.
- b) At least one of these appears to be a symbiont having been detected in all animals sampled from all locations.
- c) Using diagnostic keys it is now possible to delineate particular types of bacteria found on Crown-of-thorns and to therefore detect unusual or uncommon types which may be of significance to the health of the animals.

This information provides the basis necessary for a search for potentially disease-causing bacteria in Crown-of-thorns, and from this the detection of possible biological control agents.

It is towards this longer term objective that the research program in 1987 will be directed.

The principle objectives are to conduct experiments to determine:-

- (1) whether the bacteria found on Crown-of-thorns are able to cause disease if -
 - a. their populations rise substantially
 - b. the animal is placed under stress
- (2) whether removal of the normal populations of bacteria from Crown-of-thorns affects the survival of the animal in the marine environment
- (3) whether known disease-causing marine bacteria (held in the Australian Collection of Marine Microorganisms at the Sir George Fisher Centre for Tropical Marine Studies) are able to initiate disease in Crown-of-thorns.

This will supplement:-

- A. the continuing sampling programme designed to provide seasonal data on bacterial population changes on Crown-of-thorns;
- B. the continuing measurement of bacterial population levels on Crown-of-thorns populations in different physiological states;
- C. the continuing search for diseased animals in the field, and assessment of the role of bacteria in the disease syndrome.

This project is being supported in 1987 by a grant from the Marine Science and Technologies Grants Scheme. However, additional support is being sought during 1987 from the Great Barrier Reef Marine Park Authority to ensure that the more

intensive approach being taken in this study can be satisfactorily completed.

"STUDIES ON THE DISEASES OF THE CROWN OF THORNS STARFISH
ACANTHASTER PLANCI"

Investigators: Professor R.S.F. Campbell, Dr J.S. Glazebrook
and Mr L. Owens
Graduate School of Tropical Veterinary Medicine
James Cook University

Introduction

The above project, which is aimed at finding a biological control agent for Crown-of-Thorns, has been in progress for eleven months (it is jointly funded by MST and COTSAC; the MST funding has enabled an early commencement date).

Our initial approach has been to examine healthy and diseased starfish from the Great Barrier Reef and Fiji to determine whether disease (infectious or non-infectious) plays a major role in limiting the size of natural populations. Of particular interest has been the disease epizootic which resulted in a mortality rate of 99% in juvenile Crown-of-thorns on Suva Reef in the summer of 1984-85 (Zann, pers.com.).

Laboratory investigations

During the first few months we have concentrated on describing the normal histology of A.planci in order to make interpretation of pathological change more meaningful. It is obviously essential to be able to separate normal and abnormal at both the gross and microscopic level. An inflammatory response has been recorded in the Crown-of-thorns and special strains have been employed to define the function of structural components e.g. mucus secreting goblet cells in the pyloric calcae.

The histopathological examination of juvenile starfish from Fiji has yielded very promising results. An agent has been shown to be associated with degenerative/necrotic changes in the pyloric calcae, tube feet and skin (mostly the aboral surface). Significantly, microscopic changes correspond with gross changes in diseased animals, e.g. soft, weak skin and atrophied pyloric calcae are both heavily infected.

Several attempts have been made to culture A.planci cells (mainly skin) in vitro using a medium suitable for clams (Tridacna spp.). Because of problems with contamination, internal organs viz. gonad and axial gland will be tried in the future. The forementioned agent can only be propagated by means of a cell line.

In a separate piece of work, macro and micro commensals are being evaluated for use as a biological tag.

Field work

Juvenile and adult A.planci are being collected on a regular basis from Helix, Keeper and Wheeler Reefs off Townsville. Present indications are that disease is not a major factor in controlling the size of GBR populations.

One of us (JSG) has been granted permission to go to Fiji in mid January to collect fresh material from surviving starfish for electron microscopy. Notes will also be taken on whether the disease is affecting other species (host specificity).

Future work/Problem areas

Our first priority for 1987 will be to identify the agent associated with Crown-of-thorns mortalities in Fiji.

Electron microscope and cell culture studies are very time consuming and require a high degree of skill and enormous patience. The appointment of a Research Officer capable of undertaking these tasks would allow the Research Fellow (JSG) and Research Officer (LO) to concentrate on describing the condition and identifying the agent responsible.

ORAL HISTORY OF HUMAN USE
AND EXPERIENCE OF CROWN OF THORNS STARFISH
ON THE GREAT BARRIER REEF

Investigator: Regina Ganter
Griffith University
Nathan

This project aims to record the human experience of the Great Barrier Reef and of crown of thorns starfish among operators, divers and others involved in extractive industries in the Great Barrier Reef Province before 1960. Especial focus is on beche-de-mer, trochus and pearl-shell gathering activities which provided the most direct and intensive human contact with the reef environment prior to the availability of outboard-motor boats and SCUBA equipment. The knowledges held by trochus dives are of particular relevance since they regularly worked on the reefs from Bell Cay to Thursday Island in reefal locations most likely to have been habitats of the crown of thorns starfish.

Progress

A review of popular and historical literature relating to the human experience of the Great Barrier Reef has been conducted. Consultation with GBRMPA personnel and other scientists and officers is ongoing, and has yielded an initial index of potential interviewees which served as the basis for fieldwork approaches. The fieldwork phase of the project consists of three journeys of four to five weeks' duration. The third journey, to Lockhardt River, Bamaga, and Torres Strait, is scheduled for January. The second journey (Brisbane - Cooktown - Hopevale - Wujal-Wujal) has just been completed and a quantitative analysis of the information gathered is not yet available.

During the first journey (Brisbane to Townsville), 15 crown of thorns starfish sightings prior to 1960 were reported in 33 interviews. Two interviewees report crown of thorns starfish aggregations, one outside Mackay in 1950, and one in the Cape Melville/Howick Group in 1951. It is hoped to cross-substantiate the latter sighting during the third fieldwork journey.

One Innisfail-based fishing charter operator reported finding crown of thorns starfish spines in the stomachs of tricky snapper (red sweetlip, red throat - Lethrinus chrysostomus) recently. He was open to the suggestion that these may have been the spines of sea urchin, but is concerned about the possibility that harmful quantities of copper sulphate may enter the food chain if used in eradication programmes. One retired fisherman reported regularly finding crown of thorns spines in the stomachs of grey snapper and tricky snapper near Bramble and Britomart Reefs before World War 11. He was adamant that they were the bristles of crown of thorns starfish and not of sea urchin.

One interviewee stated that dead patches of reef served as an indicator for an abundance of trochus shell. A variety of traditional and contemporary treatments for injuries contracted from crown of thorns starfish and other marine creatures have been suggested. No sightings of starfish migration, or folklore surrounding the starfish, have been encountered.

Among Murray and Darnley Islanders, the Meriam term for crown of starfish, ur-me-meg translated as "fireplace", is well known. The Western and Central Islanders appear to be less familiar with the term ndikeri in their language. At Hopevale Mission the crown of thorns is generally referred to as "porcupine", and at Wujul-Wujul the Kuku-Yalanji term for sea-porcupine, jalan was used. In general, Torres Strait Islanders appear to have known the crown of thorns starfish as a familiar but unimportant part of the reef. The relationship of mainland Aboriginal coastal peoples to the starfish cannot yet be satisfactorily described.

The interviewees range in age from 48 to 96, and the 61-70 age bracket is most strongly represented in the current sample. At least 14 persons who had been suggested by various sources as potential interviewees have died within the last two years, four of them since August, a circumstance which underlines the urgency which is attached to the gathering of information from former participants in the shelling and beche-de-mer industries.

In some instances the interviewees were concerned about being recorded because the identity and intention of future interlocutors remain anonymous to the speaker. These interviewees were assured that the research officer would be able to protect any statements they make. An amendment to the consultancy contract to this effect is under way.

The project is running within the projected time-frame and budget allocations, and has met with a positive, and even warm response from interviewees.

SOCIO-ECONOMIC CONSEQUENCES OF COT

Investigator: Dr T. Hundloe
Griffith University
Nathan, Queensland

This research requires gathering and analysing a considerable amount of primary data from users.

At the time of writing the survey of tourists is near completion. The sample and questionnaire for this element of the research were designed in June/July 1986. This was done in consultation with GBRMPA officers. The sample was designed so as to take into account appropriate socio-economic variables of the population and seasonal variations in tourism. Interviewing took place at selected locations between Bundaberg and Mossman, in both winter and summer. The summer season interviewing is not complete as the field work in central Queensland during early December had to be curtailed before its completion due to inclement weather. Approximately 12 person-days of interviewing were lost in this period. It will be possible to undertake this field work at a later date, though some additional travel costs will be incurred. It is not envisaged that this change in the timing of the interviewing schedule will delay the research to any significant extent.

The survey of key tourist operators (in locations affected by COT) is planned for the near future as is the survey of non-users. The questionnaires for these elements of the study will be designed in consultation with GBRMPA.

The survey instruments being used are based on standard economic and attitudinal techniques. To estimate the economic value of the Reef and to test for differential values due to COT damage standard travel-cost and contingent valuation methods are being applied. Preliminary results will not be available for some time yet. Of some potential methodological importance is the very recent and yet unpublished research by Knetsch on potential biases in the contingent valuation method. We were alerted to this development in theory by Knetsch on his recent visit to Australia and the Great Barrier Reef. If Knetsch's recent work is validated we would expect that our results - and those of anyone else applying the standard methodology - will be an underestimate of the willingness-to-pay to the Reef. It is unfortunate, in terms of the design and administration of the questionnaire for tourists, that this methodological development occurred after this element of the study had commenced and, in fact, is nearly completed. To the extent possible due regard will be paid to this development in the interpretation of results.

RISK ANALYSIS PROGRESS REPORT

Investigators: Dr J. Parslow and Dr T. Hundloe
Griffith University
Nathan. Queensland

A risk analysis for COT involves:

- (i) the assignment of probabilities or likelihoods to each of set of possible outcomes, for each of a set of management actions;
- (ii) the assignment of values (economic or otherwise) to alternative outcomes and actions;
- (iii) a decision analysis based on probabilities and values.

We still plan a two-pronged approach to step (i). The first approach depends on an analysis of historical data (and the assumption that the system will continue to behave as it has in the past). Ms Jan Priest has been hired as a research assistant to carry out a statistical analysis of the COT data base. One of us (JP) made a trip to Townsville in June to arrange access to GBRMPA and AIMS data records. The data analysis is some way from completion. We have been unable so far to obtain the CEP survey results on COT from AIMS, and are presently working from the GBRMPA historical data base. Our plan is first to characterize the spatial and temporal variation in sampling frequency and technique, and then to identify the spatial and temporal pattern of outbreaks, so far as this is possible, given the sampling limitations. We hope to identify high and low risk regions, and obtain crude estimates of the probability of attacks on reefs in different areas and times.

Probability estimates can also be derived from stochastic, dynamical models of the system. Modelling has been held up by some very large gaps in our understanding of COT ecology, particularly the larval and early juvenile stages, but these are beginning to be filled. A variety of modelling approaches are currently under way, and we have had discussions with modellers at AIMS, JCU, U of Q. and Griffith. We have also developed a simple model of starfish populations on a network of reefs, subject to stochastic variation in larval survival and recruitment.

We are not yet in a position to make quantitative predictions, but some qualitative ideas about COT dynamics seem to have gained a fair degree of acceptance. One is that, given the enormous fecundity of COT, the apparent high survival of larvae at background plankton concentrations, the high biomass of adult food resource and the likelihood of wild fluctuations in recruitment success due to turbulent dispersal, outbreaks are not surprising but seem almost inevitable. Comparisons have been made by a number of modellers with insect pest outbreaks in temperate forests, particularly with the spruce budworm system modelled by Holling.

A second point, based on empirical evidence and simulation modelling, is that provided outbreaks of COT continue to occur at roughly 15 year intervals and at previous intensities, widespread permanent degradation of corals seems unlikely. However, it

should be noted that the mechanisms responsible for a long-term cycle are unclear. The models of insect pest outbreaks referred to above have shown a flip in behaviour between long-term cycles, with resource recovery between outbreaks, and persistent endemic outbreaks with the resource constantly degraded. This possibility is obviously of concern with respect to COT. The behaviour of the insect models can be produced by widespread control attempts. The Japanese experience, where large scale attempts at control have coincided with persistent infestations, may be relevant. The key elements of COT population ecology with respect to cycling seem to be the degree of connectivity among reefs and the variability of recruitment, which depend upon the physics of larval dispersal, and the possibility of density and/or resource dependent survival, particularly for juveniles which have been observed to suffer high mortality rates. Considerable effort is being devoted to the question of larval dispersal under the COTSAC funding, and more information about juvenile survival should become available, now that field studies of juveniles are possible.

Management actions seem likely to be restricted to attempts at local control; that is, the maintenance of relatively small areas of undamaged coral free of starfish. A field trial was conducted by GBRMPA in July, and we will help to analyse the data. Short-term small-scale control is technically feasible, although the economics are still to be studied. There are suggestions that starfish may be attracted to areas of high coral cover. This may have implications for the economics of control, and for its effect on COT population dynamics at the level of the individual reef.

Data on the economic benefits of control will come from a separate research project which focused on the socio-economic effects of COT. Progress on that study is presented separately.

POTENTIAL HUMAN CAUSES OF CROWN OF THORNS STARFISH
IN THE SOUTH PACIFIC

Investigators: Dr Leon Zann
Great Barrier Reef Marine Park, PO Box 1379, Townsville
J & G. Brodie
University of the South Pacific,
Box 1168, Suva, Fiji

Introduction

The objectives of this project are to identify any commonalities among the widely separated areas of the Indo-Pacific which have experienced crown of thorns outbreaks. The study will specifically test the hypothesis that there is a relationship between fishing pressure and cot outbreaks (many Pacific reefs are under intense fishing pressure and should therefore be subject to more regular outbreaks of cots than uninhabited remote reefs).

There is an emphasis on isolated island situations (where there is a low possibility of reefs being "seeded" by secondary infestations from the original outbreak).

Progress

The literature has been reviewed and all published reports of infestations (and negative sightings where available) have been entered into a database (similar in structure to the GBR Database). Characteristics of islands and reefs (long/lat; island type; sea temp; isolation index; human population density and index; fishing pressure etc) are being entered into a linked database (consultant: K. Weaver).

As there are notable gaps in the published reports (especially the negative sightings), a questionnaire has been produced for researchers in the area. These are being circulated.

Detailed surveys are being conducted in Fiji where there is a detailed knowledge of fishing activities and target species. Preliminary surveys indicate that the area around the capital, Suva, has suffered chronic infestations while those elsewhere have been more sporadic.

A detailed survey of the Cook Group, which is comprised of islands of several different types (volcanic, atolls), covering a wide longitudinal range, and with varying fishing and human population pressures has been conducted by a consultant (Mr G. Andrews).

Future Research

The surveys in Fiji will continue until April 1987. Surveys of other groups will be undertaken opportunistically by scientists visiting the areas (eg Western Samoa has suffered recent outbreaks; these will be surveyed in early 1987 by scientists engaged in a SPREP survey).

A major problem exists in obtaining negative sightings from the area. The area is not well studied and the remote uninhabited

reefs are rarely visited (for obvious reasons). It is hoped that postal questionnaires will fill in gaps.

Because of a heavy work load, the senior researcher has had very limited time to devote to the study. It is hoped that he will be able to devote a block of time to this project in 1988 (eg 2-3 months at AIMS or JCU) at the correlations/write-up phase.

INTERIM PROJECT COMPONENT REPORT:
MAPPING THE DISTRIBUTION OF WATER MASS CHARACTERISTICS
(PRODUCTIVITY, SEDIMENT AND CIRCULATION) OF THE GREAT
BARRIER REEF REGION USING REMOTELY SENSED IMAGERY.

Investigator: Mr D. van R. Claasen, Great Barrier Reef
Marine Park Authority, Box 1379, Townsville

Introduction

This report covers the period since commencement of the project in April, 1986.

Some slippage in timing has occurred from the original timelines developed for the project proposal late 1985. The project was not approved until April. This resulted in a 3 month delay in commencement of the activities proposed for 1985/86. Additional delays during the ordering, delivery and testing of the computer package and in searching for image data in the U.S.A. have introduced a further three months of lag time so that the program is approximately 6 months behind the original schedule. Project details are presented below.

Acquisition of imagery (by 30.08.86)

15 usable and available CZCS data scenes have been located in Australia. A consultant, W.D. Carter in Washington, D.C., was engaged to carry out a detailed search for additional data from the NOAA/NESDIS archives containing scenes acquired from 1978 to the present. Carter identified 107 scenes which had potential for analysis. Out of these we have selected 44 scenes for acquisition./ The order was forwarded on 13 November. Expected delivery time is 10-12 weeks from date of receipt.

Acquisition and Installation of Computer Package

It was anticipated that the micro-BRIAN hardware/software image analysis package would be installed by 30.07.86. It was received by CSIRO for testing and software debugging by end June 1986. The computer was received here in mid-August. A subsequent hard disk and graphics board problem meant a two week delay while replacement parts were obtained. A new issue of the software was also received. The system was fully operational by end September.

Image Preprocessing

The Australian Survey Office has agreed to provide preprocessing and subsetting support on receipt of the image data. The ASO will also produce end products to desired map scales subject only to time and other programming demand constraints.

Because of the large number of scenes it will be more effective if subsets could be done in house using the Vax tape drive and transfer to the micro-BRIAN workstation for all subsequent processing. The development of a subsetting program has been requested from the Data Base Manager and preliminary work has been done. Completion is expected before delivery of the data tapes (January-February).

It will be necessary to engage the part time technician on a fee for service basis at about that time to allow for familiarisation with the BRIAN package and subsetting routines. It is expected that the required number of images will take 2-3 months to complete.

Ancillary Data

Weather data for the ordered scenes will be acquired over the next two months.

A detailed work plan for the technician is now being developed.

Program Alterations

The program for 1985/86/87 now reads:

- . acquisition of imagery (from 20.06.86 to 16.02.87)
- . acquisition/installation of computer (complete)
- . Australian Survey Office Support obtained (2.5.86)
- . subsets developed (from 05.86 to 03/87)
- . calibrate and enhance image subsets (09/86 TO 25/05/87)
- . calibrate CZCS enhanced data and ancillary data to determine surface productivity distribution and correlate with COTS distribution (from 07/87 to 12/87).

For information.

r4238.m

NOTE:

A progress report on Assoc. Professor Endean's study: "Study of crown of thorns starfish predators on or in the vicinity of reefs of the Great Barrier Reef" will be sent at a later date.

THE CROWN-OF-THORNS STUDY

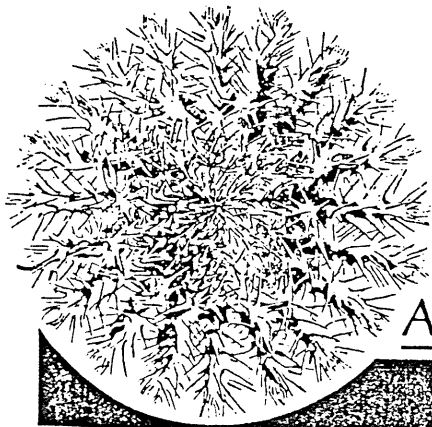
PROGRESS REPORT ON RESEARCH

September 1, 1986

Prepared by:

Dr P. Moran, Study Leader

Ms C. Ridgwell, Administrator



Australian Institute of Marine Science

The Crown-of-thorns Study

PREFACE:

The information given in this document has been extracted from research reports given to the Study Leader by the relevant Chief Investigator(s). This information reflects the progress made since the Crown-of-thorns Study began almost 7 months ago. During this period good progress has been made in nearly all projects and in two cases the results from research already have been described in papers which have been submitted for publication in the scientific literature. It should be noted that of the 36 projects funded by the Assessment Panel (see Summary Document, April 1986) only 4 have not begun. Two of these have been dropped entirely from the Study due to funding restrictions imposed by the Government in its 1986/87 budget (see Projects 2(f) & 2(g)). The other two projects have not started as yet since they are concerned with investigating aspects relating to the larvae of A. planci. By the time funds were given the spawning season had finished and few larvae could be obtained for these projects. It is planned that they will begin towards the end of this year with the advent of the spawning season (see Projects 5(c) & 5(h)).

Whilst progress in most other projects has gone according to plan some setbacks have been experienced in particular projects due mainly to logistic difficulties (eg. equipment failure). Where such difficulties have been experienced they have not been sufficient to significantly alter the objectives or progress of the projects concerned.

The 1986/87 fiscal year will be an exciting one since it is anticipated that the first major results from most projects will be forthcoming in this period. Also, it is likely that a synthesis of our knowledge of the phenomenon may start to be realised involving the results from several different disciplines. It should be borne in mind that up to the present time progress in many of the projects has involved such tasks as planning experiments, purchasing equipment, hiring personnel, and beginning field work. By the end of the 1986/87 fiscal period it will be possible to accurately assess the value of projects (based on the results obtained) and to determine future scientific goals. At the moment, planning of future research endeavours is made more difficult since no continuity of funding has been assured for the overall COTSAC Program. This is not conducive to planning and conducting "longer term" projects. A more

cost-effective and efficient way of planning this large Study could be gained by ensuring that funds are available for the next 3 years as recommended by COTSAC.

PROGRESS OF RESEARCH: AIMS PROJECTS

1. Population dynamics of predator.

(a) Geographic patterns in genetic variation of Acanthaster planci populations. (Chief Investigators: Dr J. Benzie, Dr J. Stoddart).

Dr J. Benzie was appointed during late July to undertake the research in this project in collaboration with Dr J. Stoddart (AIMS). Since then sampling of several outbreaking populations on reefs near Townsville (Wheeler, Grub and Stanley) has been conducted. Analysis of these samples is underway. Also, the experimental design of the sampling component of this project is being planned and equipment and chemicals for the electrophoretic analyses are being purchased. Visits by Dr Stoddart to the Evolutionary Biology Unit (SA) and the Department of Conservation and Land Management (WA) (prior to Dr Benzie's appointment) provided the basis for technique development and future sampling efforts, respectively.

(b) Inheritance patterns of isoenzymes in Acanthaster planci. (Chief Investigators: Dr J. Stoddart, Dr R. Olson).

Towards the end of the 1985/86 breeding season, one attempt was made to cross animals of known genotype. Problems with the culturing of larvae on that occasion prevented any electrophoretic analyses. As additional gametes could not be collected after that time (since no ripe adults could be found) the project had to be discontinued but it will recommence during the 1986/87 breeding season. Despite this setback techniques for analysing the micro quantities of tissue available from a metamorphosing larva have been developed.

(c) A field test of the larval starvation hypothesis for Acanthaster planci. (Chief Investigator: Dr R. Olson).

In November 1985 six in situ culturing systems were assembled on a single, large table. This equipment was used in December to conduct the first field test of the larval starvation hypothesis. The object of this experiment was to determine: 1. Whether it was possible to

rear the larvae of Acanthaster planci to settlement in the absence of elevated food levels. 2. Whether the time to settlement on natural food levels is appreciably longer than under conditions of food satiation.

This experiment was most successful as larvae were reared to settlement in just 14 days (two days shorter than previously reported) in the absence of elevated food levels. Food satiation made little difference to larval success, suggesting that larval development may be optimal under normal conditions. The results of this project have been written up and submitted to the Journal Limnology and Oceanography.

Although the results of this first experiment cast considerable doubt on the larval starvation hypothesis there are a number of further experiments which need to be conducted as part of this same topic. One such experiment was conducted recently in Japan (during the spawning season in the northern hemisphere) to determine what effect the size of the culture chambers has on larval development. Additional experiments that involve testing whether coral reef lagoons act as "incubators" for Acanthaster larvae will be conducted at the end of this year at Lizard Island.

(d) Fertilisation rates of Acanthaster planci in the field. (Chief Investigator: Dr R. Olson).

This project was planned to commence during the 1986/87 fiscal year. However, in view of the results that have already been obtained from the in situ culturing experiments several new and more important questions, to that raised in this project, have been developed. As a consequence it is planned to replace this project with one that investigates whether tactile stimulation is an important primary settlement cue for larvae of Acanthaster planci. The proposed aims and methods of this project are given in a separate document (see Recommendations to Assessment Panel: October, 1986).

(e) Substrate selection by larvae of Acanthaster planci. (Chief Investigator: Dr R. Olson).

Although there exists anecdotal information to suggest that

Acanthaster larvae are selective in their choice of settlement site, there have been no quantitative studies conducted on this subject. Observations during recent larval experiments in Japan suggest that coralline algae are not necessary for Acanthaster larval settlement, but they do appear to enhance settlement. At the end of the in situ culturing experiments two species of coralline algae (one from the top of the reef in an exposed habitat and the other from a cryptic, low light intensity, habitat) were offered to brachiolaria larvae. All settlement occurred only on the latter type suggesting that even within the coralline algae there may be some settlement specificity. A series of experiments will be conducted at the end of this year using substrata of different types to further test this notion. In addition, the in situ culture systems will be used to determine whether the chemicals that are known to be released from coralline algae are sufficient to enhance larval settlement over a distance.

(f) Development of techniques for the production of large numbers of larvae and juveniles of Acanthaster planci. (Chief Investigators: Mr P. Dixon, Dr R. Olson).

Two culturing systems have been successfully tested for this project at the end of the last spawning season. One system is laboratory based and consists of eight 4 litre beakers equipped with stirrers and continuous flow food supply. This system is capable of producing about 30,000 larvae every 2-3 weeks. The second method utilises the in situ techniques developed for project 1(c). By using new 20 litre chambers it will be possible to develop about 15,000 larvae (ready for settlement) from each culture system. Newly settled juvenile starfish will be maintained in flow-through perspex chambers which have already been constructed. It is anticipated that enough larvae will be produced to satisfy the requirements of several projects (eg. project 5 (c)) and that approximately 5,000 juveniles will be available to enable experiments to be undertaken in the field.

In conjunction with this research a series of experiments have been initiated recently which seek to determine whether cryogenic techniques can be developed to store gametes and larvae obtained during a spawning season so that they can be used during times when

they are not available (i.e. during non-spawning periods or when adults become rare). At present several tests are being undertaken to determine the most appropriate cryoprotectant for this study.

(g)Feeding rate of Acanthaster planci in the field. (Chief Investigators: Dr P. Moran, Dr D. Klumpp, Assos. Prof. J. Lucas (James Cook University), Mr J. Keesing).

A postgraduate scholarship was made available for this study and it was taken up by Mr J. Keesing in July. Since then the experimental design of this project has been developed and field equipment has been purchased. Several laboratory based experiments have been conducted to test the most suitable means of tagging individual starfish over short periods of time (i.e. 2-3 days). Collections of different types of corals have been made to ascertain the likely amount of biomass removed by starfish when they feed and the comparative nutritional values of a variety of corals. Caging experiments will be conducted in the field towards the end of this year to compare the feeding rates of different sized starfish.

(h)Feeding preferences of Acanthaster planci in the field. (Chief Investigator: Dr P. Moran).

Field surveys of approximately 2,000 individual starfish have been conducted to date. These surveys have involved recording approximately 20 different parameters for each starfish. They have been conducted on the following outbreacking reefs: Helix, Wheeler, John Brewer and Stanley. It is anticipated that records for almost 5,000 starfish will have been obtained by the end of the 1986/87 fiscal year. Such information will be of enormous importance in determining whether starfish show a particular preference for certain types of coral, whether they tend to feed diurnally or nocturnally and the factors which may influence this behaviour.

(i) Rate of decomposition of adult A. planci in the field (Chief Investigator: Dr P. Moran).

Preliminary experiments have been conducted on John Brewer reef where the decomposition of 40 dead starfish (killed in freshwater) was monitored over a 5 day period in 4 permanent study plots. The results from this experiment showed that the decomposition of starfish in the field is likely to vary considerably and that this may be dependent on the location of the starfish and the amount of predation which may occur on the dead bodies. In the case of the latter factor this was found to be highly variable and a list of 15 species of animals were recorded to prey on the remains of the starfish. This study will be carried out over a longer period of time as many of the starfish had still not fully decomposed by the end of the fifth day. Also the surface sediments at these sites will be sampled next year to determine whether accumulation of the skeletal remains of these starfish has taken place since the experiment began.

(j) Ephemeral patches of phytoplankton in the central Great Barrier Reef as a potential food source for larvae of Acanthaster planci. (Chief Investigator: Dr M. Furnas, Mr P. Liston).

A postgraduate scholarship was offered to Mr P. Liston in August to undertake the research in this project. Apart from this, progress has been made on developing a continuous pumping and data logging system for measuring phytoplankton abundance in the field. All major components for this equipment have been ordered or received. At present, constructions are proceeding on sampling gear and the power supply and interface board for the logging system. The software which has been previously used to run the logging system is currently being converted to enable it to work on a more modern computer. The first field trip for this project is to be conducted in early January 1987.

2. Dynamics of prey and ecosystem context.

(a) Recolonisation and recovery of coral communities. (Chief Investigators: Dr T. Done, Dr P. Moran).

Both phases of this project have progressed on schedule. They involve photo-digitisation and interpretation and line transect studies. Digitisation of approximately 25% of all archived photographic material has been completed. This has been made possible through the part-time employment of an experimental scientist. Funds originally designated for additional digitisation equipment (see AIMS proposal, December 1985) were used for this purpose. Progress in this study would have been greater except for an intermittent fault in the digitising equipment. This has been rectified and it is anticipated that all digitisation will be completed by the end of 1986. Subsequent tasks will be to conduct photogrammetric analyses of the digital data stored on computer and to compile various life history data.

Permanent markers for the line transect study sites at John Brewer Reef have been erected. Resurveys of the coral communities at these sites will be conducted in February 1987 in conjunction with surveys for the ground-truthing of LANDSAT imagery (see project 4(b)). A further 3 permanent transect sites (where corals were recorded to the generic level) have been established on Bowden Reef in the hope that it will experience an outbreak of starfish in the near future. Surveys of corals at these sites were completed during July this year. With the advent of an outbreak of starfish at Wheeler reef permanent line transect sites surveyed in 1984 will be resurveyed next year to monitor the recovery of the coral communities. This task is especially important as these communities were not affected by starfish outbreaks in the 1960s and 1970s. It is anticipated that this will be completed by the end of 1987.

(b) Interpretation of the history of disturbance to coral communities through analysis of morphology and population structure in massive Porites spp. (Chief Investigators: Dr T. Done, Assoc. Prof. P. Sale (Sydney University)).

Progress has been made in the refinement of the Porites/Crown-of-thorns model. A manuscript on this work is near completion. Field work for this project has just been conducted on a number of reefs between Cairns and Townsville. The preliminary findings from this work indicate several extremely interesting results concerning the possible occurrence of outbreaks of starfish in the past. Surveys of the population structure of Porites spp. in the Capricornia area have been planned and will take place during the summer of 1986/87.

(c) Genetics of population fluctuations of corals. (Chief Investigator: Dr J. Stoddart).

To date, 600 samples of the coral, Acropora digitifera, (original choice of species being A. humilus) (see AIMS proposal, December 1985). have been collected from 2 sites and analysed electrophoretically. One site representing a 'before outbreak' population was established at Wheeler Reef, where substantial A. planci predation of corals is now occurring. This population will be resampled if it is heavily predated in the future. The other site sampled was at Heron Island and the corals collected represent a population with a low history of predation. Sampling of corals will continue at new sites over the forthcoming year. The results from this work will be integrated with that obtained by the AIMS Reef Studies Group which is examining genetic patterns within this species of coral.

(d) Growth and survivorship of coral remnants following outbreaks of Acanthaster planci. (Chief Investigator: Dr T. Done).

The permanent study sites at John Brewer Reef have been remapped for coral remnants as originally planned. The number of surviving remnants has declined at these study sites. Similarly, coral growth

rates and recruitment of new colonies is very low. Resurveys of these areas will be continued over the next year.

(e) Effects of outbreaks of Acanthaster planci on fish communities. (Chief Investigator: Dr D. Williams).

Visual censuses of the major fish families have been conducted during May 1986 on 3 reefs affected by A. planci (Rib, John Brewer, Lodestone) and one which has not been affected by this starfish (Davies). The results from these surveys confirm earlier observations of major decreases in the densities of coral-feeding butterfly fishes as well as in the densities of two of the most abundant planktivores, Chromis atripectoralis and Pomacentrus popei, on reefs that have been affected by outbreaks of A. planci. A decrease in the density of the latter species has lagged behind that of the butterfly fishes by almost 12 months. Studies of recruitment to these reefs in early 1986 confirm an earlier hypothesis that this decrease is the result of recruitment failure following the outbreaks. No changes in the abundance of algal-grazing species or commercially important coral trout, Plectropomus spp., were detected in the May surveys. Studies of adult fish and recruitment will be continued throughout the next year.

(f) Effects of outbreaks of Acanthaster planci on the interaction between corals and algae: trophodynamic implications. (Chief Investigator: Dr D. Klumpp).

This project has been dropped from the Crown-of-thorns Study. Originally it was planned that a Research Scientist would be appointed to carry out the work in this project in collaboration with Dr D. Klumpp (AIMS). A suitable applicant was chosen for the position although no formal offer of employment was made because it was not known whether the overall Study would be fully funded by the Federal Government in the 1986/87 fiscal year. Because of a significant reduction in the amount of funds allocated to this Study for the ensuing year it was decided that new projects or new appointments in staff could not be initiated.

these (g) Effects of outbreaks of Acanthaster planci on the interaction between scleractinian and alcyonacean corals. (Chief Investigator: Dr T. Done).

This project also has been dropped from the Crown-of-thorns Study. Like the previous project a suitable candidate for the position had been chosen some months ago but the offer of employment was deliberately delayed until it was known whether the Federal Government would continue to fund the Study. As these funds were significantly less than what was expected it was decided not to proceed with the project and therefore the candidate was not appointed.

3. Interaction of predator and prey.

(a) Macro-scale studies of the distribution and abundance of Acanthaster planci and corals (Chief Investigators: Mr D. Johnson, Mr D. Brunckhorst, Mr C. Mundy, Ms D. Bass, Dr P. Moran, Dr R. Bradbury, Dr R. Reichelt).

Over the last 6 months a sampling protocol for this project has been devised. Also all necessary field and logistical equipment for the surveys have been obtained. A major development during the initial stages of this project has been the establishment of a comprehensive database on the Institute's main computer. This database was established to provide easy access to information which can be used for the following activities: 1. The selection of reefs to be surveyed. 2. The planning and budgeting of field trips. 3. The writing of technical reports.

In addition to this, 11 reefs within the Cape Upstart region (just south of Townsville) and 9 reefs off Townsville have been surveyed. The results from these surveys have been processed and a general analysis of the data has been completed. Reefs at the far north and south of the Great Barrier Reef will have been surveyed by the end of 1986.

(b) Mesoscale studies of the distribution and abundance of Acanthaster planci on selected reefs. (Chief Investigator: Dr P. Moran).

During 1986 surveys of crown-of-thorns and corals have been continued on John Brewer Reef (6/3/86), Wheeler Reef (7/3/86, 13/8/86), Bowden Reef (7/4/86, 15/8/86), Helix Reef (10/4/86, 7/5/86), Stanley Reef (16/8/86), Davies Reef (15/8/86) and Rib Reef (5/5/86). Although it was not originally planned to be surveyed Stanley Reef has been included in the Study because of the large number of smaller starfish which have recently been recorded there (as part of Project 1(h)). Each of these reefs will have been resurveyed at least once by the end of the 1986/87 fiscal year. To date, these surveys have produced several interesting results relating to the pattern and duration of outbreaks on these reefs. They also indicate that outbreaks may continue for considerable periods of time (4-6 years) on some reefs as a result of the further recruitment of starfish. This is being investigated in more detail by conducting the predator preference studies (see project 1(h)) also on these reefs.

4. Technological and analytical methodology.

(a) Enhancement of substrate reflectance in Landsat imagery with special attention to reef damage by Acanthaster planci. (Chief Investigators: Dr D. Jupp (CSIRO), Dr R. Reichelt).

This project has advanced through the following actions:

1. Training of COTSAC member in microBRIAN analysis at CSIRO (Canberra) and at AIMS.
2. Development of computer software for microBRIAN for the specific hypothesis being investigated in this project.
3. Preliminary analysis of John Brewer Reef depth data using the microBRIAN system.
4. Purchase of image tapes for reefs off Townsville.

Depth data exists for approximately 18 reefs in the Townsville region. It is proposed that depth channels be constructed for a set of reefs and integrated with Landsat data to test the substrate enhancement hypothesis of the project. Following this the images obtained for John Brewer Reef will be rectified and resampled. They will be provided with a depth channel and the algorithms hypothesised as enhancing reflectance will then be applied. Field data obtained from other projects (eg. project 3(b)) will be collated as data channels into the microBRIAN system and tested for correlation with the enhanced imagery. Progress in this project has been retarded to some extent because of hardware faults in the microBRIAN system. As the system is now operational it is anticipated that the project will be completed during the first half of 1987.

(b)Evaluating procedures for the verification of Landsat images with reference to the effects of outbreaks of Acanthaster planci on reefs. (Chief Investigator: Dr R. Reichelt).

As in the previous study progress in this project has been affected due to hardware faults in the microBRIAN computing system. As a consequence, the field trip scheduled to John Brewer Reef to verify the Landsat data has been postponed. However, while these delays are being experienced the field component of the project is being planned in more detail. To this end several discussions have been held with experts from other institutions (CSIRO, GBRMPA) to devise the most appropriate field strategy for this project. This involved a consideration of the following: the type and form of biological data to be collected; the most suitable method for collecting this data, study sites to be used; means of locating study sites on aerial photographs and classified images. The actual "ground-truthing" part of this study will be undertaken in March 1987 in conjunction with substrate reflectance research to be conducted by the CSIRO.

(c) Numerical models of the hydrodynamic regime around schematised and actual reefs (Chief Investigators: Dr K. Black (VIMS), Dr J.C. Andrews).

This project encompasses a comprehensive modelling program to simulate 11 actual reefs on the Great Barrier Reef as well as numerically examining schematised reef shapes. The type of modelling being undertaken is: 1. hydrodynamic (tidal, wind and long-period current circulation); 2. wave induced circulation (wave currents across reef flats); and 3. larval dispersion (using a pollution-type Lagrangian model).

Significant progress has been made in all 3 categories. The hydrodynamic modelling has advanced with completed simulations of Davies, Wheeler, John Brewer and Green Island reefs. Field data for the other locations has been digitised, some additional bathymetries have been digitised and continuing discussions are being held with the collaborators about the history of crown-of-thorns starfish on the selected reefs. In some instances the results have been most enlightening and a paper ("Eddy formation in non-steady flows") has been submitted to the Journal of Geophysical Research as a direct result of this research.

Wave modelling has been enhanced by the modification of a wave refraction computer model (developed by Dr Black) to provide a higher order accuracy solution. This has already been undertaken for Davies reef and the bed friction for the model was obtained by simulating a coral reef on the south shore of the Hawaiian Island of Oahu.

The project is now ready to enter the stage of simulation of larval dispersal. The computer model for this is operating and verification tests have been undertaken. Initial simulations of Davies reef show the complexity of the advection/dispersion processes on the reef.

Simulations of the selected reefs and the larval dispersal modelling will be completed on schedule. With these results and utilising results from other projects in the Crown-of-thorns Study, it is planned to provide an overview and to identify the important phenomena responsible for the dispersal and settlement of crown-of-thorns starfish at the small-scale on the Great Barrier Reef.

(d) Numerical models of the hydrodynamic regime at John Brewer Reef. (Chief Investigators: Dr J.C. Andrews, Dr K. Black (VIMS)).

The initial phases of this project have only just begun as its development relies on the amount of progress made in the previous project (see AIMS proposal, December 1985, for more details). To date, a small portable computer has been purchased (with hard disk attachment) to house the flow model (barotropic) that has been developed at the Victorian Institute of Marine Science and used in project 4(c). As the progress in project 4(c) is on schedule it is anticipated that the Experimental Scientist employed to initially assist Dr Black will transfer to Townsville at the beginning of 1987 and help Dr Andrews in establishing the flow model to be used for the study on John Brewer reef. Plans are currently being developed for the field component of this project

(e) Dispersal of Acanthaster planci outbreaks over the whole Great Barrier Reef: a simulation study. (Chief Investigator: Dr R. Reichelt).

The first stage of this project has now been completed. This has involved writing a large general computer program ("shell") which will contain the actual detailed models. This program has been developed to run on the AIMS computing system and is in the process of being transferred to run on the Cyber 205 supercomputer. Visits to the Institute by Dr M. Dale (CSIRO Cunningham Laboratories) and Dr D. Green (ANU) have greatly facilitated the progress of the project.

(f) Analyses and models of existing data. (Chief Investigators: Dr R. Bradbury, Dr R. Reichelt, Mr S. Bainbridge, Dr P. Moran).

The first stage of this project has been successfully completed. This has involved the extraction of a series of working data sets from the main crown-of-thorns starfish data base which was established (from records obtained from the GBRMPA and the 1985/86 CCEP Starfish Survey) at the beginning of this year. Analyses have been made of the 'years x latitude' data set in collaboration with

Dr W. Grev (Biologische Anstalt Helgoland, Hamburg) using his suite of modelling techniques. It is anticipated that this particular research will be completed by the end of 1986. Analyses of 'reef states through time' are presently being undertaken using parallel grammar inference engines developed by Dr M. Dale, and using Markov approaches to the transitions of states through time. Multivariate analyses of the geographic data set are also being conducted.

(g) Tagging of Acanthaster planci using micro-injectable transponders. (Chief Investigators: Dr P. Moran, Mr R. Peden (Deakin University)).

Over the last 6 months research has concentrated on improving the interrogation distance (i.e. the distance over which the transponders signal can be picked up) of the micro-injectable tagging system (Identification Devices Datascan Unit). This highly experimental work has met with some success as tests carried out at Deacon University have succeeded in developing a new antenna for the Unit (which is circular in shape and 31 cm in diameter) which enables the transponders to be read if they are located anywhere inside the plane of the antenna or up to 10cm outside it. This would mean that tagged starfish of average size could be easily interrogated using this method.

As these tests had been conducted in air the antenna unit was then waterproofed and measurements were taken in seawater. The results from these tests indicated that almost 50% of the energy transmitted from the new antenna would be lost to the surrounding environment. Additional experiments have shown that this loss may be overcome by increasing the electromagnetic pulse being generated from the Datascan Unit. Redesign and reconstruction of this complex system is needed if this problem is to be overcome.

The initial stages of this work is presently being undertaken at Deakin University and will be completed by the beginning of 1987. It is anticipated that the system will be available for testing on a captive population of starfish in the field by April/May 1987, unless further major technical difficulties are experienced.

PROGRESS OF RESEARCH: EXTERNAL PROJECTS

6(a) Determination of Acanthaster reef flat infestation patterns by low level aerial photography. (Chief Investigator: Assoc. Prof. D. Hopley (James Cook University)).

The following work has been carried out since the project started in April this year.

1. A series of 35mm infra-red photographs of A. planci have been taken. Like other echinoderms it shows a relatively strong reflectance within the near infra-red part of the spectrum. This is to be investigated further.

2. A series of photographs of a number of reefs off Townsville were obtained on June 22 (tidal height: -0.1m, cloud ceiling: 4,000-5,000 ft.). These reefs included; John Brewer Reef (leeward and windward margins; colour film), Helix Reef (total area at low and high level; colour and infra-red colour), Grub Reef (single transect across reef from leeward to windward margin; colour and infra-red colour) and Wheeler Reef (total area; colour and infra-red colour).

The photography obtained was of high quality and clearly shows the value of colour infra-red film in mapping reef tops. Unfortunately it does not appear to be possible to pick out individual A. planci in shallow water on reefs as originally proposed in this project. However, the low level flight across Helix Reef does suggest that there may have been aggregations of starfish on the reef top. As it was not possible to groundtruth these close to the time of photography it may be necessary to further test for such results. Despite this, what is very clearly shown from the results on all reefs, is that areas recently killed by Acanthaster can be readily identified using colour infra-red photography. Such a technique will be extremely valuable for examining the general patterns and rates of recovery of corals in shallow water.

6(b)The dynamics of physiological parameters of high density crown-of-thorns populations (Chief Investigator: Assoc. Prof. J. Lucas (James Cook University)).

This project has 3 objectives. Firstly, to determine whether there are detectable physiological symptoms of aging, nutritional status and unfavourable environmental conditions in outbreaks of crown-of-thorns starfish and how these change during the course of such events. Secondly, to ascertain whether the growth of starfish is indeterminate or determinate. Thirdly, to develop an energy budget for the crown-of-thorns starfish. Finally, to determine whether it is possible to age starfish through: 1. cellular age pigments; 2. growth rings and layering in skeletal components; 3: analyses of spine length/body diameter ratios.

Funds for a substantial part of this project have been gained through other sources (Marine Sciences and Technologies Scheme). Those given under the Crown-of-thorns Study were used to supplement this amount, particularly to employ a Research Assistant to help process the many samples already obtained in this project. These funds also were used to purchase equipment which would greatly facilitate this work.

It should be noted that the fourth objective is new and is research that is proposed to be undertaken during 1987 (see Recommendations to Assessment Panel: October, 1986). It has been included because, to date, no satisfactory method of determining the age of crown-of-thorns starfish is available. This has been a disadvantage for the present project and for many other population studies of this starfish. It will continue to be a problem for successful modelling of crown-of-thorns population dynamics, especially for reefs receiving repeated outbreaks.

Progress during this year has followed the original schedule with field trips to Keeper and Helix reefs on a number of occasions. As insufficient starfish could be found at Keeper reef in February sampling for physiological studies has been suspended until the end of the year. This allowed extra time to be devoted to the Helix reef collections, which with other shiptime, will enable a comprehensive assessment of the reproductive physiology of mature starfish on this reef immediately prior to spawning.

Laboratory analysis of the samples is proceeding on schedule

with the recently acquired electronic balance facilitating faster sample processing. Unavoidable delays in obtaining the semi-micro bomb calorimeter has caused inconvenience in the calorific analysis of winter reproductive material.

Analysis of the data obtained from starfish in the Capricornia section (field trip in March) and Helix and Keeper reefs has shown interesting trends in the relationship between size versus specific metabolic rate and organ indices. A subset of these data, dealing with size dependent variables during the October 1985 sample period, was prepared for publication (also presented at the Second International Symposium on Indo-Pacific Marine Biology) and is currently under review (Bulletin of Marine Science).

Valuable data on metabolic patterns in A. planci have been gleaned from monitoring juvenile and adult activity patterns, including preliminary work on estimating the relationship between distance covered and metabolic oxygen consumption. Between now and the end of the year the major impetus will be towards working up the huge database of physiological and morphological parameters, with a view to establishing guidelines for the final year's research.

Helix reef is still proving to be an ideal site for this study of the dynamics of an outbreak population of A. planci. Starfish numbers peaked in the summer of 1985, at which time the coral cover was declining rapidly. Starfish health, as measured by a suite of parameters, has declined noticeably since then, and it appears that starfish numbers are also beginning to wane. There is every reason to expect that these numbers will continue to decline so that by this time next year very few starfish will remain on Helix reef. The population outbreak should have run its course within the 3 year time allocation of this project.

6(c)A study of the temporal and spatial distributions of Acanthaster larvae in relation to survival and dispersal. (Chief Investigator: Dr R. Hartwick (James Cook University)).

The original aim of this project was to obtain information on the occurrence, movements and changes in abundance of Acanthaster larvae by sampling close to a high density population of spawning starfish. Unfortunately this part of the project has not been

conducted as yet, since the spawning season had finished by the time funds had been given. In some ways this has been an advantage as it has allowed more time to prepare for this "high risk" undertaking. As a consequence it is now planned to conduct the field sampling component of this project from 2-12 January at Wheeler reef, in collaboration with Dr M. Furnas (see project 1(i)). As Wheeler reef has a large population of adult starfish on it at the moment it offers the best chance of being able to achieve the objectives of this project. Information on the reproductive state and spawning of these starfish will be obtained, where possible, for the time of sampling by Dr P. Moran.

6(d)Simulation of large-scale population dynamics of crown-of-thorns starfish in the Great Barrier Reef system. (Chief Investigators: Dr M. James, Dr L. Bode, Prof. K. Stark, Mr L. Marsh, Mr I. Dight (James Cook University)).

Under the direction of the chief investigators, the development of appropriate modelling techniques is well underway. Mr I. Dight has been appointed as full-time Research Officer to the project and has begun development of an initial numerical model based around a hypothetical assemblage of reefs. Identification of the biological and physical components most crucial to modelling the major processes involved has been an important aspect of the research to date. One such process is concerned with the dispersal of the larvae of A. planci. The hydrodynamic model envisaged to simulate the dispersal process will be derived from existing software developed originally to study tropical cyclone surge. The existing model, already successfully modified and tested, will be further developed for the present purpose. This model will be two-dimensional and depth-integrated with forcing for the determination of net particle advection provided by input of barometric, bathymetric, tidal constituent and wind stress data superimposed upon the effect of the East Australian current. The longitudinal and lateral concentration distributions of larvae are to be determined by means of a separate two-dimensional mass transport calculation driven by the velocity field. Recognising that Eulerian (fixed reference frame) methods are inherently unsuitable for such calculations, two alternative methods

based on Lagrangian considerations (moving particles and moving meshes) are being investigated for their suitability. Each of these can be combined with a separate dispersive component.

Another important aspect of the project has involved an assessment of the potential role of epidemics in the distribution of Acanthaster populations. This process is presently being modelled using field data obtained from a large population of juvenile starfish on Suva Reef, Fiji. The results of preliminary epidemic models are encouraging. The models predict both the severity of an epidemic in relation to population size and distinguish between the likely pathogens (i.e. bacteria, virus and protozoa). It is anticipated that a selected epidemic model will ultimately be incorporated into the simulation model of the large-scale population dynamics of A. planci.

- 6(e) Field studies of aspects of the ecology of Acanthaster planci. (Chief Investigators: Dr R. Endean, Dr A. Cameron (University of Queensland)).

Over the last 6 months field surveys have been conducted on Normanby Island reef, Green Island reef, John Brewer reef, Beaver reef, Potter reef, Rib reef and Grub reef to locate suitable populations of persistent, long-lived, coral species such as Porites, Diploastrea, and also favids and mussids. Apart from Normanby Island (which experienced outbreaks in the late 1960s), these reefs have all been recently affected by outbreaks of A. planci. A further series of sites are being established on Heron Island and Lady Elliott Island reefs which have no previous outbreak history. The population structures of the persistent species at these sites are being compared with those on reefs which have suffered recent outbreaks to determine the extent to which these types of corals have been affected by outbreaks of A. planci. These surveys also include careful searches of substrata to identify recent recruits of these species. This information will be used to determine the role of outbreaks in the recruitment of massive corals. Apart from the demographic surveys (which include measurements of the spatial distribution and size - heights, diameters and circumferences - of colonies), maps are also being prepared of the extent of damage

sustained by particular colonies. These maps will be used to monitor the recovery of these colonies through time.

6(f) Dynamics of recruitment and the densities of juvenile crown-of-thorns starfish between 15 S and 20 S on the Great Barrier Reef (Chief Investigator: Dr P. Doherty (Griffith University)).

Once contracts for this research were exchanged in April 1986, Mr J. Davidson was appointed as Research Assistant to this project. By the time this was done, it was several months after the time of spawning when the youngest starfish (0+ individuals) can be found. Given this and the finding of 50-100mm (1+ individuals)(i.e. recruits from the 1984/85 spawning season) in various habitats on several reefs off Townsville some minor changes were made to the sampling design of this project. As information from studies conducted in Fiji have indicated that 1+ individuals are not likely to have moved far from the site of settlement it was decided that the presence of these starfish on reefs provided an unexpected opportunity to learn more about the settling preferences of larvae. Accordingly, the sampling design of this project was modified to get the best estimates of the distribution and abundance of these larger starfish.

The final design which was chosen (taking into account the need to standardise current survey techniques for juveniles and the amount of time available for the surveys) involves taking a pair of samples (10m x 1 m belt transect) from the base of the windward reef slope, top of the windward reef slope, the windward reef flat, the leeward reef flat, the leeward reef margin and the base of the leeward reef slope. This suite of 12 samples will be repeated at one other site on each reef giving a total of 240m x 1m per coral reef. This sampling strategy provides a systematic coverage of the 3 variables; aspect, depth and substrata. The more controversial choice was between surveying 4 sites per exposure with no replication and two sites per exposure with replication. The latter was adopted because this design will allow the variance in starfish numbers to be partitioned over two spatial scales.

The first surveys of this project have been completed on 5 reefs off Townsville (Lodestone, Keeper, Little Broadhurst, Bowden and 19029). These reefs are all located near the coastal side of the reef

tract and were chosen to complement other research currently being conducted on juveniles. Two other surveys are planned for reefs south and north of the Townsville region (i.e. Whitsundays and Innisfail region). These are to be completed before the end of 1986.

6(g) Analysis of physical mechanisms controlling plankton patchiness on the Great Barrier Reef. (Chief Investigators: Dr J. Parslow, Dr A. Gabric (Griffith University)).

This project aims to increase our understanding of the manner in which large-scale stirring and mixing mechanisms affect plankton patchiness on the Great Barrier Reef. These processes directly affect the dispersal of Acanthaster larvae and the statistics of their recruitment to reefs. The patchiness of larvae will also affect the statistics of field sampling programmes, and patchiness of larvae and their planktonic food resources and predators may be critical to larval survival.

The length and time scales of the different motions on the Great Barrier Reef have been identified in a variety of recent studies. These have been used to calculate the likely cross-shelf and long-shelf excursions for planktonic patches. Rough estimates of the dispersion of a patch in an ensemble average sense could be made using these length and time scales. However, estimating the relative dispersion of a patch about its centre of mass and the intensity and space scales of within-patch fluctuations is considerably more difficult. This problem has received increased attention in the last 6 years or so. So far much of the time in this project has been spent in reviewing this literature and identifying theoretical approaches which seem most promising for the Great Barrier Reef.

The approach which presently seems to offer most promise for the analyses to be conducted in this project is that successfully used by Zimmermann and Oncle. It should be possible to extend it to calculate joint particle distributions and therefore calculate parameters associated with relative dispersion and concentration fluctuations. It should also be easily adapted (relatively) to the interaction of predominantly cross-shelf tidal currents and long-shelf wave oscillations which characterise the Great Barrier Reef. The results of previous numerical models of tidal and wind-driven circulation may

be used to estimate the size and velocity characteristics of residual eddies. It should also be possible to allow for other dispersal mechanisms such as trapping in reef lagoons or inside channels and embayments, which may be particularly important on the reef.

Based on this theoretical review and discussions with oceanographers in Townsville, numerical modelling is already underway and is likely to continue into 1987.

6(h)Development of monoclonal antibodies against larvae of Acanthaster planci: a pilot study to detect and characterise larval membrane markers for this species. (Chief Investigators: Dr P. Hanna, Dr V. Lee, Dr B. Richardson (Deakin University)).

This research has not commenced since samples of larvae could not be obtained at the start of the project. This was because the spawning season had finished by the time funds were given to support this project. Immunization of mice with intact larvae of A. planci will commence as soon as samples become available in late October or early November. In anticipation of screening procedures for the production of antibodies the following items have been purchased: ELISA reagents, millipore filters, tissue culture plates and media.

6(i)Dynamics of the Acanthaster/hard coral interaction (Chief Investigators: Dr V. Harriott, Mr D. Fisk (Reef Research and Information Services)).

At present, about 70% of the initial broad scale surveys of A. planci have been completed. The surveys have taken 2 forms:

1. Searches for corals scars, large juveniles and adults by two divers over a timed 5 minute period at selected study sites.
2. Searches small juvenile starfish in replicate (6) 0.5m x 0.5m rubble quadrats at selected sites.

To date, 22 starfish have been found in the timed swims at a total of 33 sites. Eight of the 15 sites proposed for rubble searches have been completed and no 1+ individuals have been found. There is some indication of possibly 3 overlapping year classes but interpretation of the size frequency distribution will be left until

sample sizes are larger. The starfish appear to be patchily distributed over the area of the reef. Once the initial searches have been completed, replicate searches will be conducted in the central and northern sectors of the bommie field to investigate these patches in more detail. Line transect surveys of areas on Upolo and Michaelmas reefs, close to where settlement plates for this project are to be placed, will be completed by the end of this year. This data will be used to interpret the role of local recruitment in the settlement patterns observed.

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