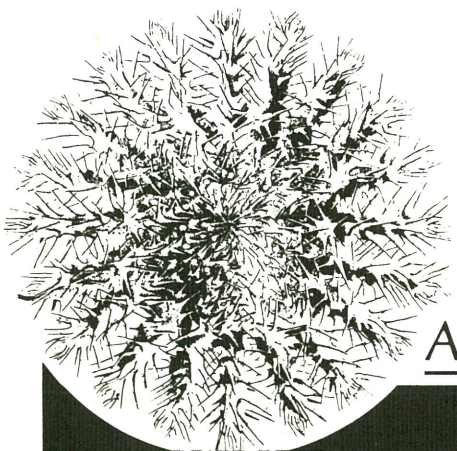
Status Report 1987/88

Edited by P. Moran, Study Leader & C. Hughes, Administrator



Australian Institute of Marine Science

The Crown-of-thorns Study

Crown-of-thorns Study Report 9

February 1988

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Edited by P. Moran & C. Hughes

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PREFACE

This document provides a summary of the progress of all ecological projects in the Crown-of-thorns Study being coordinated by the Australian Institute of Marine Science. The progress reports were prepared by the Chief Investigators of each project and edited by the Study Leader so as to achieve a consistent format throughout. The document is meant to define the amount of progress which has been made in projects between May 1987 and February 1988. A final report of all research is planned for August 1988 coinciding with a meeting of the Crown-of-Thorns Starfish Advisory Review Committee.

Apart from describing the progress of research in the Study this report also seeks to fulfill two other functions. First, to describe the budget of the Study, particularly in relation to the amount of funds allocated to each project and the status of funds and projected expenditure (up to 30 June 1988) for each internal project. Secondly, to introduce 4 new projects which will be undertaken over the next year. Two of these result from recommendations of a Methodologies Working Group which met towards the end of 1987 at the instigation of COTSARC and GBRMPA. These two projects are concerned with undertaking pilot studies of manta tow and line transect techniques. The third project arises from work carried out during this year as part of project 1 (a) and will involve experiments that seek to obtain general data about the spawning and fertilization success of adult Acanthaster planci in the field. Similarly, the fourth project builds on continuing research which in this instance comes from project 1(e). This new project will investigate the mechanisms involved in the settlement of larvae of the crown-of-thorns starfish. Separate budgets have been developed for each of these new projects.

OVERVIEW OF PROGRESS

The progress of almost all ecological projects in the Crown-of-thorns Study since May 1987 has been very good. An indication of how well progress has proceeded can be gauged by the fact that about two thirds of all projects are now at a stage where results are being analysed or they have been completed. A summary of the progress of ecological projects in the Study is presented in Table 1. The overall rate of progress in the Study is all the more creditable given that the research has had to be undertaken under ever tightening financial conditions.

From Table 1 it should also be noted that almost a third of the projects involves research which is continuing and could possibly be extended over many years. This comprises studies of coral recolonisation and recovery (e.g. projects 2(a)(b)(d), 6(d)(h)), starfish recruitment (e.g. project 6(e)), starfish and coral distribution and abundance (e.g. projects 3(a)(b)) and the crown-of-thorns database (e.g. projects 4(e)(f), 6(c)). Whilst these projects involve a continuation of field work or mathematical modelling it is pleasing to note that many are producing results (and publishing them) as they proceed.

Only one of the projects in this Study (project 1(b)) has been unsuccessful in achieving its original objectives. This was due mainly to logistic difficulties. The project required minimal funding and resources, both of which were supplied by AIMS.

Perhaps the most important aspect of the Study at the present time is that the results from certain projects (e.g. projects 1(c)(d)(e), 2(a)) are beginning to be used in other projects; particularly those involving mathematical models (e.g. projects 4(c)(d), 6(c)). It is expected that this practice will increase as more biological and ecological projects near completion. This signals the first stages in the development of a synthesis of the results achieved in the Study. Continued development of this approach will yield a greatly improved understanding of the crown-of-thorns phenomenon in the future.

Table 1 Summary of the progress of ecological projects.

Project No.	Status
1 (A)	Analysis of results (further samples being collected)
(B)	Unsuccessful (logistic difficulties encountered)
(C)	Analysis of results (further experiments planned)
(D)	Analysis of results (further experiments planned)
(E)	Analysis of results (further experiments planned)
(F)	Successful; larvae produced for all projects
(G)	Field and laboratory work continuing
(H)	Analysis of results
(I)	Analysis of results
(J)	Field work completed
2 (A)	Analysis of results (field surveys completed)
(B)	Results analysed (field work at One Tree Is. continuing)
(C)	Completed (results analysed; final report prepared)
(D)	Field work continuing (preliminary results being analysed)
(E)	Results analysed (field work continuing)
3 (A)	Results analysed (field work continuing)
(B)	Field work continuing (analyses underway)
4 (A)	Completed
(B)	Analysis of results (analysis of SPOT imagery)
(C)	Completed (publication of results)
(D)	Field work completed (model devised; runs continuing)
(E)	Two models completed (large scale wave model underway)
(F)	Database analyses completed (qualitative models continuing)
(G)	Antenna completed and waterproofed (further trials planned)
6 (A)	Analysis of results (studies on aging continuing)
(B)	Completed
(C)	Models completed (publication of results)
(D)	Field work continuing (analysis of results)
(E)	Field work continuing
(F)	Results analysed (publication of results)
(G)	Antibodies developed
(H)	Field work continuing
(I)	Project suspended (pending location of juvenile population)
(J)	Not yet commenced

ADMINISTRATION

Project allocations for 1987/88

A total of $553,460 was allocated by COTSARC in August 1987 to ecological projects on the crown-of-thorns starfish. These funds were given to support the research of internal projects during the 1987/88 fiscal period and that of external projects during the 1988 calendar year. The amounts allocated to the AIMS program and the external projects are given in Appendix 1 along with the funds actually requested. It will be noted that allocations were extensively reduced to all projects in view of the fact that the amount of funds requested far exceeded that available for allocation. Additional expenditure cuts of approximately $72,000 were made to the AIMS program in line with the budgetary recommendations of COTSARC. In view of these budgetary restrictions approximately $45,000 of additional shiptime (associated with projects 1(g) and 3(a)) has been supported by AIMS over the past 9 months. Also two staff positions (associated with projects 2(a) and 4(f)) in the AIMS program were terminated at the end of 1987.

The overall working budget for the Study during the 1987/88 period was $603,153 which included the carry forward of $49,693 of AIMS funds from the previous fiscal year. Approximately $29,000 of these funds ($16,000 to AIMS projects and $13,000 to external projects) however had already been committed. The remaining amount of almost $20,000 increased the total allocation for AIMS projects in 1987/88 to $447,987. A breakdown of the budget for the Study is given in Table 2 (by project) and Table 3 (by expenditure heading). The allocation of funds within each of the internal projects is presented in Table 4.

Present expenditure

Total expenditure within the Study at the end of January 1988 was $395,074 (see Table 5). Of this amount, $285,096 had been spent on AIMS projects whilst the remaining amount was allocated to external projects. A further $29,000 will be given to external projects towards the middle of 1988 according to the terms and conditions established by AIMS.

It is anticipated that an additional $157,284 will be spent on internal projects up until the 30 June 1988. Thus it is likely that the AIMS program will be underspent by about $21,795 at the end of this fiscal year (see Table 5). This is mainly due to reductions in the cost of salaries and on-costs. Additional savings were made particularly in project 1(c).

Approximately half of the estimated surplus of funds has already been committed to pay for costs arising from publishing the Technical and Research Reports of this Study, obtaining samples of crown-of-thorns starfish specimens from several localities in the Indian Ocean for population genetic studies (project 1(a)), and conducting larval research in Okinawa (associated with new project 1(k)) during the spawning season in the northern hemisphere. It is planned to carry forward the remaining funds into next fiscal year and to disseminate them to either external or internal projects.

Table 2 Funds allocated for ecological research in 1987/88: by project.

Project No.		Sum Committed	Estimated Expenditure 1987/88	Total Allocated 1987/88	
1A	221051	2,085	37,500	39,585	
1B	221052	-	-	-	
1C	221053	1,530	65,500	67,030	
1D	221054	-	500	500	
1E	221055	213	287	500	
1F	221056	-	1,000	1,000	
1G	221057	3,952	14,700	18,652	
1H	221058	-	800	800	
1I	221059	-	-	-	
1J	221060	-	11,000	11,000	**139,067**
2A	221061	-	12,000	12,000	
2B	221062	-	1,000	1,000	
2C	221063	-	300	300	
2D	221064	-	-	-	
2E	221065	-	900	900	**14,200**
3A	221068	5,100	116,300	121,400	
3B	221069	-	400	400	**121,800**
4A	221070	-	-	-	
4B	221071	2,220	26,100	28,320	
4C	221076	-	7,500	7,500	
4D	221072	-	26,300	26,300	
4E	221073	588	850	1,438	
4F	221074	-	15,000	15,000	
4G	221075	-	500	500	**79,058**
5A	221080	500	109,550	110,050	**110,050**
		16,188	**447,987**	-	**464,175**
6A-J	221079	**12,795**	**126,183**	-	**138,978**
TOTAL		**28,983**	**574,170**	-	**603,153**

Table 3 Funds allocated for ecological research in 1987/88: by expenditure heading.

Heading	Sum Committed	Estimated Allocation 1987/88	Total Allocation 1987/88
SALARIES AND ALLOWANCES	-	307,400	307,400
TRAVELLING AND SUBSISTENCE			
Field Travel	-	7,010	7,010
Domestic Travel	-	4,660	4,660
Overseas Travel	-	2,500	2,500
STORES	3,900	12,062	15,962
FREIGHT AND CARTAGE	-	1,000	1,000
OPERATION COSTS - VEHICLES	-	14,000	14,000
SHIP CHARTER	9,000	13,300	22,300
AIRCRAFT CHARTER	2,200	-	2,200
INCIDENTALS			
Dive Ops and Medicals	-	500	500
Fringe Benefit Tax	-	2,000	2,000
University Fees	-	500	500
Bench Fees	-	8,130	8,130
Food	-	1,800	1,800
Car Rental	-	900	900
PUBLICATIONS	500	-	500
COLLABORATIONS			
Fares and Travel Costs	588	1,600	2,188
Accommodation	-	200	200
Salaries and On-costs	-	25,000	25,000
Other external costs	-	875	875
ON-COSTS - AIMS	-	44,550	44,550
	16,188	447,987	464,175
EXTERNAL PROJECTS	12,795	126,183	138,978
TOTAL	**28,983**	**574,170**	**603,153**

Table 4 Allocation of funds within AIMS projects for 1987/88.

	Sum Committed	Estimated Allocation 1987/88	Total Allocation 1987/88
PROJECT 1A (221051)			
Salaries and Allowances	-	36,000.00	36,000.00
Stores	2,085.00	1,500.00	3,585.00
	2,085.00	37,500.00	39,585.00
PROJECT IB (221052)			
	-	-	-
PROJECT IC (221053)			
Salaries and Allowances	-	46,300.00	46,300.00
Travelling and Subsistence			
- Field Travel	-	1,300.00	1,300.00
- Domestic Travel	-	2,800.00	2,800.00
- Overseas Travel	-	2,500.00	2,500.00
Stores	1,530.00	300.00	1,830.00
Freight and Cartage			
- Field Trips	-	200.00	200.00
Hire of Aircraft and Ships			
- Vessel Charter	-	2,000.00	2,000.00
Incidentals			
- Bench Fees	-	7,900.00	7,900.00
- Food	-	1,800.00	1,800.00
- Car Rental	-	400.00	400.00
	1,530.00	65,500.00	67,030.00
PROJECT ID (221054)			
Stores	-	500.00	500.00
	-	500.00	500.00
PROJECT IE (221055)			
Stores	213.00	287.00	500.00
	213.00	287.00	500.00

Table 4 Cont'd

	Sum Committed	Estimated Allocation 1987/88	Total Allocation 1987/88
PROJECT IF (221056)			
Stores	-	1,000.00	1,000.00
	-	1,000.00	1,000.00
PROJECT IG (221057)			
Travelling and Subsistence			
- field Travel	-	600.00	600.00
Stores	52.00	800.00	852.00
Hire of Aircraft and Ships			
- Vessel Charter	3,900.00	3,300.00	7,200.00
Collaborations			
- Salaries and On-Costs	-	10,000.00	10,000.00
	3,952.00	14,700.00	18,652.00
PROJECT IH (221058)			
Travelling and Subsistence			
- Field Travel	-	500.00	500.00
Stores	-	300.00	300.00
	-	800.00	800.00
PROJECT II (221059)			
	-	-	-
PROJECT IJ (221060)			
Travelling and Subsistence			
- Field Travel	-	200.00	200.00
Stores	-	800.00	800.00
Collaborations			
- Salaries and On-costs	-	10,000.00	10,000.00
	-	11,000.00	11,000.00
PROJECT 2A (221061)			
Salaries and Allowances	-	12,000.00	12,000.00
	-	12,000.00	12,000.00

Table 4 cont'd

	Sum Committed	Estimated Allocation 1987/88	Total Allocation 1987/88
PROJECT 2B (221062)			
Travelling and Subsistence			
- Field Travel	-	310.00	310.00
- Domestic Travel	-	360.00	360.00
Incidentals			
- Bench Fees	-	230.00	230.00
Freight and Cartage	-	100.00	100.00
	-	1,000.00	1,000.00
PROJECT 2C (221063			
Stores	-	300.00	300.00
	-	300.00	300.00
PROJECT 2E (221065)			
Travelling and Subsistence			
- Field Travel	-	500.00	500.00
Stores	-	400.00	400.00
	-	900.00	900.00
PROJECT 3A (221068)			
Salaries and Allowances	-	103,300.00	103,300.00
Travelling and Subsistence			
- Field Travel	-	2,500.00	2,500.00
Stores	-	2,000.00	2,000.00
Hire of Aircraft and Ships			
- Vessel Charter	5,100.00	8,000.00	13,100.00
Incidentals			
- Car Rental	-	500.00	500.00
	5,100.00	116,300.00	121,400.00
PROJECT 3B (221069)			
Travelling and Subsistence			
- Field Travel	-	300.00	300.00
Stores	-	100.00	100.00
	-	400.00	400.00

Table 4 cont'd

	Sum Committed	Estimated Allocation 1987/88	Total Allocation 1987/88
PROJECT 4B (221071)			
Salaries and Allowances	-	26,000.00	26,000.00
Stores	20.00	100.00	120.00
Hire of Aircraft and Ships			
- Aircraft Charter	2,200.00	-	2,200.00
	2,220.00	26,100.00	28,320.00
PROJECT 4C (221076)			
Collaborations			
- Fares and Travel Costs	-	1,000.00	1,000.00
- Salaries and On-Costs	-	5,000.00	5,000.00
- Other Costs	-	875.00	875.00
Stores	-	625.00	625.00
	-	7,500.00	7,500.00
PROJECT 4D (221072)			
Salaries and Allowances	-	24,700.00	24,700.00
Travelling and Subsistence			
- Field Travel	-	300.00	300.00
Stores	-	1,300.00	1,300.00
	-	26,300.00	26,300.00
PROJECT 4E (221073)			
Collaborations			
- Fares and Travel Costs	588.00	600.00	1,188.00
Stores	-	250.00	250.00
	588.00	850.00	1,438.00
PROJECT 4F (221074)			
Salaries and Allowances	-	14,000.00	14,000.00
Travelling and Subsistence			
- Domestic Travel	-	500.00	500.00
Stores	-	500.00	500.00
		15,000.00	15,000.00

Table 4 cont'd

	Sum Committed	Estimated Allocation 1987/88	Total Allocation 1987/88
PROJECT 4G (221075)			
Stores	-	500.00	500.00
		500.00	500.00
PROJECT 5A (221080)			
Salaries and Allowances	-	45,100.00	45,100.00
Travelling and Subsistence			
- Field Travel	-	500.00	500.00
- Domestic Travel	-	1,000.00	1,000.00
Stores	-	500.00	500.00
Freight and Cartage			
- Field Trips	-	700.00	700.00
Operational Cost Vehicles	-	14,000.00	14,000.00
Incidentals			
- Diving Ops and Medicals	-	500.00	500.00
- Fringe Benefit Tax	-	2,000.00	2,000.00
- University Fees	-	500.00	500.00
Collaborations			
- Accommodation	-	200.00	200.00
On-Costs - (AIMS)	-	44,550.00	44,550.00
Publications	500.00	-	500.00
	500.00	109,550.00	110,050.00

Table 5 Present and projected expenditure within ecological projects for 1987/88.

Project No.	Amount Allocated 1987/88*	Expenditure to 31.1.88	Anticipated Expenditure 31.1.88 - 30.6.88	Anticipated Balance to 30.6.88**
221051	4,185	3,709	1,211	(735)
221053	20,730	17,952	1,748	1,030
221054	500	534	-	(34)
221055	500	276	-	224
221056	1,000	1,703	-	(703)
221057	18,652	7,520	10,640	492
221058	800	600	200	-
221060	10,725	10,630	95	-
221061	-	(17)	-	17
221062	1,000	884	-	116
221063	300	6	-	294
221065	-	(1,030)	680	350
221068	18,100	19,554	1,607	(3,061)
221069	400	-	-	400
221070	-	3	-	(3)
221071	2,320	2,086	70	164
221072	1,600	353	900	347
221073	1,438	710	200	528
221074	1,000	23	550	427
221075	500	-	-	500
221076	7,500	7,500	-	-
221080	372,325	212,100	138,783	21,442
NEW 3C	300	-	-	300
NEW 3D	300	-	-	300
	464,175	285,096	157,284	21,795
EXTERNAL	138,978	109,978	29,000	-
TOTAL	**603,153**	**395,074**	**186,284**	**21,795**

* All salaries have been shown in project 221080

** Figures in brackets indicate over-expenditure

PROJECT DESCRIPTIONS

PROJECT 1(A) GEOGRAPHIC PATTERNS IN GENETIC VARIATION OF ACANTHASTER PLANCI POPULATIONS

Chief Investigator(s) Dr J. Benzie and Dr J. Stoddart

Status

Field collections of A. planci have been completed, including successfully locating a second non-outbreaking population near Townsville (Centipede Reef). Laboratory analyses of all samples for 10 enzymes, in all some 12,000 individual enzyme assays, have been completed. Difficulty in finding significant numbers of 1st year class animals was still encountered, but this did not affect the main aim of the project; testing hypotheses of dispersal.

Results/implications

Full statistical analyses of the results will not be completed until mid March. Interesting patterns of genetic variation have emerged, but the implications of these for hypotheses of dispersal must await completion of the statistical analyses. Decisions with respect to assaying further enzyme systems also require completion of these statistical analyses.

Completion

If no further enzyme assays are required, submission of the Great Barrier Reef genetic data for publication should be achieved by August 1988.

PROJECT 1(B) INHERITANCE PATTERNS OF ISOENZYMES IN ACANTHASTER PLANCI

Chief Investigator(s) Dr J. Stoddart

Status

No further crosses were attempted in the 1987/88 breeding season because of the pressure of other commitments and difficulties in rearing larvae. Further attempts to obtain these data will be made in the 1988/89 breeding season, but given the difficulties outlaid in the 1986/87 report the possibility of success appears limited. Therefore, the project will not be pursued beyond that time. Although very useful as supportive data for aspects of project 1(a), the inheritance data are not required for successful completion of that project. It is noted that this project is not specifically funded by COTSAC.

PROJECT 1(C) A FIELD TEST OF THE LARVAL STARVATION HYPOTHESIS FOR ACANTHASTER PLANCI

Chief Investigator(s) Dr R.R. Olson (Harbor Branch, Florida)

Status

During the summer of 1987 a number of experiments were undertaken at Lizard Island which investigated the survival of larvae in low nutrient conditions and their total swimming time in the plankton. Unfortunately, larvae could not be cultured in situ on the outer barrier reef, as was originally planned, for logistic reasons. However, several studies were undertaken which involved rearing larvae in the laboratory using water that had been collected from different locations across the continental shelf. These experiments provided good data on larval development under low nutrient conditions and their main dietary constituents. They were also used to provide data on the total swimming time of larvae in the water column. To date, 3 papers have been published which discuss various aspects of the results of research in this project.

Results/implications

The major findings of these experiments are:

1. The development of larvae of Acanthaster planci within Great Barrier Reef waters does not appear to be food limited. Previous findings have shown that larval starvation was not important in explaining recruitment variations. The research conducted during the last summer show that development time is not likely to be determined by food availability.

2. Larvae seem to feed primarily on pennate diatoms (especially Nitzschia closterium and Neosynedra tortosa). There were no signs of bacteria in the guts of larvae indicating that they are not a likely source of nutrition. The larvae of Acanthaster cleared their guts of all particulate matter in less than 2 hours.

3. Larval form (particularly arm length) is determined by the conditions in which larva are raised.

4. A preliminary calculation of an energy budget for the larvae of Acanthaster (based on 0_2 consumption measurements) shows that capture of about 5-10 Nitschia cells per hour is probably sufficient to maintain the metabolism and growth of a larva. Further refinement of these calculations is needed.

5. It is likely that the larvae of Acanthaster planci may spend up to 20-25 days in the plankton and still undergo settlement and metamorphosis.

Future Research

A series of experiments will be conducted in the laboratory on the physiology of larvae particularly in relation to their respiration and feeding. Additional in situ studies of the effects of temperature and diet on larval development are planned for early 1989 at Lord Howe Island provided several logistic difficulties can be overcome.

Completion

Should the field trip to Lord Howe Island go ahead the research in this project will be completed by April next year. The Chief Investigator of this project will take up a Queen Elizabeth II Award at the University of Sydney towards the middle of this year. The research listed above, and in projects 1(d) and 1(e), will form part of the work undertaken during the tenure of the award.

PROJECT 1 (D) VERTICAL MIGRATION AND PHOTOTAXIS OF LARVAE OF ACANTHASTER PLANCI

Chief Investigator(s) Dr R.R. Olson (Harbor Branch, Florida)

Status

A series of experiments were conducted at Lizard Island during the summer of 1987 which were concerned with the vertical orientation and migration of larvae. This research was not as successful as originally hoped as the 1 m high culture chambers (described in previous report) did not work out. Despite this several other experiments on the phototaxis of larvae were successful and yielded useful results.

Results/implications

While very little data were obtained on the vertical migration of larvae other important data of relevance to this question were gained. The major findings were:

1. Larvae become negatively buoyant just before settlement. The eggs of Acanthaster planci also are somewhat negatively buoyant.

2. Larvae showed demonstrated settlement in response to a light gradient, settling mostly at an intermediate light level of less than 100 $\mu E/cm^2/s$.

Future Research

Additional measurements of the buoyancy of larvae throughout their development is planned for October and November of this year. Due consideration will be given to overcoming the difficulties encountered during last summer in obtaining data on vertical migration.

Completion

The research in this project will be completed by the end of this year provided the logistic difficulties can be overcome.

PROJECT 1(E) SUBSTRATE SELECTION BY LARVAE OF ACANTHASTER PLANCI

Chief Investigator(s) Dr R.R. Olson (Harbor Branch, Florida)

Status

Experiments concerning this aspect of the larval ecology of Acanthaster planci provided the central focus for much of the research conducted at Lizard Island during the last summer period. This involved investigating settlement on naturally fouled blocks, settlement on blocks soaked in extracts from coral rubble, settlement on various types of coralline algae (particularly Lithothamnium and Porolithon), settlement on boiled algal substrates and chemical extraction on Lithothamnium.

Results/implications

The major results of this research can be summarised as follows:

1. Larvae are clearly induced to settle and metamorphose by the presence of either chemicals or bacteria.

2. The source of this inducer takes at least 10 days to develop on clean surfaces.

3. The inducer present in coralline algae was not active in methanol, chloroform or phosphate buffer extracts of the coralline algae.

4. Larval settlement occurred on Lithothamnium but not Porolithon.

Completion

Results of substrate experiments conducted at Lizard Island during last summer continue to be analysed. Several papers are in preparation which report the results of this work. This research is expected to finish at the end of this year.

PROJECT 1(F) DEVELOPMENT OF TECHNIQUES FOR THE PRODUCTION OF LARGE NUMBERS OF LARVAE AND JUVENILES OF ACANTHASTER PLANCI

Chief Investigator(s) Mr P. Dixon

Status

Large numbers of larvae were produced for projects 1(c-d), 1(k) (new project) and project 6(g) during the spawning season. Research investigating the use of cryogenic techniques for sorting gametes and larvae has not been undertaken due to the lack of controlled-rate freezer equipment.

Results/implications

Several different culture vessel designs were tested during the year, firstly with larvae of the sand dollar, Arachnnoides placenta, and then with larvae of Acanthaster planci (during the spawning season). The most efficient design consisted of a glass aquarium (400l capacity) fitted with an internal filter screen (for retaining larvae while allowing continuous water flow). Six specially designed gas bubblers were positioned on the bottom of the aquarium to aerate the water. This design is capable of producing approximately 500,000 larvae within a 16 day period. The 1 m high vertical in situ chambers developed for project 1(d) were also found to be a good low maintenance procedure for culturing larvae in the field. Due to the limited time available for culturing and the high demand for larvae most effort has been channelled towards producing large numbers of larvae. While many juveniles have been produced for experiments in project 1(e) techniques still have to be devised to be able to maintain large numbers of these young starfish for experimental purposes.

Completion

Larvae will continue to be supplied to the projects listed above. They also may be produced for studies of the pathology of Acanthaster planci (James Cook University, Department of Veterinary Science) and carbohydrate and amino acid metabolism of larvae (James Cook University, Department of Zoology). Further development of techniques for handling large numbers of juvenile starfish will be undertaken. This research will continue until the Study finishes at the end of this year. Further research on cryogenics is planned should a controlled-rate freezer become available.

PROJECT 1(G) FEEDING RATES OF ACANTHASTER PLANCI IN THE FIELD

Chief Investigator(s) Dr D. Klumpp, A/Prof. J. Lucas (Zoology Department, James Cook University), Mr J. Keesing (Student) and Dr P. Moran

Status

Field and laboratory studies are continuing within this project. As outlined in the previous report considerable emphasis in the last year has been given to developing a suitable short term tagging method to enable the feeding rates of individual starfish to be determined in the field. The tags have now been used successfully on 3 field trips allowing individual starfish to be recognised over a 5 day period. Aquarium trials suggest longer periods of recognition are possible given sufficient resources.

Results/implications

Measurement of feeding rates of Acanthaster planci is being conducted in a low density population at Davies Reef. Two field trips have been undertaken to this reef within the last 6 months: October 1987 (summer pre-spawning) and January 1988 (summer post-spawning). A third trip is planned for June this year (winter). Data on the feeding rates of starfish in high density populations are not being obtained since it was found that observations needed to be made every 3-4 hours due to the high mobility of the starfish. It was only possible to maintain this level of measuring intensity for a maximum of 48 hours given the resources (particularly personnel) available. Because the population at Davies Reef was less mobile the frequency of observations was reduced considerably to once a day over a 5 day period. Despite this reduction only about 20 starfish could be monitored during each field trip as the population was well dispersed. A total of over 200 recorded observations have been collected to date.

Studies on daily activity patterns and feeding behaviour have been concluded. Strong size dependent behavioural patterns were observed amongst juvenile starfish (<20 cm diameter) being highly cryptic during the day and feeding nocturnally. Larger starfish exhibited greater variability in their behavioural patterns.

Studies are being conducted to determine the available tissue content of different coral species and the relative efficiency of Acanthaster planci in removing the tissue from these species. This research will enable more accurate measures of feeding rate to be made as previous studies have expressed feeding rates in terms of apparent surface area or skeletal weight of coral eaten. To date, only samples of Acropora latistella and Pocillopora damicornis have been analysed. Acanthaster planci removes about 10% more tissue from Acropora latistella as this coral has a significantly greater tissue content (gDW tissue/gDW skeleton).

Future research

Comparisons of skeletal density between species and tissue content to surface area ratios between species will be carried out within the next 6-9 months. This work awaits the collection of suitable coral samples. Further field and laboratory work on the feeding rate and behaviour of individual starfish is planned at least until the end of this year.

Completion

It is expected that this project will conclude towards the middle of 1989.

PROJECT 1(H) FEEDING PREFERENCES OF ACANTHASTER PLANCI IN THE FIELD

Chief Investigator(s) Dr P. Moran, Dr R. Reichelt and Mr P. Speare

Status

The field component of this project was completed at the end of 1987. At present the data collected are being checked and sorted. Preliminary analyses have been completed and more extensive analyses, which involve extracting major patterns within the data, are now underway.

Results/implications

Since the last progress report an additional 1000 starfish were sampled on Centipede (low density population) Stanley and Little Broadhurst (high density populations) Reefs. Just over 700 of these records were obtained during the night.

Completion

Analyses of the large data base are proceeding and are likely to be completed towards the latter half of this year.

PROJECT 1(I) RATE OF DECOMPOSITION OF ADULT STARFISH IN THE FIELD

Chief Investigator(s) Dr P. Moran

Status

The field experiments in this project were completed during December 1987. Four 2 x 2 m quadrats were established on the north-eastern side of Little Broadhurst Reef (on the edge of the lagoon). Approximately 8 newly killed starfish (which had been starved for about 10 weeks) were deposited randomly within each of these quadrats. The decomposition of these starfish was monitored twice daily.

Results/implications

Eighteen of the 24 starfish were still recognisable at the end of 4 days. However, by the sixth day most had decomposed into a finely scattered mass of spines and calcareous spicules. During the course of the experiments a number of animals were observed to ingest the remains of these starfish. These included: Cheilinus diagrammus, Cheilinus fasciatus, Pomacentrus popei, and an unidentified goby, parrot fish and holothurian. Also a large specimen of Acanthaster planci was found feeding on the decomposing remains of one of the starfish in the quadrats. These results highlight the fact that death and decomposition of starfish in the field may take place over several days. Given these results it is interesting to ponder why so very few starfish have been observed dying in the field despite the large numbers of individuals present in some outbreaks.

Completion

The results of this work are being written up for publication.

PROJECT 1(J) EPHEMERAL PATCHES OF PHYTOPLANKTON IN THE CENTRAL GREAT BARRIER REEF AS A POTENTIAL FOOD SOURCE FOR LARVAE OF ACANTHASTER PLANCI

Chief Investigator(s) Dr M. Furnas and Mr P. Liston (Student)

Status

As of 22 February, virtually all of the fieldwork associated with the project has been completed. This includes 3 cross-shelf transects in the central GBR (2 seasons) and north-south transects from Townsville to Princess Charlotte Bay (November, 1987) and Townsville to the Swain Reefs (May, 1987; February, 1988). These transects include continuous monitoring of chlorophyll (nominally 30 m resolution) in both the GBR lagoon and within the reef matrix. Semi-continuous zooplankton sampling (nominally 8 km resolution) was also carried out while underway.

The post-graduate student (Mr P. Liston) conducting the project is currently involved with the following activities to analyze the samples and data collected:

1. Calibrating underway fluorescence profiles and collating with navigation data.
2. Counting underway zooplankton samples and entering data into data base for numerical analysis.
3. Beginning preliminary numerical and graphical analyses of the data sets to identify patterns observed to date and see what techniques would be best for analyzing particular data sets.

Results/implications

Preliminary analyses of the chlorophyll transect data indicate significant cross-shelf changes in the degree of phytoplankton patchiness in the central GBR. Variability in surface chlorophyll concentrations within the reef matrix are higher than within the open GBR lagoon. Specific chlorophyll features can be related to elements of reef structure. In transects running behind hard outer barrier reefs, distinct features have been observed near or adjacent to gaps between reefs.

In terms of absolute chlorophyll concentrations, variability is generally low (<3-fold). Significant variability has been observed on a range of length scales, ranging from sub-kilometre to tens of kilometres. Readily measureable levels of chlorophyll patchiness are frequently evident in the absence of significant variability in surface temperatures.

The analysis of the zooplankton data, which will be the major thrust of Mr Liston's thesis is still at an early stage. Initial analyses of the zooplankton data have discerned distinct cross-shelf assemblages of surface zooplankton in the central GBR and mesoscale regional variability in surface zooplankton community structure.

Completion

Anticipated completion of this project is September 1989.

PROJECT 2(A) RECOVERY AND RECOLONISATION OF CORAL COMMUNITIES

Chief Investigator(s) Dr T. Done and Dr P. Moran

Status

The analysis of data from sterophotographs is still continuing whilst line transect surveys of the permanent study sites at John Brewer Reef were completed during the middle of last year.

Results/implications

Digitisation of the stereophotography of the 3 study sites at John Brewer Reef was completed midway through last year. Analyses of 2 of these areas, with respect to colony growth (prior to the 1983 outbreak), and the extent of coral mortality, also were completed at that time. Since then work has progressed on analysing the data from the remaining third site. Some interpretation of photographs needs to be undertaken before this is completed. Preliminary results from the entire data set accumulated on John Brewer Reef will be produced by July this year.

Surveys of coral recovery at four permanent study sites on John Brewer Reef were completed during June 1987. Information (to the species level) was obtained using 50 m line transects positioned at 5 depth contours (reef flat, 3 m, 6 m, 9 m and 12 m) at each site. These data have been checked and transferred to the ORACLE database on the AIMS mainframe computer (VAX 785). The database is now complete (containing some 30,000 individual records) and analyses will be undertaken once all coral specimens have been identified.

Future research

The Institute has recently purchased an underwater video system which is expected to provide a means of quantifying the status of coral communities over much greater areas than is presently possible. Trials of this equipment will be carried out over the forthcoming year to determine the potential of this technique. It is also planned to use this equipment for estimating biases associated with both manta tow and line transect techniques.

Completion

Analyses of data from the remaining site on John Brewer Reef will be completed by the end of this year. Evaluation of the underwater video system will continue over the next 6 months. Recommendations pertaining to the suitability of this technique for monitoring benthic communities are expected to be produced by the end of this year.

PROJECT 2(B) INTERPRETATION OF THE HISTORY OF DISTURBANCE TO CORAL COMMUNITIES THROUGH ANALYSIS OF MORPHOLOGY AND POPULATION STRUCTURE IN MASSIVE CORALS

Chief Investigator(s) Dr T. Done and A/Prof. P. Sale (University of Sydney)

Status

Two simulation studies have been completed; the results of one have been published while those of the other have been submitted for publication. Both studies evaluated field data on the amount of damage caused by Acanthaster planci to massive Porites corals. A third study which involves a comparison of these corals on a reef unaffected by Acanthaster is now in progress.

Results/implications

Simulations of Porites populations suggested the circumstances in which they might recover from starfish outbreaks of varying intensities and frequencies. A population in which both colony growth and recruitment were high could absorb some frequencies without sustaining irreversible change to the population's size structure. By contrast, more frequent and/or more severe outbreaks can cause the loss of all large individuals of Porites from the population.

The main implication of the work is that it highlights the need to take into account population structure when considering the extent of damage and recovery of coral communities after disturbances such as outbreaks of Acanthaster planci. Moreover, the model provides a tool with which field data on coral damage may be evaluated in a simple manner.

Future research

Field data on Porites population structure and damage at One Tree Island are presently being collected by staff from the Research Station. These data will provide a better understanding of the population dynamics of Porites corals in relatively undisturbed locations, and thus help to place in perspective the evaluation of disturbed populations.

Completion

Collection of field data at One Tree Island should be completed by the end of this year. Analyses of these data will be undertaken in early 1989.

PROJECT 2(C) GENETICS OF POPULATION FLUCTUATIONS OF CORALS

Chief Investigator(s) Dr J. Stoddart

Status

A report summarizing the results of this project is being prepared. Lack of opportunity to sample Acropora digitifera populations from reefs in the vicinity of Green Island was encountered during the course of the project. Initial samples from the reefs of Green Island itself demonstrated the presence of unique genetic variation. Further sampling would have revealed whether this was a general characteristic of the region or a result of Green Island's history.

Results/implications

Work on this project during the preceding 7 months has been restricted to data analysis. This is now complete. The results of this study and a companion AIMS project (Projected Research Activities, Project 2.9.1) suggest that patchy devastation of coral populations by A. planci should not present long-term genetic problems.

Completion

This project will conclude on 4 March, 1988, coincident with the resignation of the Chief Investigator from his position at AIMS.

PROJECT 2(D) GROWTH AND SURVIVORSHIP OF CORAL REMNANTS FOLLOWING OUTBREAKS OF ACANTHASTER PLANCI

Chief Investigator(s) Dr T. Done

Status

The survivorship of coral remnants in badly damaged plots on John Brewer Reef has been monitored twice in the last year. The field work for this project is continuing with the support of AIMS. Preliminary analyses of the data collected are underway.

Future research

The fate of the surviving coral remnants will continue to be followed on the permanent sites at John Brewer Reef over this year.

Completion

This project is expected to continue at least until the end of the year.

PROJECT 2(E) EFFECTS OF OUTBREAKS OF ACANTHASTER PLANCI ON FISH COMMUNITIES

Chief Investigator(s) Dr D.McB. Williams

Status

The fieldwork in this project is continuing. Already, the results of this research have been reported in one scientific publication and at several Conferences.

Results/implications

Surveys of adult fish densities were undertaken on Rib, John Brewer and Lodestone Reefs in October 1987. Recruitment studies have recently been completed on these reefs as well as Myrmidon and Pandora Reefs. These data substantiate the patterns in adult and recruit densities discussed in previous reports.

Completion

It is planned that this project will continue for as long as possible and that surveys of adult and recruit densities will be conducted annually.

PROJECT 3(A) MACROSCALE STUDIES OF THE DISTRIBUTION AND ABUNDANCE OF ACANTHASTER PLANCI AND CORALS ON THE GREAT BARRIER REEF

Chief Investigator(s) Ms D. Bass, Mr D. Johnson, Mr B. Miller-Smith and Mr C. Mundy

Status

Field surveys for the 1987/88 year have almost been completed. Only reefs in the Whitsunday/Pompey area remain to be surveyed and this will be undertaken in May. The survey team has provided assistance throughout the year to several field projects including: projects 1(a)(g)(h)(i), 2(a), 3(b), and 4(b). Team members also have been involved extensively in assisting with research on evaluating and refining the manta tow technique (see projects 3(b)(c)).

Results/implications

Originally, 113 reefs were expected to be surveyed during 1987/88. However, additional reefs have been surveyed in all completed sectors this year except for the Townsville/Cape Upstart area. The current tally of reefs surveyed is 118. It is anticipated that this figure will increase to approximately 135 once reefs in the Whitsunday/Pompey region have been surveyed. The revised manta tow system (updated to include category data concerning feeding scars, crown-of-thorns size and cover of soft corals and sand/rubble) has proved extremely useful and is to be retained. The surveys have identified several reefs south of Townsville which have experienced recent outbreaks of crown-of-thorns starfish over the last year.

Problems

Data management procedures have had to be reviewed recently with the termination of employment of the program database manager. This has meant considerable reorganisation of tasks within the survey team and a streamlining of the previous database system. Whilst this has lead to a more efficient operation the time taken to check, store and retrieve data has increased due to the other commitments of team members.

In an effort to increase the speed of publication of results a computer plotter (purchased by AIMS) is now being used to print the manta tow pseudo-histograms. During the initial preparation of the system many problems were experienced which subsequently have been overcome. These problems have caused delays in the production of the 1986/87 survey report. It is expected that the 1987/88 report will be produced by the end of 1988 now that the system is functioning smoothly.

Completion

This project will continue to monitor the state of reefs in the GBR for as long as possible.

PROJECT 3(B) MESOSCALE STUDIES OF THE DISTRIBUTION AND ABUNDANCE OF ACANTHASTER PLANCI AND CORALS ON SELECTED REEFS

Chief Investigator(s) Dr P. Moran

Status

The field component of this project is still underway. Already, surveys of almost half the number of reefs under investigation have been completed. Evaluation of the manta tow method is being undertaken as part of this project. Data obtained from this technique are being compared with those collected by swim searches over the same area. This evaluation also has involved triplicate trials (i.e. where three observers are towed from the one manta board) to determine the repeatibility and observer variation associated with the manta tow method. The data from this research are presently being analyzed by Dr Dennis Sinclair (Department of Statistics, University of Newcastle).

Results/implications

By the end of last year surveys of John Brewer, Lodestone, Keeper and Helix Reefs had been completed. Over the last 6 months surveys of Centipede, Davies, Bowden, Wheeler and Little Broadhurst Reefs have been carried out on two occasions. The starfish populations on both Davies and Bowden Reefs have been increasing rapidly over the last few months. Those on Wheeler and Little Broadhurst Reefs are presently declining whilst only a very small number of starfish have been observed on Centipede. This reef will be followed with great interest as it is one of only a few mid-shelf reefs near Townsville which has not experienced an outbreak of starfish over the last 3 years. Quarterly surveys are planned for these 5 reefs over the next year or until the starfish populations on them have diminished to near pre-outbreak levels.

Completion

Surveys of the starfish populations on the remaining 5 reefs will be continued until the Study finishes at the end of the year.

PROJECT 4(A) ENHANCEMENT OF SUBSTRATE REFLECTANCE IN LANDSAT IMAGERY WITH SPECIAL REFERENCE TO REEF DAMAGE BY ACANTHASTER PLANCI

Chief Investigator(s) Dr R. Reichelt and Dr D. Jupp (CSIRO Division of Water and Land Resources)

Status

This project has no operational budget this financial year and is almost completed. The data from last year's field trip are being analysed at present. Enhancements to the microBRIAN system have been completed which have enabled depth-modelling studies to proceed. No major problems were encountered.

Results/implications

The main result, to date, has been that the spectral and spatial resolution of Landsat MSS data is unsuited to substrate mapping beyond the level of geomorphological zone. Coral and algae regions of the reef 'appear' the same in Landsat data that have been examined. Therefore, the historical database of Landsat data is not suited to retrospective mapping of starfish influence, nor is it likely to be fruitful to use Landsat MSS data as a monitoring tool. The same conclusions would apply to new satellite sensors with properties similar to Landsat MSS, (e.g. the NASDA (Japan) Marine Observation Satellite, MOS-1).

Future research

An unexpected extension to the original goal of the project has been made possible through the purchase, by AIMS, of a SPOT image of John Brewer Reef, taken within a month of the May 1987 field study (see project 4(b)). The image was delivered in January 1988. This will enable SPOT data, with its higher spatial resolution, to be assessed in the same way as Landsat MSS has been assessed.

Completion

It is expected that this project (including the additional results from the SPOT imagery) will be completed by June 30, 1988.

PROJECT 4(B) EVALUATING THE PROCEDURES FOR THE VERIFICATION OF LANDSAT IMAGES WITH REFERENCE TO THE EFFECTS OF OUTBREAKS OF ACANTHASTER PLANCI ON REEFS

Chief Investigator(s) Dr R. Reichelt and Mr S. Bainbridge

Status

This project is linked closely to project 4(a). The main goal here is to compare ground truth procedures with Landsat MSS information content to determine the optimal field procedures given the limitations of the imagery. The study has been extended, by the fortuitous purchase of a SPOT image (by AIMS for $3000), to include an assessment of field techniques for the verification of SPOT imagery, which has about 16 times higher spatial resolution than Landsat MSS.

Results/implications

Although the data are still being analysed it is expected that the results will be applicable to both Landsat MSS and SPOT data, and almost certainly applicable to the new generation of Earth Observation Satellites to be launched in the 1990's on the Polar Platform.

Problems

A helicopter charter was undertaken with the assistance of the Army. Dr Kuchler led the field work designed to give low-level reflectance data from a variety of coral reef substrate (such as an area of high coral vs low coral, etc) but the exercise had to be abandoned when intermittent cloud cover caused discrepancies between the solarimeter (upward looking) and the spectrometer (downward looking). This work would have produced exceedingly useful data had the weather not intervened.

Completion

The study is expected to be completed by June 30, 1988.

PROJECT 4(C) NUMERICAL MODELS OF THE HYDRODYNAMIC REGIME AROUND SCHEMATISED AND ACTUAL REEFS

Chief Investigator(s) Dr K. Back (Victorian Institute of Marine Sciences) and Dr J.C. Andrews

Status

The project has progressed on schedule with no difficulties other than the large time commitment associated with this comprehensive modelling project.

Results/implications

A full series of schematised reefs has been simulated to complete the hydrodynamics stage of the schematised and actual reef model. This has been reported on and is presently under editorial review. The modelling is now concentrating on the dispersal stage and some of this work has been finalised. The results have been extremely enlightening, giving insights into the removal and retention rates of larvae of the crown-of-thorns starfish on coral reefs. Details of this have been presented at several conferences over the past year. Manuscripts describing this work are presently being planned, nearing completion or have been accepted for publication.

Completion

Modelling of the dispersal of larvae is expected to be completed by the end of this year.

PROJECT 4(D) NUMERICAL MODELS OF THE HYDRODYNAMIC REGIME AT JOHN BREWER REEF

Chief Investigator(s) Dr J.C. Andrews and Dr K. Black (VIMS)

Status

This project attempts to use real field data to calibrate a numerical model for the combined tidal and wind-forced circulation at John Brewer Reef, and to apply those circulation patterns to calculate the trajectories, residence times and likelihood of outbreaks on the reef.

Background:

This is an extension of project 4(c) which is largely schematic, using steady state wind-currents (10 knot SE wind) and mid-range tides with constant amplitudes (no spring/neap cycle) applied to a suite of reefs selected to cover the spectrum of reef shapes encountered in the GBR. Project 4(d) has a particular focus on John Brewer Reef, uses a fine scale grid and real field data to simulate actual currents and trajectories around and over the reef. This project is on schedule with most field work having been completed.

Results/implications

Progress is reported for each of the modules laid out in the original proposal.

1. **Construction of bathymetric data bank**: completed. Australian Survey Office high resolution charts have been mapped onto a regular grid with a 50 m resolution and a coverage of 25 km x 25 km. This coverage and resolution is finer than required so the grid is subsetted for operational use.

2. **Construction and testing of hydrodynamic models:** completed. New boundary conditions which involve the manipulation of far-field momentum equations to produce far-field sea level gradients from measured far-field currents and incorporating the wind stress have been tested against field data and have proved superior to traditional methods.

3. **Field calibration and model validation:** Sufficient redundancy was built into the field program to allow the project to proceed despite heavy equipment losses in the field. Comprehensive field data on both the far-field and near-field circulation and on sea level variations have been recovered and processed. Initial model runs using these data augur well for successful delineation of circulation at John Brewer Reef and consequently for successful particle trajectory runs under module/objective 4. Velocity simulations should conclude by the end of April.

4. **Particle trajectory simulations:** A model for advection of particles by a known current field has been devised and tested. The problem of spin-out of particles on curved trajectories (tolerated by other workers to date) has been overcome by using an innovative second order formulation for the trajectory. Trajectory runs are planned from May through July 1988. Final writing-up should be complete by the end of October.

Problems

See above about equipment losses and previous reports about being constrained to take measurements in winter. Plans to take additional (limited) summer measurements were cancelled due to the high costs associated with instrument losses.

Future research

Historical hydrodynamic data existed for Helix Reef before data were available for John Brewer Reef. Most model development was done using Helix Reef as a test area. This allowed a full treatment of the dynamics there, with a focus on coral larvae (for which there were biological data), and very impressive advances were made in understanding self-seeding and between-reef transport of coral larvae. Although there are no plans to do so, it would be efficient to repeat those numerical experiments but with a focus on crown-of-thorns starfish larvae.

Completion

This project is due to finish in early September, 1988.

PROJECT 4(E) MODELS OF THE DISPERSAL OF ACANTHASTER PLANCI OUTBREAKS.

Chief Investigator(s) Dr R. Reichelt

Status

This work consists of a number of separate modelling studies several of which will extend beyond the life of the Crown-of-thorns Study.

Results/implications

1. **Non-spatial predator-prey model**: is completed and is presently being written up. The numerical simulation results indicated that starfish populations could increase rapidly over a period of several years (but not instantaneously unless the outbreak is secondary). Observations at Wheeler Reef conform to this pattern of exponentially rising population numbers leading up to the outbreak and subsequent crash. This model is being developed further as a management/control tool which will demonstrate the qualitative properties of 'controllable' versus 'uncontrollable' populations of starfish. Application of the model to field situations is presently limited by the lack of data with which to calibrate the model.

2. **Outbreak behaviour on a single reef**: has been modelled with a simple spatial model that showed large populations will 'automatically' aggregate (or remain aggregated) when coral abundance is depleted rapidly enough to cause a 'feeding front' to occur. This model is presently being modified to track individual starfish which will allow simulation of behaviors such as pheromonally induced aggregation of small clumps of starfish. The first version of the model was presented (and accepted for publication) as a paper at the May 1987 Meeting of the Simulation Society of Australia.

3. **Large scale wave behaviour**: observed after analysis of the historical database is being modelled using a spatial model derived from a reaction-diffusion-transport system of differential equations. The work is underway in collaboration with Professor P. Antonelli (Univ. of Alberta). The results so far indicate that the local scale behaviour of the predator-prey interaction can be linked to the large scale behaviour of the travelling wave of outbreaks on the GBR. Analysis of the model is directed at determining the conditions under which a wave will form and also the conditions that would cause the wave to be disrupted. A manuscript from this research is presently under review.

Completion

The modelling studies described above will continue at least until the end of the year.

PROJECT 4(F) ANALYSES AND MODELS OF EXISTING DATA

Chief Investigator(s) Dr R. Bradbury, Dr R. Reichelt and Dr P. Moran

Status

Satisfactory progress has been made in the project as a whole, although not all of the individual tasks have been addressed. This is because advantage has been taken of the visits of some of the external collaborators to push ahead on some tasks at the expense of others. Two publications dealing with the results of the CCEP Crown-of-thorns Study are now in review.

Results/implications

The tasks which have generated the most progress are as follows.

1. **Qualitative models of the phenomenon (Task 1):** analysis of the historical aspects of the phenomenon considered as a grammar of reef states written in time has been completed by Dr M. Dale (CSIRO) and is now being written up for publication.

2. **Continuous analogues of state transition models (Task 6):** is being conducted with Professor P. Antonelli. This work is now complete and has been accepted for publication.

3. **Statistical summary of the GBR database (Task 7):** has been completed and submitted for publication. It is now in review.

4. **Predictive analysis of the GBR database (Task 8):** has been completed and the manuscript is now ready for submission.

Completion

These analyses are continuing on schedule with no major problems being experienced. The individual tasks within this project will continue at least until the end of this year. A workshop is planned in early August 1988 for modellers actively working on the phenomenon.

PROJECT 4(G) TAGGING OF ACANTHASTER PLANCI USING MICRO-INJECTABLE TRANSPONDERS

Chief Investigator(s) Dr P. Moran and Mr R. Peden (Deakin University)

Status

Work on waterproofing the antenna unit of the ID system has been completed at Deakin University.

Future research

Over the next few months the unit will be tested in the AIMS outdoor aquarium on a small population of captive starfish. These tests will be used to determine whether there are any further problems associated with reading the transponders underwater and also to test the robustness and waterproofing of the antenna. Should this be successful the main ID system will be placed in a waterproof container so that it also can be used underwater. Once this has been accomplished field trials will be undertaken to ascertain any further logistic problems. As the technique has been tried only in the laboratory this will offer an opportunity to test the effectiveness of the technique using a population of marked starfish which are highly mobile. Estimates of tag recovery rates in the field will be undertaken as a final evaluation of the method.

Completion

Provided no further technical problems are experienced field trials of the system should be completed by the end of this year.

PROJECT 6(A) THE DYNAMICS OF PHYSIOLOGICAL PARAMETERS OF HIGH DENSITY CROWN-OF-THORNS POPULATIONS

Chief Investigator(s) A/Prof. J.S. Lucas, Mr B. Kettle (Student) and Mr R. Stump (Student) (Zoology Department, James University of North Queensland)

Status

Final samples of starfish were collected from Helix Reef in May 1987. All samples have now been analysed, including those taken for intra-animal variation studies. A preliminary assessment of the results was presented at the 1987 ANZAAS Conference at James Cook University (September).

The ageing assessment project was commenced in 1987 as a part-time study (by Mr Stump) within the larger study. A preliminary study as part-requirement of a Master's Qualifying course revealed the potential of "age-pigments" in the pyloric caecae as a means of ageing crown-of-thorns starfish. In January, 1988, Mr Stump was accepted to enroll as a full-time M.Sc. student. The COTSAC funds given for 1988 will be used as a stipend and for maintenance within the project.

Results/implications

Helix Study:

Preliminary analysis of the results generated concern about the degree of variability attributed to subsampling of starfish arms. Despite references to the suitability of subsampling in the literature it appears that a large part of the variability of preliminary results was due to this factor. An additional field exercise has been conducted to provide further insight to this variability. This study quantified this contribution to variability of the subsampling technique.

To date the major trends in data analysis have confirmed that three predictors (coral cover, season and wet weight) can be used to estimate the compartmental indices of crown-of-thorns starfish. It appears that this starfish is capable of partitioning heavily towards reproduction (at the expense of body wall and caecal indexes) even when coral cover declines to very low levels at the end of an outbreak. This effort appears to contribute to post-reproductive morbidity and the ultimate decline of the population.

Problems

Failure of all attempts to maintain animals in the university aquarium system occurred in 1987. An additional grant has been provided from a GBRMPA augmentative grant scheme for bench fees and travel for experimental work on animals at the Orpheus Island Research Station.

Future research

Over the next year research into the ageing of crown-of-thorns starfish will involve:

1. Continuation of the investigation of "age-pigments" including; further development of a rapid and accurate method for quantifying pigment levels from pyloric caecae, TEM ultrastructural identification and quantifying pigment in situ, testing the effects of arm regeneration, sex and starvation on pigment levels, further assessment of the use of NMR spectroscopy for pigment analysis and characterization;

2. Morphometric analysis of the ratio of arm-spine length to diameter ratios and;

3. SEM studies of skeletal growth including marker studies using a range of chemical markers to determine the mode of skeletal deposition.

Completion

Funding for the Helix study ceases in March. By then analysis of the results is expected to be completed. Preparation of a Ph.D. dissertation entitled: "Time course of physiology for a high density crown-of-thorns population" has begun. It is expected that this thesis will be completed by May. Investigations of ageing starfish will continue at least until the end of 1988.

PROJECT 6(B) A STUDY OF THE TEMPORAL AND SPATIAL DISTRIBUTIONS OF ACANTHASTER LARVAE, IN RELATION TO SURVIVAL AND DISPERSAL

Chief Investigator(s) Dr R.F. Hartwick (Zoology Department, James Cook University of North Queensland)

Status

This project has been completed. A final report on the results of this research and its implications will be submitted in July 1988.

PROJECT 6(C) SIMULATION OF THE LARGE SCALE POPULATION DYNAMICS OF CROWN-OF-THORNS STARFISH IN THE GREAT BARRIER REEF SYSTEM

Chief Investigator(s) Dr M.K. James, Dr L. Bode, Professor K.P. Stark, (Department of Civil and Systems Engineering, James Cook University of North Queensland) (Report prepared by Mr I. Dight)

Status

In this project the population dynamics of A. planci have been investigated by developing large scale models of the dispersal of larvae throughout the Cairns and Central Sections of the Great Barrier Reef Marine Park. This has been achieved, with some very interesting results, and the first phase is essentially completed. Preliminary results have been presented in two conference papers (with a third to be presented at PACON in May 1988.). Four journal articles are currently in preparation.

Results/implications

Since the last report the following progress has been made:

1. Hydrodynamic models have been completed for both Sections.

2. A database of water movement patterns has been developed, corresponding to forcing by tides, the East Australia Current, and a wide range of wind speeds and directions.

3. A particle-tracking model has been developed and implemented for the Cairns Section. Extensive simulations of larval movement under time-varying wind fields have been performed.

4. Preliminary development of a probability matrix for dispersal of larvae between regions within the Cairns Section has been completed.

In the southern part of the Cairns Section, and also in the Central Section, three forms of asymmetry in the circulation have been identified, resulting in the long-shelf (southward) transport of larvae, cross-shelf (onshore) transport, and strong source-sink relationships between reefs.

These asymmetries can account for the high incidence of outbreaks on mid-shelf reefs. Reefs identified by the simulation results as having greater susceptibility are Green Island, Scott, Feather, Ellison and Otter Reefs. These results are in broad agreement with observations.

However in the northern part of the Cairns Section, west of the Ribbon Reefs, dispersal is more confined and the patterns are different. Great importance is attached to this observation, since it appears likely that the distinctive dispersal pattern in the northern region may be of fundamental significance for the entire Acanthaster phenomenon.

The implications of these findings are many, not only for Acanthaster, but for a far wider context of ecological and management issues. As most coral reef invertebrates and fish produce offspring which have the potential to disperse quite widely as pelagic larvae, it is the pattern of connectivity defined by larval dispersal which determines the ecological structure of the GBR system.

Completion

The modelling tools and database will be extended and further employed in a new project, commencing in March 1988 (project 6(j): Assessment of the Acanthaster phenomenon through a consideration of the life-history strategy of A. planci).

PROJECT 6(D) FIELD STUDIES ON ASPECTS OF THE ECOLOGY OF ACANTHASTER PLANCI

Chief Investigator(s) A/Prof. R. Endean and Dr A. Cameron, (Zoology Department, University of Queensland)

Status

Temporal monitoring of populations of massive scleractinian corals from 9 families (identified at species level and mapped in 3 dimensions) established in permanently marked study sites has been continuing on Holbourne Island fringing reef, Beaver Reef, Normanby Island fringing reef (Frankland group), John Brewer Reef, and N. Brook Island fringing reef.

Results/implications

Time-series analyses of these data, and data from other permanent sites, will facilitate long-term comparisons of population structures, growth rates, recruitment, levels of mortality from Acanthaster planci, subsequent secondary mortality from soft coral, algal and sponge overgrowth, and other "background" sources of mortality on reefs both affected and so far unaffected by A. planci population outbreaks.

Complimentary to these detailed studies, belt transect censuses (generally 3 by 300 m.sq. transects at 3 sites on each reef) of the size structures and degrees of damage on massive corals identified at generic level have been conducted on John Brewer Reef and N. Brook Island Reef. These data will be compared with data collected previously using the same methodology on a further 10 reefs. In combination with the more detailed species-level information, these data will enable prediction of times of recovery for massive coral assemblages on reefs devastated by A. planci (the time required for the populations to resemble those established prior to A. planci outbreaks). A 6 reef subset of the transect data (Green Island, John Brewer, Potter, Hastings, Fitzroy Island and Low Isles Reefs), and coral overgrowth data from Holbourne Island Reef, have been analysed for presentation at the Sixth International Coral Reef Symposium (August 1988, Townsville). Preliminary analyses of both data sets indicate that the adult-dominated massive coral assemblages currently being destroyed by A. planci could not have developed under past A. planci outbreaks of similar frequency and intensity to those of the last 20 years. Two publications have been prepared as a consequence of this and other related projects.

Future research

Further transect censuses, and the mapping of further permanent sites will be carried out in the next year. Continued biannual monitoring of all permanent mapped sites will be facilitated by the use of an underwater video camera. Video images of each coral in the permanent sites will greatly enhance temporal comparison. Video recordings of the belt transects, now also permanently marked, will also provide more data on these communities, particularly estimates of cover of other benthic elements, and changes in these communities through time.

Completion

It is hoped that this research will continue for at least several years. All the initial objectives of this project will be completed by the end of this year.

PROJECT 6(E) 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(s) Dr P.J. Doherty (Griffith University)

Status

In 1987, the 16 reefs surveyed during 1986 were resurveyed using the same techniques except that all sampling was done as late as possible in the year (November-December) to increase the chance of detecting the youngest age-class.

Results/implications

This sampling revealed a very similar assemblage of reef asteroids to the previous year with one exception. Both the absolute and relative abundance of A. planci, especially small sizes, were much reduced (7 versus 97 individuals) and most of those present were 2+ years or older. The numbers of 2+ individuals on these reefs were correlated with the numbers of 1+ individuals recorded in the previous year. The data suggest that we have been observing a cohort of starfish spawned during the 1984/85 summer and these populations have not received substantial replenishment during either of the two subsequent breeding seasons. There was no evidence of range extension to southern reefs where juvenile A. planci were not recorded in 1986.

The consistency of the results between the two annual surveys provides reassurance that the methodology is capable of detecting very small (0+) A. planci when they are present. The low numbers of recruits from the last two seasons may indicate that the present outbreak of starfish is waning or simply indicate that heavy settlement is a rare phenomenon. This is likely to be clearer after the third and final set of surveys planned for November/December of this year.

Future Research

In the period preceding this final fieldwork, the following tasks remain to be done; (1) work up the substratum maps from the last cruise, (2) complete data entry into an electronic database, (3) initiate multivariate analysis of the asteroid assemblages and their associations with environmental variables, and (4) present preliminary results at the Sixth International Coral Reef Symposium. These tasks will be done with only casual assistance as salary has had to be diverted to sustain the original field program.

Completion

All fieldwork should be completed on target by January 1989. It is expected that another three months will be required to complete the data analysis to the stage where final reports can be prepared.

PROJECT 6(F) ANALYSIS OF PHYSICAL MECHANISMS CONTROLLING PLANKTON PATCHINESS ON THE GREAT BARRIER REEF

Chief Investigator(s) Dr J. Parslow (CSIRO Division of Fisheries Research, Hobart) and Dr A. Gabric (Griffith University).

Status

This project is nearing completion. Funds given in 1986 have been used to support this project up until the end of 1987. A final research report will be submitted in July this year.

PROJECT 6(G) DEVELOPMENT OF MONOCLONAL ANTIBODIES AGAINST LARVAE OF ACANTHASTER PLANCI: A PILOT STUDY TO DETECT AND CHARACTERIZE LARVAL MEMBRANE MARKER(S) FOR THIS SPECIES

Chief Investigator(s) Dr P.J. Hanna, Dr V.W.K. Lee and D B. Richardson (Division of Biological and Health Sciences, Deakin University)

Status

In the 7 months since submission of the last project report a monoclonal antibody has been produced which exhibits species-specific properties against larvae of crown-of-thorns starfish.

Results/implications

The monoclonal antibody was developed from formalin-fixed 5-day old larvae of Acanthaster planci supplied by Professor Masashi Yamaguchi in August 1987. The antibody reacts with cilia present on the surface of newly emerged blastula but does not react with the membranes of eggs.

With older larvae, including gastrula, bipinnaria and those of 11-day brachiolaria, the antibody reacts with the cilia present in clumps on the larval surface but not those in the major bands of locomotory cilia. These clumps are particularly evident over the stomach region and are more dispersed towards the adhesive disc region. Larvae in control tests show no apple-green fluorescence.

The antibody cross-reacts with Australian Acanthaster planci bipinnaria larvae supplied by AIMS but to a lesser degree than that for the Japanese material against which it was made. It does not cross-react with bipinnaria larvae of the Great Barrier Reef starfish, Culcita sp. nor larvae of the sand dollar, Arachinoides placenta. Tests are planned for immunofluorescent discrimination of Acanthaster planci larvae in 'spiked' plankton samples (to be supplied by AIMS).

Future research

Tests are in progress to characterize the antibody and the surface antigen with which it reacts. Further fusions are underway to produce monoclonal antibodies which also show species-specificity but react with other structures such as cilia in the prominent locomotory bands. These could be even better in diagnostic fluorescence tests for Acanthaster planci larvae than the monoclonal antibody already developed.

Completion

Tests to determine the presence of Acanthaster planci larvae in gut contents of its predators have been tentatively planned for the end of 1988. Additional funds are requested to cover travel costs to Townsville and this final experimental work. Further research will depend on the results of these tests.

PROJECT 6(H) DYNAMICS OF THE ACANTHASTER/HARD CORAL INTERACTION

Chief Investigator(s) Mr D.A. Fisk (Reef Research and Information Services)

Status

Field work on A. planci abundance and coral recruitment and recovery are continuing. The results of this work are being compiled for presentation at the 6th International Coral Reef Symposium.

Results/implications

A. planci at Green Island:

Surveys of crown-of-thorns starfish were undertaken in November 1987 using 5-minute timed swims (46 sites), and 1/2 x 1/2 m rubble searches (15 sites) where the number of replicates per site were reduced from 4 to 3. No 0+ crown-of-thorns starfish were found in the rubble searches.

Nine starfish were recorded from the timed swims with size frequencies of: 0-5cm.:1 indiv.; 6-10cm.:4 indiv.; 11-15cm.:3 indiv.; 16-20cm.:0 indiv.; 21-25cm.:1 indiv. This suggests a continuing reduction in abundance and no sign of population growth since the commencement of surveys in late 1986. All individuals were located adjacent to recently eaten Acropora colonies.

Coral regrowth and juvenile dynamics:

Line transects were conducted in November 1987 as was the remapping of permanent quadrats for juvenile corals. These data are still being collated. Survival rates are still relatively high (>60%) and some spectacular growth rates are being recorded by certain Acropora species.

Coral recruitment:

Settlement plates were recovered from Michaelmas, Upolo, and Green Island reefs in November and a replacement set deployed. Analysis of this set confirm the results of the winter plates which were dominated by the Pocilloporidae. As with previous data, Upolo spat abundances were the highest (total of 123 spat), followed by Michaelmas (102), then Green Island (33). These figures are from a subset of 2 pairs of plates per rack, and 4 x forereef and 4 x backreef racks per reef.

Completion

No problems were encountered during this field program. This research will continue at least until the end of the year.

PROJECT 6(I) THE WITHIN REEF DISTRIBUTION PATTERN OF JUVENILE ACANTHASTER PLANCI

Chief Investigator(s) Professor H. Choat (Department of Marine Biology, James Cook University of North Queensland)

Status

At present this project is suspended until a population of newly settled and/or juvenile Acanthaster is located.

Results/implications

It is now clear from a number of sources that such populations will be localized in space and persisting for relatively brief periods at such specific sites.

This conclusion is based on the results of COTSARC funded surveys by Dr P. Doherty and the AIMS Survey team, by direct observation on several reefs by Mr M. McCormick and from a review of information collected by Dr A. Ayling, Mr B. Kettle and Mr R. Bell.

Acanthaster planci is probably an ephemeral species with scattered but intense episodes of recruitment followed by rapid growth and subsequent mortality of these cohorts. The behaviour of recently recruited cohorts is a matter of intense interest to the COTSARC program. There are two ways by which such a study might be accomplished. Locate a cohort of juveniles within the logistic capabilities of the survey group and study them intensively or develop ones own cohort for localized study by rearing (see project 1(f)). Neither are feasible at this stage.

Future research

The present program will be maintained in readiness should a suitable population be found. If this does not eventuate by late 1988 some thought should be given to re-allocating the funds.

NEW PROJECTS

PROJECT I(K) SPAWNING SUCCESS AND FERTILIZATION RATES OF ACANTHASTER PLANCI

Chief Investigator(s) Dr J. Benzie, Mr P. Dixon and Dr P. Moran

Background

Outbreaks of the crown-of-thorns starfish, Acanthaster planci, could conceivably result from increases in spawning success if the fertilization of gametes was normally limited by some factor(s). It has been suggested that the fertilization rates of free-spawning species are probably high (Pennington, 1984) given that the release of eggs often is cued by the presence of active sperm. Whilst Acanthaster planci has been observed on several occasions to spawn in aggregations there are no data to indicate the likely fertilization rates that may occur in the field under these (or any other) population densities.

An investigation of the fertilization rates of Acanthaster planci in the field was originally proposed as part of the Crown-of-thorns Study during 1986 (Moran, 1987). This research was not undertaken however, due to logistic difficulties and a change in research priorities brought about as a result of the findings of project 1(c). Investigations of this important problem are being proposed once again since new conceptual approaches have allowed the development of simpler experimental designs and a larger proportion of the work to be conducted in the laboratory rather than in the field. Preliminary field and laboratory work (undertaken during the last spawning season) has identified the main factors that need to be taken into account in conducting this research and demonstrated the logistic feasibility of the experimental designs.

Research objectives

One of the main factors which could account for the differential recruitment of Acanthaster planci is spawning success. No data exists on the number of gametes produced by an individual or the proportion of viable zygotes which results from a given number and density of gametes.

It is considered that these data could be used as an empirical basis for general mathematical models of the effects of fertilization success in relation to varying densities of Acanthaster planci. Such models may be extremely useful in assessing the importance of these processes in relation to other factors such as larval feeding and predation. Data on fertilization success also may be of value in hydrodynamic (e.g. projects 4(c)(d) and 6(c)) and plankton patchiness models (e.g. project 6(f)).

The aims of this project are:

1. To describe the quantity and dispersal of gametes released from individual starfish in the field.

2. To determine the rates of fertilization and production of viable zygotes, in the laboratory, that would be expected from the gamete densities measured during the field experiments.

Research Plan

Two types of research are planned as part of this project. The first is field based whilst the other is laboratory based. Both can only be carried out successfully during the spawning season, from November to early January.

Field experiments:

In order to conduct this research it will be necessary to construct a platform (approximately 5 m in length) over a section of reef flat to allow sampling of waters downcurrent of a spawning starfish without causing undue disturbance to the water column. The starfish would be placed at a pre-determined location upstream of the platform and induced to spawn using methlyadenine. Preliminary experiments have demonstrated that this technique is feasible and that eggs should be detectable up to 5 metres from the spawning starfish. Samples will be collected along 3 transects; one directly downstream of the starfish and one either side (radiating at 30 degrees from the centre line), to provide data on dispersion. Each transect is likely to be about 3 metres in length. The development of automatic gamete counting devices (based on modified designs for counting coral eggs) is being considered together with real-time data logging as this would considerably increase the efficiency and productivity of the field experiments.

Laboratory experiments:

Portions of gonads from individual starfish will be excised and stimulated by methyladenine to release their gametes. Sperm and eggs of different ages, densities and ratios will be mixed in separate containers to determine the effect of these factors on fertilization success. Fertilized eggs from each treatment will be cultured separately for as long as possible (at least until early brachiolaria) to estimate the viability of the zygotes produced. Preliminary experiments have shown that in some situations larvae may not survive to settlement despite the fact that fertilization is high and their development occurred under optimal conditions. Survivorship of fertilized eggs may well depend on which month of the spawning season fertilization occurred.

Culturing of fertilized eggs will be undertaken in the system that has been used to develop large numbers of larvae for other projects within the Crown-of-thorns Study (refer to project 1(f)).

Resources needed:

The field component of this project will require large amounts of equipment, manpower and shipboard facilities (e.g. laboratory). For this reason it is planned that the shiptime requirements of this project will be met by AIMS. It is hoped that time (about 12 days) on the R.V. Lady Basten will be made available to undertake this research. Costs associated with building the field platform, constructing automatic egg and sperm samplers and purchasing field equipment are requested. A relatively small amount of funds (mainly for chemicals and glassware) are also required to undertake the laboratory based studies. The costs associated with this project are presented in Table 6.

Duration:

Given that this project can only be conducted during the spawning season it is anticipated that this project will be completed by the end of January 1989. The field experiments are scheduled for the 10-21 December (in between spring tides).

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Table 6 Budget for project 1(k): 1988/89

Item	Cost ($)	
	COTSAC	AIMS
1. Salaries:		
Research Scientist* (Dr J. Benzie)	-	-
Research Scientist** (Dr P. Moran)	-	3,500
Experimental Scientist* (Mr P. Dixon)	-	-
2. Allowances:		
Travel and field (6 personnel for 12 days @ $20 per day)	1,440	-
3. Vessel charter:		
12 day field trip @ $4,200 (R.V. Lady Basten)	-	50,400
4. Consumables:		
Cost of erecting platform	1,000	-
Field gear (buoys, ropes, pumps, etc)	1,000	-
Chemicals	560	-
Glassware and containers	1,000	-
5. Capital equipment:		
Construction of automatic samplers	2,000	-
TOTAL	**$7,000**	**$50,400**

* salaries attributed to projects 1(a) and 1(c)
** based on 10% of available time

PROJECT 1(L) THE ROLE OF BACTERIA FROM CORALLINE ALGAE IN OUTBREAKS OF CROWN-OF-THORNS STARFISH

Chief Investigator(s) Dr C. Johnson, Dr. D. Sutton (Sir George Fisher Centre) and Mr P. Dixon

Introduction

Outbreaks of crown-of-thorns starfish (COT), Acanthaster planci, have an enormous impact on the structure of coral reefs by preying on corals and mediating a transition from a coral- to an algal-dominated system (Moran 1986). Since recruitment processes dictate to a large degree subsequent population patterns, knowledge of the recruitment processes of COT, and in particular the factors that influence their settlement and metamorphosis, is fundamental to an understanding of the mechanisms that trigger outbreaks. Here is outlined research to test the hypothesis that bacteria specifically associated with the surface of coralline algae play a key role in COT outbreaks by producing compounds that induce settlement and metamorphosis of COT larvae.

Bacterial production of molecules that induce COT settlement:

It is well established that coralline algae affect settlement rates of a wide variety of marine invertebrate larvae, inhibiting metamorphosis in a few species (Padilla 1981, Breitburg 1984) but enhancing settlement in many more (e.g. Barnes and Gonor 1973, Morse et al. 1979, Steneck 1982, Rumrill and Cameron 1983, Morse and Morse 1984), including COT (R.R. Olson pers. comm.). Early research was interpreted to indicate that γ-amino butyric acid (GABA) produced by the coralline was the inducing compound for many invertebrate species (Morse et al. 1979,1984 and references, Rumrill and Cameron 1983, Trapido-Rosenthal and Morse 1985), but more recent evidence has suggested that phycoerythrin, or other phycobiliproteins or compounds associated with these algal pigment-proteins, are the inducing substances (Morse and Morse 1984, Morse et al. 1984). Two observations indicated that the inducing compounds are uniquely available on the surface of crusts (Morse and Morse 1984); first, crude extracts of both encrusting coralline algae and fleshy red algae induced settlement, but only the crusts showed inducing activity when plants were intact, and second, water allowed to flow over intact crusts did not show inducing activity unless the surface was brushed simultaneously. However, although there is strong evidence that phycobiliprotein-associated molecules do have potent inducing activity, it is unlikely that these compounds would be bound to the surfaces of crustose corallines. They are contained in the stroma of chloroplasts of intact cells, and to access them a larvae must penetrate cells by grazing. If a larvae can graze the massive calcified walls of cells of coralline algae, it is unclear why it should not be able to penetrate cells of delicate fleshy and filamentous species. The question remains, what is the origin of the inducing molecules that are uniquely available on the surface of coralline algal crusts?

An alternative explanation is that the inducing compounds are produced by bacteria growing on the crust surfaces. Several other observations are also consistent with this notion, but the idea needs to be tested critically. Crusts in temperate waters support unique populations of bacteria that are specifically associated with their surfaces but rare elsewhere in the marine environment (Lewis et al. 1985, C.R. Johnson unpub. data). Since these bacteria must rely on another organism to provide some of the compounds required for growth, they are most abundant growing from within the plasmalemmae of damaged algal cells and are relatively sparse on the calcified cell walls (C.R. Johnson unpub. data). Moreover, the overall distribution of bacteria on crust

surfaces is patchy, with highest densities occurring in areas of recent damage to the crust (C.R. Johnson unpub. data). Thus, the hypothesis that bacteria produce the inducing compound(s) is consonant with the finding of R.R. Olson (Moran and Hughes 1987, see project 1.e) that circumscribed areas on some corallines have potent inducing activity but other regions on the same thallus do not.

Deep water recruitment hypothesis:

A second hypothesis to be tested, and following from the first, is that beds of coralline algae in deep water act as nursery areas for COT and play a pivotal role in outbreaks. Several points support this idea, viz. outbreaks on the GBR have nearly always been observed first as aggregations of 2-4 yr old animals ascending reef fronts from deep water, and large numbers of juvenile COT have never been found in shallow water on the GBR despite a considerable search effort (P. Moran pers. comm.). Crustose corallines grow extensively, either attached or as unattached rodoliths or maerl, in deep water in both temperate (Adey 1966,1971, Adey and MacIntyre 1973, Sears and Cooper 1978) and tropical waters (Lang 1974, Littler et al. 1985, Scoffin et al. 1985 and refs.), including those of the GBR (J. Veron, pers. comm.). In addition, corallines are a suitable food source for juvenile COT, and their complex matrix of interstitial spaces provides protection from predators.

Research Plan

Collaborations:

The proposed research is to be a joint project in collaboration with Dr David Sutton who will supervise the microbiological work (Sir George Fisher Centre, Townsville), and Mr Paul Dixon (AIMS) who will provide COT larvae. The research can be separated into three parts; to determine (i) whether bacteria from coralline algae enhance settlement of COT larvae, (ii) whether localized areas of potent inducing activity on coralline crusts correlate with high densities of epiphytic bacteria, and (iii), if positive results are obtained from these investigations, to determine the extent of cover of coralline algae in deep water at the base of, and close to, selected outbreak-reefs in the midshelf central GBR region.

Bacteria and COT settlement:

The principal goal of this work is to bioassay extracts prepared from bacteria isolated from coralline algae for their effect on settlement of COT larvae. We intend to test extracts from bacteria isolated from both temperate and tropical coralline algae.

During 1987 isolates were prepared from coralline crusts from South Africa and characterized (C.R. Johnson unpub. data), and these cultures are currently held at the Sir. George Fisher Center in Townsville. Crude extracts are presently being prepared from these cultures, and we propose to undertake bioassays with sand dollar (Arachnoides placenta) larvae immediately (April 1988), and subsequently with COT larvae. Bioassays are conducted by adding each bacterial extract to several replicate vessels containing larvae that are competent to settle and metamorphose, and comparing larval behaviour in these vessels with that in a control series which do not contain the extract.

To protect against deterioration of the extracts in storage, and to provide a basis for later work with COT larvae from the GBR, it is important that the COT bioassays are performed as soon as possible. Since the 1987/88 COT spawning period on the GBR has passed, the most expedient option is to conduct the bioassays in the lab of Dr. M Yamaguchi, Univ. of Ryukyus, Japan, during June 1988.

Four types of extract are being prepared from each isolate after growing in broth culture to stationary phase (determined by spectrophotometric analysis). The extract types are (i) supernatants of intact, growing cells, which contain soluble surface antigens and exuded metabolites, (ii) supernatants of cells ruptured by French pressing, which, in addition to leached metabolites and surface antigens, contain soluble metabolites that do not leach from living cells, (iii) a suspension of cellular debris sterilized by antibiotics after French pressing, and (iv) a suspension of intact cells immobilized and sterilized by antibiotics.

Studies of bacteria from GBR corallines are conveniently broken into two sections; first, the isolation, purification and production of bacterial extracts for bioassays, and second, the characterization of bacteria from coralline algae. The first part of the work will be conducted from Sept. 1988-May 1989, and the second portion will continue for ca. 4 mo after this time.

Specimens of common species of coralline algae will be collected from shallow and deep water, and macerates of their surface tissues prepared immediately. Aliquots will be transferred through a sterile SW dilution series for plating onto agar media aboard ship. Later, in the laboratory, isolates will be subcultured serially to ensure purity, and maintained on agar media. In addition, subcultures will be freeze-dried and placed in long-term storage conditions to ensure survival. Extracts for bioassays will be prepared from selected isolates and combinations of isolates grown in broth cultures as described earlier. Depending on the number of morphologically distinct isolates obtained and the time between collection and subsequent culture testing, preliminary taxonomic tests may be undertaken. The isolation procedure will be undertaken immediately prior to, and during, the known spawning period of COT since seasonal changes in algal metabolites may influence their epiphytic microbial populations and thus the presence of compounds that induce COT settlement.

The second part of the bacterial work (characterization of coralline bacteria) will follow if positive results are obtained from the bioassays. Characterization requires a lengthy series of biochemical tests. If it is shown that bacteria from coralline algae produce metabolites that induce settlement of COT it will be necessary to know (i) the identity of these microbes, and (ii) whether they are associated specifically with corallines, as has been shown for temperate species (Lewis et al. 1985, C.R. Johnson unpub. data), or are common elsewhere in the marine environment. This will entail culturing isolates obtained from non-coralline sources (e.g. water column, dead coral, incubated glass slides), and comparing these populations with those that grow on coralline algae.

If coralline-bacteria do induce settlement, knowledge of the species involved will allow simplified techniques for isolation and identification to be developed. This will facilitate further studies of the relationship between bacteria and COT settlement on a variety of substrata. Moreover, this may be important in explaining COT outbreaks on particular reefs and in indicating reefs susceptible to infestation.

Distribution of surface bacteria and COT settlement:

Settlement of COT larvae on pieces of coralline algae will be observed in the laboratory to identify regions that manifest high inducing ability. Common species of corallines from shallow and deep water will be analyzed. Crust pieces will then be examined with SEM to determine the correlation between extent of inducement of COT settlement and density of epiphytic bacteria. Standard SEM techniques will be followed and need not be detailed here.

Extent of cover of coralline algae in deepwater:

This will be assessed by a small-scale survey around selected outbreak-reefs in the midshelf central section of the GBR (e.g. Davies, Wheeler, Helix, John Brewer and Glow reefs) using divers, video equipment and other underwater viewing technology as it becomes available (e.g. ROV or submersible). The survey will proceed only if is it shown unequivocally that corallines from deep water promote settlement of COT, and thus would not commence until after May 1989.

Resources needed

Bacteria and COT settlement:

Current work on the bacteria from South Africa is covered by existing resources at AIMS and the Sir George Fisher Centre, but funding will be required to cover costs associated with conducting research in Japan (estimated at ca. $A2200).

The proposed initial work to isolate, purify and produce extracts from bacteria from GBR corallines will necessitate a full-time research assistant from September 1988-May 1989 inclusive. In addition, ship time for collection of specimens (provided by AIMS), and materials to maintain the bacterial cultures will be required (see Table 7).

Resources required to characterize bacteria isolated from GBR corallines and other substrata will not be itemized here since this work will proceed only if the bioassays yield positive results, i.e. after May 1989.

Distribution of surface bacteria and COT settlement:

This will require ship time for collection of specimens, and funds to cover an estimated 20 hr of SEM time at James Cook University.

Distribution of coralline algae in deep water:

Details will not be itemized here since this work will proceed in June 1989 only if the bioassays of corallines and extracts of their bacteria yield positive results.

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Table 7 Budget for project 1(l): 1988/89

	Item	Cost ($)		
		COTSAC	AIMS	GFC [1]
1.	Salaries:			
	C.R. Johnson [2]	-	4200	-
	D. Sutton [3]	-	-	1200
	P. Dixon	**	-	-
	Research assistant grade 12 [4]	14920	-	-
2.	Allowances (diving and travel):	240	120	-
3.	Vessel Charter:			
	Harry Messel (6 days @ $3800 d^{-1})	-	22800	-
4.	SEM time (20 h @ $35.00 h^{-1})	700	-	-
5.	Consumables:			
	Agar, petri dishes, yeast, liquid nitrogen, tryptone, antibiotics, chemicals for preliminary taxonomic tests, glassware	1880	-	-
	TOTAL	**$17740**	**$27120**	**$1200**

1 Sir George Fisher Centre
2 Based on 20% of time
3 Based on 5% of time
4 Based on $637 + $114 (18% added for cost increases as per Australian Research Grants recommendations) + $14 (locality allowance) = $765 per fortnight
** Salary from COTSAC project 1(c)

PROJECT 3(C) INVESTIGATION OF SAMPLING BIASES IN MANTA TOW SURVEY WITH PARTICULAR REFERENCE TO CROWN-OF-THORNS STARFISH (ACANTHASTER PLANCI)

Chief Investigator(s) Dr H. Marsh and Ms L. Fernandes (Student) (Zoology Department, James Cook University of North Queensland)

Introduction

Manta towing is a relatively cheap and quick method of surveillance of reefs which has been used extensively to estimate the abundance of the crown-of-thorns starfish, Acanthaster planci (Kenchington and Morton, 1976; The Crown-of-Thorns Study, 1985). It is generally agreed that manta tow data do not represent accurate counts. However, there has been little investigation of the degree of bias and variability with regard to estimates of crown-of-thorns starfish abundance obtained using this technique. Although preliminary data (Moran and Sinclair, unpublished) indicate that a significant correlation exists between manta tow estimates of crown-of-thorns starfish and numbers counted on scuba swims, it is desirable to assess the reliability of this index under different conditions.

Research Objectives

Biases associated with the variability of transect width of reef being sampled by manta tow will be investigated. Perception and availability biases will be studied including the bias resulting from diurnal variations in the proportion of starfish that are cryptic. The questions and problems to be addressed in this project are listed below and tentatively prioritised.

1. The **width of reef** actually sampled by observers on manta boards is unknown and varies under different conditions. For this reason the width of transect sampled will be investigated experimentally. It will then be possible to estimate what area of reef an abundance value refers to in relation to the specified conditions.

2. **Perception biases** are those pertaining to crown-of-thorns starfish which are potentially visible to observers and which are missed.

Potential sources of perception bias to be investigated are:

a. Variability of intra-observer bias.
b. Variability of inter-observer bias.
c. Variation in density of crown-of-thorns starfish.
d. Variation in distribution patterns of crown-of-thorns starfish.

3. **Availability biases** pertain to crown-of-thorns starfish which are unavailable to observers because they are not visible.

Potential sources of availability bias to be investigated are:

a. Variation in visibility
b. Changes in substrate complexity.
c. Changes in the proportion of cryptic starfish.

Relevance to Management Needs/Priorities

Surveillance of the distribution and abundance of crown-of-thorns starfish is a predominant management concern of the Great Barrier Reef Marine Park Authority. The Authority (also COTSAC) has identified the development of cost effective monitoring techniques as a major priority. This project will investigate biases associated with manta tows, one of the main methods used for rapid reef surveillance. The degree of variability and bias involved with the manta tow technique will be determined so that future field data can be evaluated and utilized to its maximum management potential.

Research Plan

Investigation of the transect width sampled by manta tow:

Manipulative experiments will be carried out using plastic shapes to estimate the effective transect width sampled by manta tow observers under different conditions. Parallel rows of four different shapes will be laid down on each side of a manta tow path defined at the beginning and end by buoys (Fig. 1).

By recording manta tow counts of shapes, the transect width sampled can be estimated for each set of conditions. Multiple regression analysis will be applied to interpret the relationship between transect width and the environmental conditions (e.g. visibility, substrate complexity) under which the data was collected.

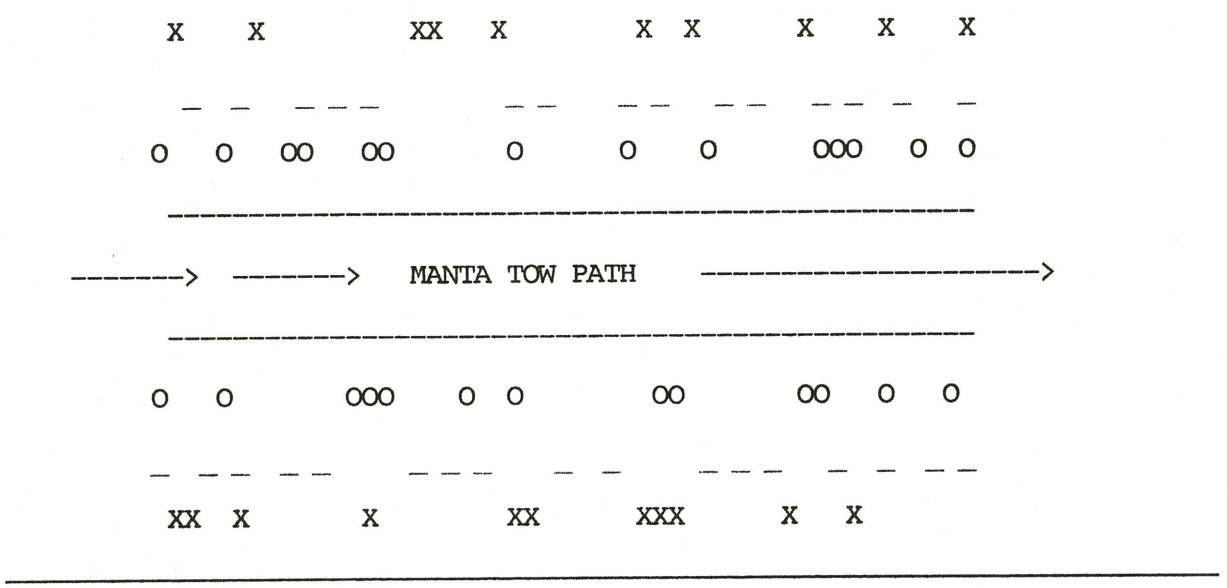
Investigation of perception and availability biases:

Biases will be assessed by comparing manta tow counts of crown-of-thorns starfish with those obtained from scuba swims of the same area. The effect, on the comparison, of different levels of measured variables will be investigated by sampling under many different conditions and on as many different reefs as possible. The relationships between manta tow counts and swim searches will be explored over a wide range of environmental conditions with regression analysis.

Investigation of the diurnal changes in the proportion of cryptic starfish:

Preliminary investigations conducted by John Keesing (James Cook University) and as part of this project have indicated that the proportion of cryptic crown-of-thorns starfish is large and varies during the day. In order to gauge the relationship between the number of starfish counted by observers on manta tow and the number actually present, it will be necessary to estimate the proportion of cryptic animals at any one time. Permanent underwater transects will be set up at three different locations (corresponding to three different levels of substrate complexity) on each of two reefs. Transects will be sampled under different conditions (e.g. of visibility, weather, observer, tide etc.) to assess difference in proportion of population available to manta tow observers. Transects will be relocated if the starfish population moves. The patterns of diurnal variations in proportion of cryptic starfish will be investigated. Analysis of variance will be applied to determine the significance of differences in proportions of populations available between sites and between reefs. It is anticipated that study sites will be located on John Brewer, Bowden and Davies Reefs.

Figure 1 Diagram of one of the layouts of plastic forms underwater to test the transect width being observed during a manta tow.



Key

-----	rectangular shapes	O	circular shapes
_ _ _	square shapes	X	butterfly shapes

Project organisation

This project commenced on January 1 1988 and is due to finish by 30 June 1989. The student undertaking this research is being co-supervised by Dr Dennis Sinclair (Department of Statistics; University of Newcastle) and Dr Peter Moran (AIMS). Consultation and liaison will be sought with Professor Howard Choat and Professor Rhondda Jones. It is planned that preliminary results from several aspects of this project will be presented at the next meeting of COTSARC.

Resources needed

The shiptime required for this project will come from that allocated within project 3(a). Expert assistance will be needed in conducting these experiments and will be provided by experimental scientists presently conducting surveys of starfish and corals within the Crown-of-Thorns Study. Where possible, field equipment (e.g. slates, tapes, dive spares, stakes) for this project will be borrowed from that used in present projects. Some funds will be needed to purchase other consumables (e.g. film, general stores, computer accessories). The Great Barrier Reef Marine Park Authority is also sponsoring this project by providing a student stipend to the chief investigator and some maintenance funds. A budget for this project is given in Table 8.

Progress

A preliminary field trip indicated the importance of diurnal changes in the cryptic behaviour of crown-of-thorns starfish; more than might be expected by chance migration. Triplicate scuba searches of the same area were conducted on three consecutive occasions over a two day period. A two-way analysis of variance showed significant differences between starfish counts at different times of day ($F=21.72$, 2x6d.f., $p<0.01$).

Trials also determined that setting up a 200 m long transect (corresponding to one manta tow) was feasible and that an appropriate width for the permanent transects needs to be established empirically before they are constructed.

Two of three tests showed no significant difference between three scuba swim counts of the transect which were repeated by different observers in a 90 minute period ($X2=13.86$, 18d.f., $p>0.50$; $X2=19.09$, 12d.f., $p>0.05$; $X2=29.42$, 18d.f., $0.05>p>0.025$). Analysis also showed that the adopted method of swim searching (which involves searching adjacent 20 m wide lanes consecutively) was as rigorous as more time consuming methods involving further subdivision of lanes ($t=2.0$, 2d.f., $p>0.1$) or involving destructive marking of animals ($t=1.0$, 2d.f., $p>0.2$).

On three occasions different observers counted significantly different proportions of the same population of starfish as cryptic ($F=47.54$, 3x8d.f., $p<0.01$; $F=20.84$, 3x8d.f., $p<0.01$; $F=3.47$, 3x8d.f., $p>0.05$). It should be possible to overcome such discrepancies by more riorous definition of the term cryptic.

A trip to John Brewer reef established that use of weighted plastic forms to investigate the transect width question was satisfactory.

Information from the literature and experienced workers indicate that permanent transects will contain starfish for a short period only (less than 6 weeks or perhaps up to 6 months) indicating the need to relocate transects during the study.

References

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Table 8 Budget for project 3(c): 1988/98

	Item	Cost ($) GBRMPA*	COTSAC
1.	Salaries:		
	Student stipend (Ms L. Fernandes)	4441	-
	Experimental Scientists** (3 x 20 days)	-	-
2.	Allowances:		
	Travel and field**	-	-
3.	Vessel Charter:		
	20 days R.V. Sirius**	-	-
4.	Maintenance:		
	Field equipment, stores etc.	1000	300
	TOTAL	**5441**	**300**

* Provided by GBRMPA Augmentative Grant

** Costs attributed to project 3(a)

PROJECT 3(D) FIELD AND LABORATORY INVESTIGATIONS OF THE LINE TRANSECT TECHNIQUE FOR MONITORING THE EFFECTS OF THE CROWN-OF-THORNS STARFISH

Chief Investigator(s) Dr G. Russ (Department of Marine Biology, James Cook University of North Queensland) and Mr C. Mundy (Student)

Introduction

Over the past decade the line transect technique has become a standard tool in the sampling of coral reef environments (DeVantier, et al., 1985; Reichelt et al., 1986). The application of the technique has been many and varied, however the objectives have generally been the same. Line transects are most often used to provide a means of identifying change in the benthic community at a permanent site through time, and a method for determining relative cover and abundance of members of the benthic community, over intermediate spatial scales (Benayahu and Loya, 1977).

For these objectives line transects are more cost and time efficient than quadrat techniques, and provide a more rigorous data set at finer resolution (species, genera, or life form) than is possible with the manta tow technique. For this reason line transects have been used in the present Crown-of-thorns Study to monitor permanent sites through time.

The line transect technique has been reviewed recently by an expert Methodologies Working Group, and a number of concerns were expressed with respect to the current application of the technique in the Study. These can be separated into two distinct but related classes; (1) concerns of an ecological nature, and (2) concerns of a methodological nature.

Ecological:

It was noted that no real measure of within reef variability of the benthic community on coral reefs was available. The view of many is that the benthic community is highly variable in both space and time. Nevertheless any given site on a reef might be considered to be isomorphic (homogeneous) at least in terms of spatial variability.

An assessment of the within-reef variability of the benthic community is required such that decisions concerning the number and size of sites can be made. In addition, this will provide an indication of the limits of extrapolation of the data to a reef as a whole. Such limits of extrapolation are of particular importance when a small number of sites are concerned.

Methodological:

Concerns of a methodological nature are primarily directed at the use of line transects to assess temporal variation. The Working Group concluded that the procedure used in the Crown-of-thorns Study, may be confounding small scale spatial variation of the benthic community with temporal change. The majority of survey techniques involve sampling biases, either observer related or design related. It was noted also that there was no existing measure of observer biases, or a measure of the repeatability for the line transect technique.

Research Objectives

This project will attempt to evaluate the line transect technique in the light of the above concerns. Five objectives are outlined below:

1. An assessment of the **micro-site variability** (scale of 10's to 100's of centimetres). Previously, any given site on a reef has been considered to be isomorphic, such that two transects running parallel across the slope and separated by up to 100 cm, would not be substantially different.

2. Assess the extent of **observer biases**, on the precision of the estimate of cover by the line transect technique. It is important to establish the repeatability of the technique, and whether variance due to observer biases are a significant component of any variability recorded in the data.

3. Assess the effect on the precision of the estimate of cover of a benthic life form, by **permanent marking of transects** at regular intervals along the transect. If results from Objective 1 suggest high micro-site variability exists, it would be important to establish if marking of transects at regular intervals can significantly reduce confounding of temporal change by small scale spatial variability.

4. Determine the appropriate field design (i.e. the **number of replicate** transects required, and their respective **locations**) at each site on the reef. When establishing a survey design with multiple sites, the number of replicate transects needed at each site can be estimated from the variance terms of the data from pilot studies. Replicate transects in a linear design may be sampling areas which are larger than the 'idealised' site, resulting in an over estimate of variance within that site.

5. An assessment of the **within-reef and within-site** variability of Davies Reef (scale of 100's of metres to kilometres). No measure of within-reef variability of members of the benthic community is presently available. Drawing from the results of objectives 1, 3, and 4, a large number of sites will be established on the front reef zone of Davies Reef. While this will not provide an absolute measure of the range of variability of sites, it will provide a clear understanding of the potential variability that can be expected.

Research Plan

Micro-site variability:

At three sites, five transects will be laid out parallel to the reef slope at 10 centimetre intervals. Data will be analysed using parametric procedures to assess differences in transects within and between sites, and if any correlation exists between transect similarity and distance between transects.

Observer biases:

Transects will be laid down and surveyed three times by each of three trained observers (N.B. The transect tape will not be moved until all 9 surveys are completed at a site). This will be repeated at three or four sites. If this is carried out over one or two days, temporal change can be assumed to be negligible, and differences found can be attributed to either, between-observer differences or within-observer differences.

Permanent marking of transects:

Surveys of permanently marked transects (i.e. marked at a number of points along the line) and transects marked at a single point will be repeated four times, at two or three sites. The tape will be laid out and rewound on each repeat survey. The variance recorded in the data from the two procedures will be analysed to determine if repeat surveys of permanently marked transects are less variable than repeat surveys of transects marked at a single point, and if this difference is significant.

Number of replicate transects:

By extending the data from objectives 1, 2, and 3, power analyses will be performed on the data set to estimate the number of replicate transects required at a site on the reef.

Within-reef variability:

Using the appropriate information from objectives 1, 2, 3, and 4, up to 12 sites will be established on the front slope of Davies Reef. Analysis of Variance techniques will be used to test for differences between all sites, and to produce an overall mean with a measure of variance. Subsets of the sites will then be randomly chosen containing between 2 and 6 sites, and analysed using the above analysis. Analyses of the collective results will then provide an indication of the reduced precision incurred when using fewer sites, and the number of sites beyond which any additional sites provide little improvement in the overall data set.

Project organisation:

This project is due to begin in April 1988 and will be completed by the middle of next year. Mr. Mundy (who is being employed within the Study as an Experimental Scientist) is being co-supervised by Dr R. Reichelt and Dr P. Moran (AIMS). Consultation and liaison will be sought with Professor Rhondda Jones (Department of Zoology) and Professor Howard Choat (Department of Marine biology) of James Cook University, and Dr D. Sinclair (Department of Statistics) of the University of Newcastle. It is planned to complete the majority of the field work before the end of July 1988 so that a preliminary report can be made available to members of COTSARC when they next meet in August of this year.

Resources needed:

Apart from funds to purchase a small amount of consumables all other resources required to undertake this project (e.g. shiptime, field equipment, personnel etc.) will be met from within project 3(a). A budget for this new project for the 1988/89 fiscal year is presented in Table 9.

References

Y. Benayahu and Y. Loya (1977) Space partitioning by stony corals, soft corals and benthic algae on the coral reef of the northern Gulf of Eilat (Red Sea) Helgolander wis. Meeresunters. 30: 362-382.

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R.E. Reichelt, Y. Loya, and R.H. Bradbury. (1986) Patterns in the use of space by benthic communities on two coral reefs of the Great Barrier Reef. Coral Reefs 5: 73-79.

Table 9 Budget for project 3(d): 1988/89

Item	Cost ($)	
	COTSAC	AIMS
1. Salaries:		
4 Experimental Scientists (x 12 days)	*	-
2. Allowances:		
Diving and travel (12 days @ $20/day) (for 4 personnel)	*	-
3. Shiptime:		
12 days R.V. Sirius (@ $600/day)	-	7200
4. Consumables:		
Stores issues (field equipment etc)	300	-
TOTAL	**300**	**7200**

* Costs attributed to project 3(a)

APPENDIX 1

Allocation of funds to ecological projects recommended by the Crown-of-Thorns Starfish Advisory Review Committee for the 1987/88 fiscal period.

Project No.	Chief Investigator(s)	Funds ($) Requested	Allocated	
6A	Lucas et al.	25,764	13,000	
6C	James et al.	5,183	5,183	
6D	Endean and Cameron	61,863	22,000	
6E	Doherty	46,403	38,000	
6G	Hanna et al.	29,959	16,000	
6H	Fisk	25,450	17,000	
6I	Choat	-	10,000	*
6J	James et al.	28,905	15,000	
-	AIMS program	499,660	427,277	
	TOTAL FOR 1987/88	**723,187**	**553,460**	

* Funds allocated from 1986/87 period