

**FINAL REPORT ON THE RESULTS
OF COTSAC MANAGEMENT
RELATED RESEARCH:
DECEMBER 1985 TO JUNE 1989**



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**Great Barrier Reef Marine Park Authority
Research Publication**

Reef

**FINAL REPORT ON THE RESULTS
OF COTSAC MANAGEMENT
RELATED RESEARCH:
DECEMBER 1985 TO JUNE 1989**

Brian Lassig



Great Barrier Reef Marine Park Authority

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CONTENTS

	Page
List of tables	ii
Abbreviations used in this report	ii
Introduction	1
Outline of projects and investigators	6
Geological Studies	8
Human Factors Affecting Crown-of-thorns Starfish	11
Non-biological Control	17
Biological Control	19
Socio-economic Research	20
Risk Analysis	21
Oral History	21
Surveys	22
Public Information	24
Miscellaneous Research	25
Results of Management-related Projects	26
Background	26
Geological Studies	26
Human Factors Affecting Crown-of-thorns Starfish	27
Non-biological Control	31
Biological Control	31
Socio-economic Research	32
Risk Analysis	33
Oral History	35
Surveys	35
Reports of COTSAC-funded Projects: Management-related Research	37
Appendix 1 Membership of the Crown of Thorns Starfish Advisory Committee (COTSAC) and the Crown of Thorns Starfish Advisory Review Committee (COTSARC)	44
Appendix 2 Summary of the report of the Crown of Thorns Starfish Advisory Committee	45
Appendix 3 Recommendations of the Crown of Thorns Starfish Advisory Committee	46
Appendix 4 Summary of findings and recommendations by Professor D.T. Anderson	48

LIST OF TABLES

		Page
Table 1.	Funds allocated to management-related and ecological projects since 1985 by the four main contributors to the COTSAC program.	5
Table 2.	Annual expenditure of COTSAC and GBRMPA funds for the management-related projects coordinated by the GBRMPA	7

ABBREVIATIONS USED IN THIS REPORT

AIMS	Australian Institute of Marine Science
COTS	crown-of-thorns starfish
COTSAC	Crown of Thorns Starfish Advisory Committee
COTSARC	Crown of Thorns Starfish Advisory Review Committee
COTSREC	Crown of Thorns Starfish Research Committee
GBR	Great Barrier Reef
GBRMP	Great Barrier Reef Marine Park
GBRMPA	Great Barrier Reef Marine Park Authority
JCU	James Cook University
UNE	University of New England
UQ	University of Queensland
USP	University of the South Pacific

INTRODUCTION

The crown-of-thorns starfish (*Acanthaster planci*), subject of intense scientific, public and political debate over the past 30 years, has attained a notoriety unprecedented among coral reef organisms. Despite more recent concerns over pollution and extensive development, it has been the most consistently controversial issue in the management of the Great Barrier Reef (Kenchington, 1987). Since 1962 when large numbers of the starfish were first recorded at Green Island off Cairns in North Queensland, two distinct waves of outbreaks have caused widespread damage to the Great Barrier Reef (GBR). The first recorded episode moved north and south from Green Island and, over the next 15 years, spread as far south as reefs off the Whitsunday Islands. Some isolated reefs in the Swain Group (off Gladstone) were also affected. After a two year gap in reported outbreaks, large numbers of starfish were again observed at Green Island in 1979. This episode has continued to the present.

During the most recent surveys off the Whitsunday Islands (April 1990) by the Australian Institute of Marine Science (AIMS), a large crown-of-thorns starfish (commonly abbreviated to COTS) population was recorded on one of 24 reefs surveyed in the area. Reconnaissance surveys by the AIMS since 1985 have indicated that up to 30% of reefs on the entire Great Barrier Reef have been affected to some extent by the starfish during the latest episode.

Concern over the fate of the GBR during the first recorded episode of COTS outbreaks (1962-1977) led to the formation of three review committees, convened to determine the degree of threat to the Reef and to recommend on required research. Two of these reviews (Walsh et al., 1971; 1975) were sponsored jointly by the Australian and Queensland Governments. The third ad hoc committee (Walsh et al., 1970) was convened by the Australian Academy of Science at the request of the Great Barrier Reef Committee.

Increasing concern over the second series of outbreaks of the crown-of-thorns starfish and damage to the Great Barrier Reef prompted the GBRMPA to establish another advisory body - the Crown of Thorns Committee. Members of this committee included Professor K. Back of James Cook University (Chairman), Dr J. Lucas (James Cook University), Mr G. Kelleher and Mr R. Kenchington (GBRMPA), Dr J. Bunt (AIMS), Mr R. Pearson (Queensland Fisheries), Professor J. Thomson and Dr R. Endean (University of Queensland). The Crown of Thorns Committee met twice in 1980 and recommended four major research directions before disbanding:

- * GBR-wide surveys of COTS and coral damage;
- * COTS population dynamics;
- * Reef sediment analysis for evidence of outbreaks over geological time;
- * Documentation of past human activity on the GBR.

Research in some of these areas was funded by the GBRMPA in the early 1980s, but because of commitments to zoning plans and lack of resources, a formal program of research was not instigated. The Crown of Thorns Committee was reconvened by the GBRMPA, with additional members representing a broad range of disciplines, in April 1984. Membership of this committee (The Crown of Thorns Starfish Advisory Committee, COTSAC) is given in Appendix 1. Terms of reference for the COTSAC were:

- * "To review the results of research into crown of thorns starfish and relevant aspects of coral ecology, with particular reference to research published or conducted since 1980."
- * "In the light of reports of the current incidence of crown of thorns starfish, and in the light of Great Barrier Reef Marine Park Authority reports and surveys, to advise on future research and monitoring directions with particular reference to cost and feasibility."

- * “To advise on possible research programs or projects relevant to management and/or understanding of the relationship between crown of thorns starfish and coral reefs.”
- * “To advise on a program for keeping the public informed on the crown of thorns starfish phenomenon and research and management actions which are being undertaken in relation to it.”

On considering available information from research conducted prior to 1984, the COTSAC noted that the current level of research activity was unlikely to lead to a short term (3-5 years) resolution of the questions raised by *A. planci* outbreaks on the Great Barrier Reef (COTSAC, 1985). To address this deficiency, the Committee identified a number of research initiatives which it believed should be implemented immediately. Research in the following areas was recommended:

1. risk analysis to contribute to assessment of the need for controls
2. monitoring the effectiveness of existing control techniques
3. feasibility of developing more efficient control techniques such as biological control by predators or pathogens
4. review of monitoring techniques for crown-of-thorns starfish and corals
5. surveys of selected reefs
6. oral history of human use and of experience of the Great Barrier Reef
7. surface and soft sediment cores to evaluate evidence of prior outbreaks
8. analysis of existing field data and modelling studies (leading to identification of priority research)
9. high priority research
10. testing of hypotheses regarding human factors which may trigger or exacerbate outbreaks
11. use of geological techniques of climate reconstruction to identify past periods when climatic conditions resembled those prevailing during recent outbreaks
12. economic and social consequences of outbreaks

The Committee recommended the research program be coordinated by the GBRMPA and supported by funding of approximately \$3 million over five years (see Appendix 2 and 3 for the COTSAC's summary and recommendations).

In July 1985 the Federal Government gave the GBRMPA \$971,000 for the first year of the program. This funding was distinguished from the normal GBRMPA appropriation and was termed COTSAC money. A Record of Understanding was established between the GBRMPA and the AIMS in which it was agreed the Authority would coordinate all projects related to management and policy development and the AIMS would be responsible for mainly ecological research. Funding was thus given to the AIMS by the GBRMPA under the terms of the Record of Understanding.

To advise on a program of research and review progress of the program, the GBRMPA established the Crown of Thorns Starfish Advisory Review Committee (COTSARC). Membership of this committee is given in Appendix 1. Terms of reference for the COTSARC were:

1. To review, at least annually, the results of research into crown-of-thorns starfish and relevant aspects of coral ecology with particular reference to research conducted in the research program as a result of the COTSAC recommendations (the COTS Research Program).
2. In the light of progress reported in “1” above and other relevant information and reports of current incidence of crown-of-thorns starfish, to advise and recommend on priorities for future research and monitoring in the COTS Research Program, including reference to cost and feasibility.

3. To advise on a program for keeping the public informed on the crown-of-thorns starfish phenomenon and research and management actions which are being undertaken in relation to it.

Following a COTSAC recommendation, advertisements for expressions of interest and research proposals were placed in the Australian press. Responses were reviewed and a research program recommended by the COTSARC. This research program was approved by the GBRMPA in February 1986.

The Federal Government allocated additional funds to the research program on an annual basis over subsequent years to the 1988/89 fiscal year, but at no stage committed funds beyond a one year period (Zann & Moran, 1988). Annual funding for the program from contributing sources is shown in Table 1.

A summary of the ecological research, coordinated by Dr Peter Moran of the Australian Institute of Marine Science, has already been published (Moran & Johnson, 1989).

This report is a companion to Moran and Johnson's report in providing an overview of the management-related projects which were coordinated by the GBRMPA from December 1985 to June 1989. Although the COTSAC had recommended appointment of a full-time coordinator for the program, the position was not formally filled because of restrictions in Australian Public Service staff levels. Coordination of the management-related projects was undertaken for most of the period on a full time basis, by Dr Leon Zann, Senior Project Manager with the GBRMPA.

Following criticism in the media of the GBRMPA's handling of the crown-of-thorns starfish issue in December 1988, the then Minister for the Arts, Sport, the Environment, Tourism and Territories, Senator the Honourable Graham Richardson, requested a review of the COTSAC research program. This review was undertaken by Professor D.T. Anderson, Challis Professor of Biology at the University of Sydney in early 1989 (refer Appendix 4 for summary of findings and recommendations). Terms of Reference for Professor Anderson's review were:

1. To review the Great Barrier Reef Marine Park Authority's present policy for managing the Marine Park in terms of the developing knowledge of the crown-of-thorns starfish and in particular the Authority's policy of limiting direct intervention to areas of special scientific and tourist interest. [The Authority's policy, adopted in 1985, states that "until more information is available, direct management intervention in the crown-of-thorns phenomenon should be limited to tactical control measures designed to protect corals at specific sites of importance for tourism or scientific research. The policy is based on the proposition that it would be irresponsible to interfere in natural processes on a large scale. If human activity could be shown to be responsible for causing or exacerbating outbreaks, the Authority would attempt broadscale control of outbreaks and to modify or stop responsible activities.]
2. To review the adequacy of the mechanisms for defining, reviewing and operating the crown-of-thorns starfish program.

The report concluded that the COTSAC research program had been defined, reviewed and operated in an efficient and productive manner and that the GBRMPA's policy for COTS control is soundly based, taking into account current knowledge of COTS populations on the Great Barrier Reef (Anderson, 1989). Professor Anderson recommended the program be continued for another 3-5 years at a dedicated and committed funding level of at least \$1million a year. He also recommended changes to the review committee to give that committee a more effective role in determining, in consultation with the GBRMPA, the pattern of expenditure of these funds.

Following a commitment by the Federal Government to provide additional funding for a further 2-3 years, the GBRMPA implemented Anderson's recommendations and established a new advisory committee under the chairmanship of Professor John Swan, the Crown of Thorns Starfish Research Committee (COTSREC). The COTSAC era had ended.

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Table 1

Funds allocated to management-related (M-R) and ecological (ECOL) projects since 1985 by the four main contributors to the COTSAC program.

AGENCY	FUNDING (\$A 000s)									
	1985/86		1986/87		1987/88		1988/89		TOTAL	
	M-R	ECOL	M-R	ECOL	M-R	ECOL	M-R	ECOL	M-R	ECOL
COTSAC	413	558	234	531	227	553	209	356	1,083	1,998
GBRMPA **	40	---	40	---	40	---	108	---	228	---
AIMS	---	259	---	497	---	534	---	526	---	1,816
MSTG	50	73	49	82	na	na	na	na	99	155
Total	503	890	323	1,110	267	1,087	317	882	1,410	3,969

COTSAC Crown of Thorns Starfish Advisory Committee, Great Barrier Reef Marine Park Authority
 GBRMPA Great Barrier Reef Marine Park Authority, Research & Monitoring Section funds
 AIMS Australian Institute of Marine Science
 MSTG Marine Science and Technologies Grants

** GBRMPA contributed the salary of the Acting Program Coordinator (1985-1989). The Authority also provided approximately \$66,000 for COTS research initiated prior to the COTSAC program. This funding is not included in this table.

na Information not available

[Table adapted from Zann and Moran, 1988]

OUTLINE OF PROJECTS AND INVESTIGATORS

This section provides details of all management-related projects coordinated by the GBRMPA and supported by COTSAC funds. Projects are grouped into the following subject areas, consistent with the COTSAC's recommendations:

- * Geological studies
- * Human factors affecting crown-of-thorns starfish
- * Non-biological control
- * Biological control
- * Socio-economic research
- * Risk analysis
- * Oral history
- * Surveys
- * Public information

Notes on Interpreting Project Outlines

Investigators' addresses shown are those during the study. Status of projects is as of the time of this report's preparation (April 1990). Expenditure is the dollar amount actually spent in the financial year (July to June). Unspent funds from projects' budgets were carried over into subsequent financial years. Because of this carry-over, COTSAC funds were, or are scheduled to be, spent in the 1989/90 financial year, even though the program concluded in June 1989.

GBRMPA procedures for funding research projects include the preparation of "Consultancy Agreements" or "Research Grants" which, among other conditions, stipulate reporting dates and report formats. For most projects, researchers are requested to submit brief "Progress Reports" during the course of their projects and a "Draft Final Report" at the completion of their research. This "Draft Final Report" is sent for external peer review and returned to the researcher for amendment in the light of reviewers' comments. The final, edited version is called the "Final Report" and its acceptance by the GBRMPA signifies the completion of the project.

In most cases, researchers were paid an "Advance" on commencement of their project, "Progress Payments" on submission of Progress and Draft Final Reports, and a "Final Payment" on acceptance of the Final Report by the Authority.

A number of the projects are continuing under funding through the new, post-COTSAC research program. This program is referred to as the COTSREC program after the Crown of Thorns Starfish Research Committee, the new advisory body to the Authority which replaced the COTSARC, following recommendations by Professor D.T. Anderson in his review of the COTSAC program.

As Table 2 shows, actual expenditure of COTSAC funds very closely reflects recommendations by the COTSARC.

Table 2

Annual expenditure of COTSAC and GBRMPA funds for the management-related projects coordinated by the GBRMPA

Project Areas	1985/86	1986/87	1987/88	1988/89	1989/90	Total	Recommended by COTSAC
Geological Studies	\$79,540	\$5,000	\$71,205	\$31,000	\$20,105	\$206,850	\$210,000
Human Factors	\$50,351	\$104,870	\$50,818	\$57,680	\$32,953	\$296,672	\$250,000
Non-biological Controls	\$7,228	\$59,259	\$6,415	\$2,800	\$675	\$76,377	nfs
Biological Controls	\$42,126	\$38,844	\$28,000	\$4,142	\$3,721	\$116,833	\$165,000
Socio-economics	\$25,000	\$14,800	\$1,760	\$2,000	---	\$43,560	\$50,000
Risk Analysis	\$25,000	\$8,000	---	---	---	\$33,000	\$35,000
Oral History	\$9,000	\$1,000	---	---	---	\$10,000	\$30,000
Surveys	\$19,900	\$6,500	\$5,000	\$14,848	\$3,500	\$49,748	nfs
Public Information	---	\$14,731	\$295	\$8,000	\$6,000	\$29,026	nfs
Miscellaneous	---	\$8,000	---	---	---	\$8,000	nfs
Administration*	\$87,482	\$61,930	\$90,166	\$88,048	---	\$327,626	\$425,000
Unallocated	\$18,173	---	---	---	\$92,608	\$110,781	
Management Total	\$363,800	\$322,934	\$253,659	\$208,518	\$159,562	\$1,308,473	\$1,165,000
Ecological Total	\$558,000	\$530,500	\$553,460	\$356,000	---	\$1,997,960	\$1,895,000
COTSAC Total	\$921,800	\$853,434	\$807,119	\$564,518	\$159,562	\$3,306,433	\$3,060,000

nfs Area of research recommended, but no funds specified.

* Administration included salaries of permanent and contracted cots research program staff, expenses incurred in COTSARC meetings and workshops, travel and incidentals. COTSARC had envisaged a full time coordinator with funds to run workshops and meetings (\$85,000 p.a. for 5 years) but this did not eventuate because of restrictions on Australian Public Service staffing levels at the time.

GEOLOGICAL STUDIES

Title	Role of <i>Acanthaster</i> in reef degradational processes: historical perspective and current influence.	
Investigator	Assoc. Prof. R.A. Henderson (James Cook University)	
Objectives	To determine whether: (1) contemporary <i>Acanthaster</i> infestations leave a skeletal record in surface sediment; (2) horizons of prehistoric sediments containing a similar skeletal record of <i>Acanthaster</i> can be recognised; (3) such skeletal aggregations are isochronous and testify reliably to prehistoric infestations.	
Status	Project completed.	
Expenditure	1985/86:	\$79,540
	1986/87:	\$5,000
	Total:	\$84,540

Title	Search for evidence within subsurface sediments of the occurrence of previous aggregations of crown-of-thorns starfish on Heron Reef, southern Great Barrier Reef.	
Investigators	Dr P. Flood (University of New England) and Dr E. Frankel (University of Technology, Sydney)	
Objectives	(1) To collect and examine subsurface sediments from vibracores for evidence of previous aggregations of crown-of-thorns starfish on Heron Reef; (2) To relate the findings on density of skeletal elements with the results of Henderson and Walbran's (1988) study of surface sediments on this reef.	
Status	Draft Final Report received 1 May 1989.	
Expenditure	1987/88:	\$20,000
	1989/90:	\$5,890
	Total:	\$25,890

Title	Search for evidence within surface and subsurface sediments for the occurrence of previous aggregations of crown-of-thorns starfish in the southern Great Barrier Reef Province. (Study 2: Capricorn and Pompey Reefs).	
Investigators	Dr P. Flood (University of New England) and Dr E. Frankel (University of Technology, Sydney).	
Objectives	<ol style="list-style-type: none"> (1) To collect and examine surface sediments for evidence of recent aggregations of crown-of-thorns starfish on selected Capricorn Reefs; (2) To collect, examine and date subsurface sediments by vibracoring at these sites; (3) To relate findings on density of skeletal elements with AIMS crown-of-thorns starfish database reports of recent outbreak histories; (4) To process existing surface sediment samples collected by Dr Frankel from reefs between Mackay and Capricorn reefs. 	
Status	Draft Final Report received 31 August 1989.	
Expenditure	1987/88:	\$9,000
	1989/90:	\$1,860
	Total:	\$10,860

Title	Distribution of crown-of-thorns starfish skeletal elements in surface sediment, Central and Southern Sectors of the Great Barrier Reef.	
Investigators	Assoc. Prof. R.A. Henderson (James Cook University) and Dr P.J. Moran (AIMS)	
Objectives	<ol style="list-style-type: none"> (1) To examine surface sediments of ten Central Section reefs for which recent AIMS surveys have accurately established crown-of-thorns starfish population densities; (2) To establish whether a relationship exists between contemporary crown-of-thorns starfish population densities and the distribution of skeletal elements. 	
Status	Draft Final Report due March 1990.	
Expenditure	1987/88:	\$19,000
	1989/90:	\$3,855
	Total:	\$22,855

Title Single element accelerator mass spectrometry of crown-of-thorns starfish skeletal remains obtained from subsurface sediment.

Investigator Assoc. Prof. R.A. Henderson (James Cook University)

Objectives (1) To resolve the stratigraphic uncertainty concerning the down-core distribution of *Acanthaster* elements in John Brewer and Green Island Reef sediment cores. This was to be done by selecting small populations of *Acanthaster* elements from small subsurface core intervals and to obtain dates by AMS techniques on individual elements to assess their age comparability.

Status Project completed.

Expenditure

1987/88:	\$23,205
1988/89:	\$1,000
Total:	\$24,205

Title Past and present distribution of crown-of-thorns starfish (*Acanthaster planci*) along the Great Barrier Reef. Study 3: northern Great Barrier Reef.

Investigators Dr. P. Flood (University of New England) and Dr E. Frankel (University of Technology, Sydney)

Objectives (1) To collect and examine subsurface sediments from vibracores for evidence of previous aggregations of COTS on several reefs to the north of Lizard Island, northern GBR.

Status Field work completed.

Expenditure

1988/89:	\$30,000
1989/90:	\$8,500
Total:	\$38,500

HUMAN FACTORS AFFECTING CROWN-OF-THORNS STARFISH

Title	Investigation of predation on <i>Acanthaster planci</i> by reef fishes: gut sample analyses and literature survey.	
Investigators	Prof. J.H. Choat and Mr R. Birdsey (James Cook University)	
Objectives	(1) To conduct a pilot study of the diet of carnivorous reef fishes, including commercially exploited lethrinids and serranids; (2) To provide a literature review of feeding habits of large carnivorous reef fishes.	
Status	Project completed.	
Expenditure	1986/87:	\$3,695
	1987/88:	\$2,707
	1988/89:	\$1,826
	Total:	\$8,228

Title	The consequences of commercial fishing on possible predators of the crown-of-thorns starfish on the Great Barrier Reef.	
Investigators	Prof. J.H. Choat and Mr A. Steven (James Cook University)	
Objectives	(1) To investigate the sources of reef fish catch return by species, time and region on the Great Barrier Reef; (2) To establish a database of such information and provide estimates on the catch rates of reef fishes.	
Status	Project completed.	
Expenditure	1986/87	\$5,000
	1989/90	\$2,500
	Total:	\$7,500

Title	The relationship between <i>Acanthaster</i> outbreaks and water mass characteristics in the Great Barrier Reef Region.	
Investigator	Dr D. van Claasen (GBRMPA)	
Objectives	(1) To produce a sequential study of the water mass characteristics of productivity as indicated by the distribution of chlorophyll "a", suspended sediment levels as indicated by water colour and circulation using remotely sensed Coastal Zone Colour Scanner (CZCS) imagery.	
Status	Five chlorophyll and five turbidity distribution maps produced and methodology described in Final Report. Initial analysis of maps in relation to <i>A. planci</i> outbreaks to be undertaken by Authority staff.	
Expenditure	1985/86:	\$28,045
	1986/87:	\$9,568
	1987/88:	\$7,268
	1988/89:	\$1,123
	1989/90:	\$3,032
	Total:	\$49,036

Title	Population dynamics of crown-of-thorns starfish on Suva Barrier Reef, Fiji.	
Investigators	Dr L.P. Zann (GBRMPA) and Mr J. Brodie (University of the South Pacific)	
Objectives	(1) To monitor growth, abundance and distribution of populations of juvenile and adult starfish on Suva Reef; (2) To monitor annual recruitment of COTS on Suva Reef.	
Status	Data to 1989 published, project continuing with COTSREC funds.	
Expenditure	1985/86:	\$4,806
	1986/87:	\$72
	1987/88:	\$366
	1988/89:	\$271
	1989/90:	\$2,670
	Total:	\$8,185

Title	Study of crown-of-thorns predators on or in the vicinity of reefs of the Great Barrier Reef.	
Investigators	Assoc. Prof. R. Endean, Dr A.M. Cameron and Dr H.I. McCallum (University of Queensland)	
Objectives	<ol style="list-style-type: none"> (1) To provide unequivocal scientific evidence on the identities of as many as possible of the specialist and generalist predators of <i>Acanthaster</i> found on or in the vicinity of reefs of the Great Barrier Reef; (2) To determine the population density of each of the identified major specialist predators and each of the major generalist predators; (3) To determine whether there are differences between reefs in the densities of these predators which can be related to the history of crown-of-thorns starfish activity and human use of the reefs. 	
Status	Project completed.	
Expenditure	1985/86:	\$13,000
	1986/87:	\$27,000
	1988/89:	\$8,000
	Total:	\$48,000

Title	Evidence of anthropogenic impact in the Green Island Region of the Great Barrier Reef.	
Investigator	Dr R.B. Johns (University of Melbourne)	
Objectives	<ol style="list-style-type: none"> (1) To attempt to identify anthropogenic inputs to the water column and to benthic sediments across selected transects; (2) To assess which, or whether or not, identified inputs can be associated with terrestrial sources; (3) To identify chlorinated hydrocarbon at the sampling stations. 	
Status	Draft Final Report received and reviewed.	
Expenditure	1986/87:	\$16,000
	Total:	\$16,000

Title	Anthropogenic influences on nearshore coral reefs, via mainland runoff, and correlations with spatial and temporal patterns in <i>Acanthaster planci</i> population explosions.	
Investigators	Assoc. Prof. D. Hopley and Ms C. Rasmussen (James Cook University)	
Objectives	(1) To ascertain the exact effect of enhanced phosphate levels on coral colony growth; (2) By way of a coring program commencing in the Cairns area, but then extending both north and south indicate how the geochemical changes may have changed through time, and thus identifying a possible change in anthropogenic influences, particularly over the last 100 years.	
Status	Project continuing; delays caused by problems with availability of chemical analysis equipment.	
Expenditure	1986/87:	\$28,900
	1987/88:	\$24,000
	1988/89:	\$22,790
	1989/90:	\$9,500
	Total:	\$85,190

Title	A land use study to investigate potential agricultural chemical inputs to marine environments in the northern Great Barrier Reef Region.	
Investigator	Mr P.S. Valentine (James Cook University)	
Objectives	(1) To provide a comprehensive account of existing land use patterns and present use of agricultural chemicals throughout the Barron River catchment.	
Status	Project completed.	
Expenditure	1986/87:	\$4,000
	1987/88:	\$1,600
	Total:	\$5,600

Title	Compilation of an information base and timetable for an interdisciplinary study of Green Island.	
Investigators	Prof. J.H. Choat and Mr I. Baxter (James Cook University)	
Objectives	<ol style="list-style-type: none"> (1) To review available information on Green Island from published studies, unpublished data and aerial and geological surveys; (2) To compile a bibliography of works relevant to the interdisciplinary study; (3) To compile a catalogue of maps and aerial photographs; (4) To produce a working map of Green Island for the planning of sampling programs and monitoring sites. 	
Status	Draft Final Report received and reviewed.	
Expenditure	1986/87:	\$1,000
	1989/90:	\$400
	Total:	\$1,400

Title	A multidisciplinary study of anthropogenic changes on Green Island: information base, ecology, systems, sedimentology, hydrology and reef growth.	
Investigators	Assoc. Prof. D. Hopley and Prof. J.H. Choat (James Cook University)	
Objectives	<ol style="list-style-type: none"> (1) To review previous published and unpublished information on Green Island; (2) To compile a bibliography of relevant literature; (3) To coordinate planning of interdisciplinary groups; (4) To survey sessile organisms and fish and establish a monitoring program; (5) To determine the thickness of sediments on expanding seagrass beds; (6) To determine the change in growth of corals; (7) To determine changes in the geochemistry of corals; (8) To determine the hydrology of the island. 	
Status	Draft Final Reports received and reviewed.	
Expenditure	1987/88:	\$14,000
	1989/90:	\$5,887
	Total:	\$19,887

Title Database of *A. planci* outbreaks in the South Pacific.

Investigator Dr L.P. Zann (GBRMPA)

Objectives

- (1) To identify any commonalities existing amongst widely separated geographic areas which have experienced crown-of-thorns starfish outbreaks;
- (2) To use this information to support or refute the "predator removal" and "terrestrial run-off" hypotheses.

Status Project continuing with COTSREC funds.

Expenditure

1985/86:	\$4,500
1986/87:	\$9,635
1987/88:	\$877
1988/89:	\$2,670
1989/90:	\$2,213
Total:	\$19,895

Title Recruitment and dynamics of *Acanthaster planci* on Green Island.

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

Objectives

- (1) To search for newly settled (0+ year) crown-of-thorns starfish in high and low hard coral cover areas, and in shallow (reef flat) and deeper (slope) habitats;
- (2) To monitor high coral cover areas for older (1+ year) individuals.

Status Project continuing with COTSREC funds.

Expenditure

1988/89:	\$11,000
1989/90:	\$3,751
Total:	\$14,751

Title Collaboration with Professor Yamaguchi in preparation for future crown-of-thorns starfish culturing work.

Investigator Mr J. Keesing (AIMS)

Objectives

- (1) To assess the feasibility of carrying out collaborative research into rearing and using juvenile *Acanthaster planci* in manipulative experiments.

Status Project continuing with COTSREC funds.

Expenditure

1988/89:	\$7,000
Total:	\$7,000

Title	The impact of the crown-of-thorns starfish <i>Acanthaster planci</i> (L.) on the community structure, demography and morphology of massive corals.	
Investigator	Mr L. DeVantier (AIMS)	
Objectives	(1) To obtain precise information on the effects of predation by <i>A. planci</i> on the population structures of approximately 100 species of massive coral.	
Status	Project continuing with COTSREC funds.	
Expenditure	1988/89:	\$3,000
	Total:	\$3,000

NON-BIOLOGICAL CONTROL

Title	A review of crown-of-thorns starfish control in Japan.	
Investigator	Ms L. Worland (Griffith University)	
Objectives	(1) To interview scientists and officials engaged in control programs in Japan; (2) To collect and translate reports, survey techniques and methods and assess their relevance to the Great Barrier Reef.	
Status	Project completed.	
Expenditure	1985/86:	\$842
	Total:	\$842

Title	Artificial barriers for crown-of-thorns starfish management.	
Investigators	Mr R. Bell & Mr B. Kettle (Marine Bio Logic)	
Objectives	(1) To determine the effectiveness of various materials and construction styles as physical barriers to the movement of juvenile and adult crown-of-thorns starfish; (2) To determine the effects of marine fouling on the effectiveness of these barriers.	
Status	Project completed.	
Expenditure	1986/87:	\$16,150
	Total:	\$16,150

Title	Evaluation of small-scale eradication of crown-of-thorns starfish using Armed Services volunteers: Grub Reef; John Brewer Reef; Holbourne Island Reef; Credlin Reef.	
Investigator	Dr L.P. Zann (GBRMPA)	
Objectives	<p>(A) GRUB REEF EXERCISE</p> <p>(1) To test the feasibility of using Service divers to control a relatively small, isolated infestation of starfish to maintain a high coral cover in the area;</p> <p>(2) To establish the detailed economic costing of the exercise to evaluate the cost/benefit;</p> <p>(3) To establish contingency plans for the eradication of starfish on reefs, and parts of reefs, of importance to tourism and science;</p> <p>(4) To re-evaluate various control methods, including the use of copper sulphate injection and spreading of quicklime.</p> <p>(B) JOHN BREWER REEF EXERCISE</p> <p>(1), (2) and (3) above;</p> <p>(4) To eradicate a pocket of starfish on the eastern reef crest.</p> <p>(C) HOLBOURNE ISLAND EXERCISE</p> <p>(1) To test the feasibility of controlling a starfish population at the whole-reef scale and (2) and (3) above.</p> <p>(D) CREDLIN REEF CONTROL</p> <p>(1) To eradicate starfish in a coral viewing area used by Roylen Cruises.</p>	
Status	Project completed.	
Expenditure	1985/86:	\$6,386
	1986/87:	\$43,109
	1987/88:	\$6,415
	1988/89:	\$2,800
	1989/90:	\$675
	Total:	\$59,385

BIOLOGICAL CONTROL

Title A preliminary investigation into factors affecting mortality of *A. planci* larvae raised under field and laboratory conditions.

Investigator Dr D. Sutton (James Cook University)

Objectives To determine:
(1) if planktonic larvae of *A. planci* develop the characteristic bacterial populations found on adult and juvenile starfish;
(2) whether marine bacteria are significant to the development and survival to settlement stage;
(3) if marine bacteria are pathogenic to *A. planci* larvae.

Status Project completed.

Expenditure

1987/88:	\$4,000
1988/89:	\$886
Total:	\$4,886

Title Identification of the bacterial populations associated with crown-of-thorns starfish and assessment of their role in the ecology of the starfish.

Investigator Dr D. Sutton (James Cook University)

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

Status Project completed.

Expenditure

1985/86:	\$18,737
1986/87:	\$20,000
Total:	\$38,737

Title	Studies on the diseases of the crown-of-thorns starfish <i>Acanthaster planci</i> .	
Investigators	Prof. R.S.F. Campbell and Dr J.S. Glazebrook (James Cook University)	
Objectives	(1) Obtain comprehensive data on the naturally occurring diseases of <i>A. planci</i> , including bacterial, viral, parasitic and other conditions (eg. starvation) which may occur clinically or subclinically.	
Status	Draft Final Report in preparation.	
Expenditure	1985/86:	\$23,389
	1986/87:	\$18,844
	1987/88:	\$24,000
	1988/89:	\$3,256
	1989/90:	\$3,721
	Total:	\$73,210

SOCIO-ECONOMIC RESEARCH

Title	An assessment of the impact of crown-of-thorns starfish outbreaks on commercial fisheries.	
Investigator	Mr P. Matthew (Fisherman)	
Objectives	(1) To describe from interviews the structure of the commercial reef fishery; (2) To establish fishermen's perceptions of changes in catches and fishing effort; (3) To relate any decreases in catch with known episodes of COTS outbreaks.	
Status	Project completed.	
Expenditure	1987/88:	\$1,760
	1988/89:	\$2,000
	Total:	\$3,760

Title	Socio-economic consequences of major populations of crown-of-thorns starfish.	
Investigator	Dr T. Hundloe (Griffith University)	
Objectives	(1) To ascertain the financial, employment and net economic effects on the users of the Great Barrier Reef of major populations of crown-of-thorns starfish; (2) To assess users' attitudes to crown-of-thorns starfish.	
Status	Draft Final Report received and reviewed.	
Expenditure	1985/86:	\$25,000
	1986/87:	\$14,800
	Total:	\$39,800

RISK ANALYSIS

Title	Biological and economic risk analysis, crown-of-thorns starfish.	
Investigators	Dr T. Hundloe and Dr J. Parslow (Griffith University)	
Objectives	(1) To undertake a risk analysis to contribute to assessment of the need for control of COTS.	
Status	Draft Final Report received and reviewed.	
Expenditure	1985/86:	\$25,000
	1986/87:	\$8,000
	Total:	\$33,000

ORAL HISTORY

Title	Oral history of human use and experience of crown-of-thorns on the Great Barrier Reef.	
Investigators	Dr A. Chase and Ms R. Ganter (Griffith University)	
Objectives	(1) To undertake an oral history study to determine what evidence there is for the occurrence of previous aggregations of COTS.	
Status	Project completed.	
Expenditure	1985/86:	\$9,000
	1986/87:	\$1,000
	Total:	\$10,000

SURVEYS

Title	Survey of crown-of-thorns starfish in Capricorn and Capricornia Sections.	
Investigators	Drs A.M. and A.L. Ayling (Sea Research)	
Objectives	(1) To survey selected reefs in the Capricorn and Capricornia Sections for COTS in conjunction with coral and coral trout surveys.	
Status	Project completed.	
Expenditure	1985/86:	\$15,000
	Total:	\$15,000

Title	A preliminary indication of the abundance and distribution patterns of <i>Acanthaster planci</i> on the Great Barrier Reef.	
Investigator	Dr A. Ayling (Sea Research)	
Objectives	(1) To compare data collected by manta tow with that collected from intensive search transect counts using SCUBA.	
Status	Draft Final Report in preparation.	
Expenditure	1986/87:	\$2,500
	1989/90:	\$500
	Total:	\$3,000

Title	A preliminary investigation of juvenile crown-of-thorns starfish, <i>Acanthaster planci</i> (L.) on reefs in the Central Section of the GBR.	
Investigator	Mr R. Bell (James Cook University)	
Objectives	(1) To survey Rib, John Brewer, Beaver Reefs and the Palm group reefs for juvenile <i>A. planci</i> ; (2) To study the population dynamics of juveniles on Rib Reef and Pelorus Island (pilot study).	
Status	Project completed.	
Expenditure	1985/86:	\$4,900
	Total:	\$4,900

Title Survey of distribution and abundance of crown-of-thorns starfish on reefs of the Whitsunday Region.

Investigators Mr R. van Woesik, Mr A. Steven (James Cook University) and Mr L. DeVantier (AIMS)

Objectives (1) To comprehensively survey fringing and offshore reefs for crown-of-thorns starfish and coral damage in the Whitsunday Region;
(2) To initiate local controls as necessary.

Status Project completed.

Expenditure 1988/89: \$8,986
Total: \$8,986

Title Use of near infra-red aerial photography for monitoring effects of *Acanthaster planci* outbreaks.

Investigators Assoc. Prof. D. Hopley and Ms P. Catt (James Cook University)

Objectives (1) To monitor changes to the shallow reef areas exposed on extreme low tides on reefs previously affected by *Acanthaster* (Helix, John Brewer and Grub Reefs); currently affected (Wheeler and Credlin Reefs) and with the potential for infestation by *Acanthaster* (Davies Reef, etc.).

Status Project continuing.

Expenditure 1986/87: \$4,000
1987/88: \$5,000
1988/89: \$5,862
1989/90: \$3,000
Total: \$17,862

PUBLIC INFORMATION

Title (1) Video Release: "The Crown of Thorns Story"
(2) Special Issue "Australian Science Magazine"

Investigator Dr L.P. Zann (GBRMPA)

Objectives (1) To produce a 25 minute educational video of the crown-of-thorns starfish phenomenon and the COTSAC Research Program for schools, tourists and others. Release June 1987;
(2) To produce a supplement issue of the Australian Science Magazine on the above for distribution to schools and others. Publication July 1987.

Status Projects completed; booklet to be updated in 1990/91.

Expenditure 1986/87: \$14,731
1987/88: \$295
Total: \$15,026

Title Interpretive crown-of-thorns starfish display for Wonderland Aquarium.

Investigators Dr L.P. Zann and other GBRMPA Staff

Objectives (1) To set up a public display of aspects of the crown-of-thorns starfish phenomenon.

Status Project completed

Expenditure 1988/89: \$8,000
Total: \$8,000

Title Interactive crown-of-thorns starfish display for Wonderland Aquarium.

Investigator Mr B. Kettle (Marine Bio Logic)

Objectives (1) To set up a computer-based interactive display of aspects of the crown-of-thorns starfish phenomenon, including research and management.

Status Draft program completed.

Expenditure 1989/90: \$6,000
Total: \$6,000

MISCELLANEOUS RESEARCH

Title	CORSPEX	
Investigator	Dr E. Wolanski (AIMS)	
Objectives	(1) To develop tracking technology and a model of behaviour of water movements around a coral reef.	
Status	Draft Final Report received and reviewed.	
Expenditure	1986/87:	\$8,000
	Total:	\$8,000

RESULTS OF MANAGEMENT-RELATED PROJECTS

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

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

Background

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

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

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

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

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

Results

GEOLOGICAL STUDIES

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

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

- (b) Radiocarbon dating of groups of COTS skeletal elements has confirmed that elements present in surface sediments generally represent the remains of contemporary *A. planici*.
- (c) The number of *A. planici* skeletal elements in ancient, subsurface sediment obtained from Green Island and John Brewer Reefs is comparable with numbers recovered from surface sediment at these localities.
- (d) Detailed stratigraphic interpretation of the *A. planici* record within subsurface cores is complicated by biogenic sediment recycling, primarily by callianassid shrimp. Although carbon dating of bulk sediment from cores shows an ordered age structure with depth, accelerator mass spectrometer ages for individual COTS skeletal elements show little relation to bulk dates.
- (e) Because of this bioturbation individual outbreaks or short-term cycles in COTS abundance cannot be identified, however, the density and distribution of subsurface elements suggest that large populations of *A. planici* are not a recent phenomenon, but have been an integral part of the GBR ecosystem for at least 7,000 years on John Brewer Reef and 3,000 years on Green Island Reef.
- (f) Analysis of surface and subsurface sediments from Capricorn-Bunker reefs (Heron, Fitzroy, Wreck, Wistari and Lady Musgrave Reefs) failed to find any COTS skeletal elements, suggesting these reefs have not supported large numbers of COTS in the past.
- (g) Surface and subsurface sediments collected from reefs off Innisfail contained COTS skeletal elements of similar densities to those recorded from Green Island Reef. The density of elements in subsurface samples from these reefs is consistent with a prolonged period of relatively high COTS population densities.
- (h) There was a decrease in the density of COTS skeletal fragments moving south from the Innisfail sector.
- (i) South of 20° there is no record of COTS skeletal elements in surface or subsurface sediments, suggesting a southern limit to large populations of COTS at this latitude.

HUMAN FACTORS POTENTIALLY CAUSING OUTBREAKS

(i) Predator Removal Hypothesis

- (a) The following predators on COTS were identified from field observations and feeding trials:
 - * *Charonia tritonis* (giant triton)
 - * *Thalassoma lunare* (moon wrasse)
 - * *Lethrinus nebulosus* (spangled emperor)
 - * *Chaetodon aureofasciatus* (butterflyfish)
 - * *Abudefduf* sp. [*?melas*] (damselfish)
 - * *Dischistodus perspicillatus* (damselfish)
- (b) Of 267 COTS examined at Holbourne Island (off Bowen) during an outbreak, 40% had missing or regenerating limbs. This sublethal damage was construed as an index of predation pressure.

- (c) A literature survey of carnivorous reef fishes of the families Serranidae, Labridae, Lutjanidae and Lethrinidae identified species of these families as potential predators on *A. planci*, although COTS were not specifically reported as a prey item.
- (d) *A. planci* fragments were found in the alimentary tract of a spangled emperor (*Lethrinus nebulosus*); one in a sample of 238 benthic invertebrate feeding fishes (including 30 *L. nebulosus*, 23 *L. chrysostomus* [red-throat emperor] and 5 *L. sebae* [red emperor]) collected from GBR reefs affected by COTS.
- (e) Although the predator was of a size capable of consuming a living adult starfish, it was unknown whether the prey had been consumed whole or as fragments ingested from bottom sediments.
- (f) Available data on fishing on the GBR is inconsistent and incomplete.
- (g) Because of these inadequacies, especially the lack of fishing effort statistics, it is not possible to gather any evidence to support or refute the hypothesis that over-fishing of COTS predators has been responsible for observed recent increases in starfish populations. [Major research projects investigating the “predator removal hypothesis” are being funded through the COTSREC program]
- (ii) Terrestrial Runoff Hypothesis**
 - (a) Lignin phenolic acids and triterpenoid alcohols are particularly strong markers of terrigenous input sources.
 - (b) Benthic sediment sampling across a transect from Cairns to Arlington Reef (approx 35km offshore) demonstrated that terrigenously derived organic material reaches mid-shelf reefs of the GBR.
 - (c) Taraxerol, a pentacyclic triterpenoid alcohol of exclusive higher plant origin was isolated and identified in sediments from Arlington Reef.
 - (d) There is some evidence for anthropogenically derived hydrocarbons, probably of petroliferous origin, near Cairns Harbour. They do not appear to extend to 20kms from the shore.
 - (e) Increased levels of phosphate in the water column are responsible for chemical and morphological alterations of the coral skeleton.
 - (f) Nutrients in the oceanic waters are being transported from terrigenous sources both in solution and adsorbed on to the sides of clay and iron oxyhydroxide particles.
 - (g) Increased levels of nutrients in the marine environment are closely related to land management practices on the nearby mainland.
 - (h) The distribution and deposition of anthropogenically-derived influences on coral reefs is more widely spread than previously anticipated.
 - (i) Non-anthropogenic influences such as El Nino Southern Oscillation events are also being recorded in the coral skeleton.
 - (j) During the year of this study (1986/87) a total of 2,056 tonnes of elemental nitrogen, 734 tonnes of phosphorus and 971 tonnes of potassium was applied to the Barron River catchment.

- (k) Major land uses contributing to fertiliser application were the following:
- Phosphorus - dairying, beef, maize, peanuts, tobacco and sugar
 - Nitrogen - dairying, maize, sugar and tobacco
 - Potassium - tobacco, sugar and potatoes
- (l) While agriculture chemicals (fertilizer) applied to farms above the Tinaroo Dam account for almost half of the total catchment application (farms below the dam accounted for the other half), the presence of the dam provides a potential short and long term storage for nutrients and an opportunity to accumulate very high quantities of some chemicals. These may subsequently be exported to the sea.
- (m) Historical data from annual ABS surveys show a dramatic increase in the use of fertilisers within the Atherton Shire (part of the Barron River catchment) beginning in the decade of the 1960s and peaking in 1974.
- (n) Controlled releases from the Tinaroo Dam (first filled in 1963) mean some water flows down the Barron River from the dam each year, but overflow conditions are irregular.
- (l) An estimated 10% (base value) of applied nutrients is exported from the catchment annually. The infrequent "pulses" caused by overflow of the dam might be highly significant in downstream marine receiving waters.

(iii) Green Island - A Case Study

Hydrology & Sedimentology

- (a) The currents around Green Island and surrounding reef are mainly forced by wind. Their velocity and direction are dependent on wind intensity and direction.
- (b) During north-east winds, the predominant currents spiral, in an anticlockwise direction, around the island onto the southern reef flat, creating an eddy effect in the lee of the island. This area is consequently an area of high retention.
- (c) During south-east winds, predominant currents flow to the north west. High retention areas are located in the lee of the island. Double vortices were recorded on the flooding tide.
- (d) There was a minimal treatment-response-discharge time for sewage. Dye released into the island's toilets was detected in the sea within one hour of release.
- (e) The reef flat and slope up to approximately 700m to the north of the sewage discharge point (located on the reef crest to the south west of the island) are usually exposed to the discharged sewage plume.
- (f) The major concentration of dye representing effluent consistently passed 50m from the end of the jetty at a bearing of 330 degrees. However, significant concentrations of dye are retained in the lee of the island for a period up to 18 hours.
- (g) Effluent escaping from holes in the discharge pipe has the potential for considerable impact on the reef environment and on reef users as compared to discharge from the outlet proper. Discharge waters from holes in the pipe are more likely to be retained in leeward eddies.
- (h) Bioturbation appears to make sediment coring an ineffective index of the suspected contemporary appearance of seagrass as the amount of bioturbation alters the stratification considerably.

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

- (i) The seagrass bed has a marked effect on the relative abundance of some species within the reef fish community. Large numbers of juvenile snapper, emperor, parrotfish, goatfish and rabbitfish were found around the base of bommies within the seagrass bed. Rare species of parrotfishes were also associated with the seagrass bed.
- (j) There was no difference in the total number of fish species recorded in seagrass and non-seagrass areas at Green Island. Furthermore, the presence of a seagrass bed did not appear to affect the distribution patterns of highly mobile schooling species (e.g. adult snapper) or more site attached species such as damselfishes.
- (k) Fish distributions did not appear to be strongly related to the sessile fauna on the bommies which they inhabit. The only exception to this was the density of parrotfish juveniles, which was found to be related to the abundance of rubble substratum.
- (l) Adult and juvenile snappers, parrotfish and goatfish were found to be absent at nearby Arlington Reef (no seagrass beds, no history of COTS outbreaks). However, no differences were found in the density of the six most common species of reef fish between Green Island and Arlington Reef study sites.
- (m) The Green Island seagrass bed is important for the recruitment of reef fishes, especially the commercially important snappers. Up to 40 juvenile snappers (mainly *Lethrinus nebulosus*) were found on bommies within the seagrass beds at Green Island while none were recorded in non-seagrass areas at Arlington Reef.

Juvenile COTS

- (n) Substrate searches (10 stations, 2 sites at each, and 4 replicate quadrats 0.5m x 0.5m at each site) and belt transect surveys (10 stations, 2 sites, 20m x 4m transects searching for feeding scars) located only two juveniles in 1989 - a 0+ and a 1+.
- (o) Most feeding scars found were caused by the corallivorous gastropod *Drupella*. *Drupella* were present in 12 of the 20 sites searched.

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

(iv) Pacific Reefs

Fiji

- (a) According to Fijian reef fishermen, COTS in the Suva area were low to moderate in abundance from the 1930s to the 1960s. A progressive build up occurred on some reefs in 1963-67 leading to a major outbreak episode from 1967-71.
- (b) A chronic phase between 1977-89 consisted of three intensive, macroscale recruitment events (1977, 1984 & 1987), and at least two localised but intensive recruitment events.
- (c) Outbreaks were the result of high juvenile recruitment.
- (d) Annual recruitment was very patchy in time and space. The macroscale recruitment events resulted in outbreaks over thousands of hectares, whereas the localised but intensive events resulted in small concentrated outbreaks over only tens of hectares.
- (e) Although growth rates within monitored cohorts were highly variable, mean growth rates of two cohorts (1984 & 1987) were similar.

- (f) Longevity of the 1977 cohort was 7-8 years; that of the 1984 cohort was 2-3 years. The latter was affected by two mass mortalities that have been attributed to a sporozoan pathogen.
- (g) Annual recruitment between 1975-89 had no overt relationship with rainfall events as proposed in the terrestrial runoff hypothesis.

Vanuatu

- (h) The distribution and abundance of COTS and the living and dead coral cover were investigated at 29 sites on 13 islands of Vanuatu, South Western Pacific, using spot dives, manta tows and belt transects in March/April 1988. About 31% of sites surveyed had been affected to varying degrees (active outbreaks: 10%; recently affected: 6%; probable past outbreaks: 14%). Reefs over a distance of 500km of the archipelago had been affected.
- (i) Reefs around the capital, Port Vila on Efate Island, were seriously affected by COTS outbreaks and despite small scale control programs in 1986, coral cover became insufficient in many tourist sites for coral viewing. Anecdotal reports indicate that the outbreak episode was probably the first in at least 20 years.
- (j) COTS outbreaks apparently began almost simultaneously in much of the group (almost 5° of latitude or 500km) around the same time (1985/86).
- (k) No direct correlation with human activities was evident. Rural islands are undeveloped, light to moderately populated, and fishing pressure is relatively light. The outbreaks are considered to result from a widespread and highly successful recruitment from a primary outbreak rather than from a series of virtually simultaneous, independent, widely scattered primary outbreaks along the archipelago.

NON-BIOLOGICAL CONTROL

- (a) Small, isolated COTS outbreaks may be successfully eradicated and limited areas (several hectares) of coral may be preserved during a major outbreak by a prolonged program of hand control.
- (b) Total costs of eradication programs (excluding labour) on the GBR, using the most efficient and effective technique available (injection of copper sulphate) were in the order of \$6 to \$17 per starfish. Inclusion of labour doubled the cost.
- (c) Control of COTS outbreaks on the macroscale (many reefs) is not possible using currently available methods.
- (d) Quicklime has limited potential for mass eradication. Large quantities are required, uniform dispersal would be extremely difficult, a large portion of starfish are hidden and would escape injury, and coral and some sessile benthos would be seriously affected.
- (e) Fences constructed with 12mm mesh, 1m in height with a 0.6m wide overturned top are effective barriers to starfish movement. These fences could be used to prevent reinfestation of cleared areas by migrating adult COTS, thereby avoiding the necessity of a sustained eradication operation.

BIOLOGICAL CONTROL

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

- (b) Diseases of COTS do occur in both wild populations and in aquarium-held specimens.
- (c) Symptoms of disease initially include declining activity of the starfish and subtle changes in physical characteristics. These initial symptoms are followed by necrosis and lesion formation, usually resulting in death within 1-2 days. Dead COTS in the field are decomposed or fragmented beyond recognition in 3-5 days.
- (d) Marine bacteria are involved in mortality of starfish. This has been demonstrated by recovery of severely affected starfish following treatment with antibiotics.
- (e) Bacteria associated with lesion formation and necrosis have not been shown to be able to initiate disease in healthy adult COTS.
- (f) A range of marine bacteria can act as facultative pathogens of adult COTS but none were identified as primary pathogens applicable to development as potential biological control agents.
- (g) Pig gastric mucin was found to be toxic to COTS, indicating that chemicals, probably less environmentally damaging than copper sulphate, can be found for small scale control of COTS populations.
- (h) Intracellular parasites resembling the vegetative (asexual) stage of sporozoans were found associated with pathological change primarily in the stomach and pyloric caecae of diseased COTS collected in Fiji.
- (i) Juvenile COTS showed changes ranging from increased transparency of the aboral disc to complete erosion of the cardiac and pyloric stomachs and eventual perforation. Adult COTS had deep ulcerative lesions covering more than 50% of the body and erosion of the central disc area which exposed the pyloric caecae, gonads and skeletal elements.
- (j) Four microscopic changes were recognised in the stomachs and pyloric caecae of diseased COTS, viz. oedema, inflammation, necrosis and fibrosis.
- (k) A mass mortality (>99%) which occurred amongst juveniles 8-23 months old on Suva Reef, Fiji, was attributed to the disease.
- (l) Of the 90 COTS examined from the GBR, 10% showed some sign of the disease, but pathological effects were minor compared to specimens from Fiji.

SOCIO-ECONOMIC RESEARCH

- (a) COTS outbreaks have not decreased overall visitation to the GBR in gross terms as visitation is currently increasing each year. At the current time, COTS do not appear to be a serious factor influencing decisions on whether or not to visit the Reef. However, reduced visitation may result in the future should the COTS seriously affect the coral sections (areas where coral can be viewed) of the GBR.
- (b) The financial value of the Reef region to tourism was derived as \$653,700,000 per annum (1987 figure). This included expenditure on travel to the region, travel within the region, accommodation, food and sightseeing trips to the coral sections of the Reef. Associated with this expenditure would be flow-on expenditure resulting from the multiplier effect.
- (c) Over and above this financial figure an economic value of the GBR exists as a result of it being a "public good". For visitors to coral sections of the Reef, this was estimated to have an economic value of \$105,623,627 per annum.

- (d) In net present value terms, the Reef region was valued, over and above current financial expenditure values, at more than one billion dollars.
- (e) In order to specifically evaluate the economic value of the coral sections of reef a contingent valuation approach, based upon a hypothetical entry fee to the coral sections of reef was conducted. This analysis derived a value of \$5,652,056 as the consumer surplus, or economic value of the coral sections of the reef. For vicarious users (persons not currently on a trip to the GBR, but gaining some benefit from either having the option in the future, knowing of its existence or knowing it will exist for future generations), the economic value of coral sections of the GBR was estimated at \$45,386,664 per annum.
- (f) The determination of these financial and economic values provided a baseline for analysing the economic effects of COTS on coral sections of the Reef. The contingent valuation approach was again implemented through the form of an additional entry fee to that contributed for the management of the Reef. In this situation a hypothetical trust fund was set up from which the entry fee contributions would be expended on the research and control of COTS. The aggregate consumer surplus for visitors to coral sections of the Reef and visitors intending to visit a coral section of reef was calculated as \$1,317,078 per annum. Vicarious users were willing to pay \$15,633,926 per annum to a trust fund that would research and control COTS.
- (g) The proportion of willingness to pay for the research and control of the starfish was considered to be considerable in comparison to the overall willingness to pay for the management of the reef (approx \$17 million for COTS research and \$68 million for total management; a ratio of about 25%).
- (h) No particular group of users indicated they had sustained a significantly stronger impact from COTS.
- (i) As a result of there currently being very little decision making effect on visitors to the region the financial impact sustained by the local economy was also considered not to be significant. However, in temporal terms, the financial and subsequent employment impacts with the regional economy may significantly increase if visitors' utility is diminished through increased damage by COTS.
- (j) The economic values accruing to vicarious users should be considered very carefully with respect to future impacts to the region. Should the GBR deteriorate through increased damage by COTS then the overall value of the Reef to Australia will decrease significantly through the loss of utility held by this group.
- (k) None of fourteen commercial GBR fishermen interviewed had seen COTS spines in fish stomach contents.
- (l) Many fishermen spoke of "dead reefs" and reefs that used to be good, but there is no evidence to suggest that this is due to COTS infestations. There is no evidence that COTS outbreaks have affected reef fishing.

RISK ANALYSIS

- (i) **Tourism**
 - (a) In 1985 an estimated 200 crewed charter boats operated in GBR waters. These vessels had a market value of over \$50 million and carried an estimated 1 million passengers.
 - (b) In 1985 the number of bare-boats was estimated at 85 (market value \$9 million), increasing to 130 (market value over \$10 million) in 1986.

- (c) By 1987 the total value of the fleet (crewed and bare-boats) probably increased to \$70 million, carrying 1.1 million passengers.
- (d) The regional spread of passenger numbers was:
- Central Area (Whitsunday Islands and adjacent outer reef, and waters adjacent to the ports of Mackay, Shute Harbour and Bowen) - 37%
 - Northern Area (outer reefs adjacent to Townsville and as far north as Mission Beach) - 29.5%
 - Far Northern Area (Green Island and adjacent reefs as well as those out from Port Douglas and Lizard Island) - 19.5%
 - Southern Area (Capricorn and Bunker Groups, the Keppel Isles, the Swain Reefs, as well as the inshore waters adjacent to the ports of Bundaberg, Gladstone and Rosslyn Bay) - 14%.
- (e) Activities of passengers were as follows:
- Sightseeing and [continental] island day trips (34%)
 - General reef trips (29%)
 - Ferry trips (26%)
 - Other (11%)
- (f) In 1987 there were in the order of 2,000 rooms/units in the island resorts (excluding Magnetic Island) with a guest capacity of approximately 5,000 persons. These were serviced by 2,500 - 3,000 employees.
- (ii) Fisheries
- (g) The total Reef Region commercial fleet was estimated at 1,075 boats in 1981, having a market value in that year of \$56.3 million. The otter trawl fleet comprised 485 vessels, valued at \$44.6 million. Operating these boats were 2,000 skippers and crew (including part-time fishers).
- (h) The conservative value of the commercial catch was estimated to have averaged at least \$27.8 million for each year from 1977/78 to 1979/80, in 1979/80 prices. In terms of volume, the Reef Region commercial catch of all species was estimated at 7,600 - 8,700 tonnes (live weight) of which the prawn catch was in the order of 4,500 - 5,000 tonnes.
- (i) For the entire Reef Region, the value of the capital invested was \$180 million (in 1986 values). The otter trawl component was approximately \$150 million. The value of the catch was approximately \$156.5 million (including \$127.5 million for the otter trawl catch).
- (iii) Economic Analysis
- (j) The consumers' surplus resulting from visits to coral sites by Reef region visitors was estimated to be \$5,650,000 per annum, or over \$8 per adult visitor. This is the annual sum of money visitors would be willing to pay over and above their fares and other costs incurred in seeing coral sites in their present condition. The value of coral sites to vicarious users was estimated at \$45 million per annum. The total economic value of coral sites was thus estimated to be over \$51 million per annum. (Other statistics presented in summary of Socio-economic Research).
- (k) Visitors to the reef expressed a willingness to pay an average of \$3.00 per visit to coral sites for the purpose of research and control of COTS, yielding a total of \$1.3 million per annum. The Australian Public (vicarious users) expressed a willingness to pay a total of \$15.6 million per annum for this purpose. The net present value for all coral

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

(iv) Controls and Rehabilitation

- (l)** Using the willingness of visitors and vicarious users to pay for COTS control, visitation rates, results and costs of attempted controls on the GBR (Zann & Weaver, 1988), it is concluded that local control programs at popular tourist sites are economic propositions. In the cases of Green Island, John Brewer Reef and Beaver Cay, funds collected from visitors would cover protection of limited coral-viewing areas by manual COTS controls.
- (m)** Estimates of costs to rehabilitate areas devastated by COTS range from \$25 to \$600 per square metre (depending on coral cover required, techniques employed and distance from coral sources). The cost of rehabilitation is much higher than COTS control.

ORAL HISTORY

- (a)** Australian reef users (especially trochus divers) expressed high awareness of COTS prior to 1960 with personal recollections dating back to the 1930s.
- (b)** Of the Australian indigenous groups, Eastern Torres Strait Islanders (from Murray, Darnley and Stephen Islands) were most familiar with COTS.
- (c)** COTS abundances often led trochus divers to abandon a reef because they made swimming and diving impossible. COTS injuries ranked below coral abrasions and eel-bites as work-related injuries.
- (d)** Eleven of the 92 respondents indicated major populations of COTS prior to 1960, with several describing outbreaks in the 1930s and 1940s.
- (e)** The (sometimes contradictory) evidence for the occurrence of previous aggregations of COTS is not sufficiently conclusive to rule out the possibility that outbreaks of the scale observed since the 1960s represent a recent phenomenon.

SURVEYS

- (i) Near Infra-red Aerial Photography**
 - (a)** Although mapping of reef flat ecology can be carried out by normal ground methods and true colour aerial photography can greatly aid in this mapping process, the differentiation of living corals and other organisms such as algae is greatly enhanced by using near infra-red aerial photography.
 - (b)** Testing of the methodology to date has indicated that it has a high potential for monitoring changes to reef top communities.
 - (c)** Evaluation of the effectiveness of images obtained from different flying heights suggests that a flying height of 3000 feet (914m) is optimal. Smaller scale images appear incapable of differentiating coral heads and signals from living coral and macroalgae are very similar. Larger scales provide enormous detail with even small coral heads less than 20cm in diameter being identifiable. However, cost effectiveness is reduced by the large number of photographs required to cover individual reefs or transects and associated digitising costs.
 - (d)** Greatest potential lies in the digitised imagery with a wide range of manipulative and quantitative procedures available. Indicative of the power of the method is the size of

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

(ii) Capricorn and Capricornia Sections

- (e) COTS abundances (using 50m x 20m transects) and coral cover (using 10m intersect transects) were estimated on 30 reefs in the Capricorn Section and on 11 reefs in the Capricornia Section of the GBRMP during December 1985 and January 1986. Ten reefs in the Swain Group (Capricorn Section) were surveyed previously in January 1984.
- (f) On Sanctuary Reef in the main body of the Swain Group there were moderate numbers of COTS on the back reef slope and in the shallow lagoon. Hard coral cover was locally reduced on the back reef slope and was less than 10% in one site.
- (g) There were small localised aggregations on three other reefs in the main body of the Swain Group: on the west tip of Horseshoe Reef, on the west face of Gannett Cay Reef, and on the north-west side of Recreation Reef. There were also small numbers (between 10 and 50) on seven other reefs in the Swain Group.
- (h) During the survey in January 1984 the small active aggregation was present on Gannett Cay Reef, but only 2 individuals were seen on the back reef slope at Sanctuary Reef (compared to 160 in 1985).
- (i) COTS were observed on 3 of 11 reefs surveyed in the Capricornia Section. Mean numbers were 4 per hectare on Fitzroy Reef and one per hectare on the other two reefs (Lamont and Llewellyn Reefs). Coral cover was high on reefs where no COTS were recorded (34% - 60%) and lowest (17.4%) at Fitzroy Reef.

(iii) Whitsunday Region

- (i) The distribution, abundance and impact of COTS were assessed on 29 fringing reefs and on 8 continental islands in the Whitsunday region in December 1988 and on 4 adjacent midshelf reefs in January 1989. When logistically feasible, COTS were eradicated by injection with saturated copper sulphate solution.
- (j) Aggregated populations were found on the following reefs:
 - * Hayman Island between Rescue and Tower Points (estimated over 1,000 COTS: 250 injected);
 - * Hook Island- Maureen's Cove (estimated 1,000 COTS: 112 injected)
 - Luncheon Bay (estimated COTS several hundred: 72 injected)
 - Pinnacle Point (estimated COTS several hundred: 29 injected)
 - Butterfly Bay (estimated COTS 1,000: 72 injected)
- (k) COTS were found on Langford Island reef and Bait Reef, mainly at depths ranging from 8-14m.
- (l) Scarring of hard corals consistent with recent COTS predation (or other corallivores) was found on White Bay reef (Haslewood Island), Catseye Bay reef (Hamilton Island), Mantaray Bay reef, Mackerel Bay reef and Saba Bay reef (Hook Island), Langford Island reef, Blue Pearl Bay reef (Hayman Island), Black Island reef, Lagoon Rocks reef (Whitsunday Island) and Hook reef.
- (m) No indication of coral predation was evident at Anchor Point, Cockatoo Point, Hook Passage (Hook Island), Whitsunday Island, Peter Bay reef, Chance Bay, reef at eastern end of Whitehaven Beach, Chalkie's Beach reef and Pallion Point reef (Haslewood Island), Driftwood Bay (Hamilton Island), Henning Island reef, Hardy Reef and Line Reef.

REPORTS OF COTSAC-FUNDED PROJECTS MANAGEMENT-RELATED RESEARCH

The following reports to GBRMPA and published papers were based on research supported, in whole or part, by COTSAC funds. GBRMPA procedures for funding research projects include the preparation of "Consultancy Agreements" or "Research Grants" which, among other conditions, stipulate reporting dates and report formats. For most projects, researchers are requested to submit brief "Progress Reports" during the course of their projects and a "Draft Final Report" at the completion of their research. This "Draft Final Report" is sent for external peer review and returned to the researcher for amendment in the light of reviewers' comments. The final, edited version is called the "Final Report" and its acceptance by the delegate of the GBRMPA signifies the completion of the project.

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**APPENDIX 1: MEMBERSHIP OF THE CROWN OF THORNS STARFISH
ADVISORY COMMITTEE (COTSAC) AND THE CROWN OF THORNS STARFISH
ADVISORY REVIEW COMMITTEE (COTSARC)**

COTSAC

Professor K.J.C. Back (Chairman)	
Dr C. Birkeland	University of Guam
Dr R. Bradbury	Australian Institute of Marine Science
Dr J.S. Bunt	Australian Institute of Marine Science (Director)
Professor R. Carter	James Cook University (Geology Department)
Dr R. Endean	University of Queensland (Zoology Department)
Dr B. Goldman	Lizard Island Research Station (Director)
Mr G. Kelleher	Great Barrier Reef Marine Park Authority (Chairman)
Dr J. Lucas	James Cook University (Zoology Department)
Mr R.G. Pearson	Queensland Department of Primary Industries
Dr P. Sale	Australian Coral Reef Society (Chairman)
Professor K.P. Stark	Great Barrier Reef Consultative Committee (Chairman)
Professor J.M. Thomson	University of Queensland (Zoology Department)
Mr R.A. Kenchington (Secretariat)	Great Barrier Reef Marine Park Authority

COTSARC

Professor J.M. Swan (Chairman)	
Dr J.T. Baker	Australian Institute of Marine Science (Director)
Dr C. Birkeland	University of Guam
Professor R. Carter	James Cook University (Geology Department)
Professor J.H. Choat	James Cook University (Marine Biology Department)
Dr R. Endean	University of Queensland (Zoology Department)
Mrs P. Hayles	Hayles Holdings Pty. Ltd.
Dr T. Hundloe	Griffith University (Australian Environmental Studies)
Dr R.A. Hynes	Queensland National Parks & Wildlife Service
Mr G. Kelleher	Great Barrier Reef Marine Park Authority (Chairman)
Dr J. Lucas	James Cook University (Zoology Department)
Mr R.G. Pearson	Queensland Department of Primary Industries
Senator M. Reynolds	Australian Government
Dr P. Sale	Australian Coral Reef Society (Chairman)
Professor K.P. Stark	Great Barrier Reef Consultative Committee (Chairman)
Professor M. Yamaguchi	University of the Ryukyus
Dr L. Zann (Secretariat)	Great Barrier Reef Marine Park Authority

APPENDIX 2: SUMMARY OF THE REPORT OF THE CROWN OF THORNS STARFISH ADVISORY COMMITTEE

- S.1 Since 1966 there has been public concern about the long-term risk to the Great Barrier Reef as a consequence of large populations of the crown-of-thorns starfish *Acanthaster planci*. The view of the committee is that the destruction of hard coral by aggregations of *A. planci* poses a serious threat to the organisation and functional relationships within some reef communities within the Great Barrier Reef, at least in the short term.
- S.2 Large numbers of crown-of-thorns starfish have been reported from many of the major reefs lying between Princess Charlotte Bay (latitude 14°S) and Townsville (latitude 19°30'S) since 1979. In addition, some reefs outside this region have also carried large numbers of *A. planci* since 1979. In the absence of detailed information on the condition of the hard coral cover of each affected reef there is a difference of opinion among Committee members about the actual extent of coral destruction that has occurred. Many of the reefs carrying major *A. planci* populations during the last five years are known to have carried large populations during the 1960s and early 1970s.
- S.3 Present evidence is inadequate for scientists to agree on the nature and significance of the phenomenon of aggregations of large numbers of crown-of-thorns starfish and thus on the extent of any consequent risk. However the Committee recognises that the presence of very large numbers of crown-of-thorns starfish is a major management problem in some areas of the Great Barrier Reef.
- S.4 The Great Barrier Reef has been included on the World Heritage List. In view of this, effective countering of any established threat to the integrity of the Great Barrier Reef should be regarded as a national priority.
- S.5 Until more information is available direct management intervention in the crown-of-thorns starfish phenomenon should continue to be limited to tactical control measures designed to protect corals at specific sites of importance for tourism or scientific research. The Committee supports the position and the actions taken by the Authority in this regard so far. The view was expressed by one Committee member that there was a need for more extensive measures. Nevertheless experience in Japan and the US Trust Territories is that attempted large scale eradication programs have limited value in controlling major populations. In the absence of a more efficient technique, control even on a local scale is often not achievable.
- S.6 The current level of research activity is unlikely to lead to a short term (3-5 years) resolution of the questions raised by the presence of very large populations of crown-of-thorns starfish on the Great Barrier Reef.
- S.7 The Committee recognises the need for further research and has identified a number of specific research areas which, if addressed now should help within 3-5 years to improve understanding of the degree of threat to the Great Barrier Reef. Nevertheless the committee stresses that such research cannot be guaranteed to answer questions relating to the desirability or feasibility of control measures.
- S.8 The Committee identified a number of research initiatives which should be taken immediately and considers that there is an urgent need for a coordinated program of crown-of-thorns starfish research in Australia. This is addressed in the Recommendations.

APPENDIX 3: RECOMMENDATIONS OF THE CROWN OF THORNS STARFISH ADVISORY COMMITTEE

- R1 The Committee recommends a risk analysis study be undertaken by the Authority to contribute to assessment of the need for control of crown-of-thorns starfish.
- R2 The Committee recommends that the Authority continue to monitor the effectiveness of current control techniques and notes that the Authority has budgeted approximately \$7,000 for this purpose in the 1984/85 financial year.
- R3 The Committee recommends assessment of the feasibility of developing more efficient techniques such as biological control by predators or pathogenic organisms (estimated cost \$55,000 per annum over three years).
- R4 The Committee recommends that a workshop be held to review techniques for monitoring crown-of-thorns starfish and coral condition (estimated cost approximately \$25,000).
- R5 The Committee recommends that the Authority continue its survey based upon general user reports and supervised surveys of a selected sample of reefs using the most appropriate available techniques. The Committee notes that the Authority has allocated approximately \$63,000 in its 1984/85 budget for such surveys.
- R6 The Committee recommends a study of oral history of human use and of experience of the Great Barrier Reef (estimated cost \$30,000).
- R7 The Committee recommends a study of surface sediments and soft sediment cores to evaluate evidence of prior major occurrences of crown-of-thorns starfish populations (estimated cost approximately \$70,000 per annum over three years).
- R8 The Committee recommends that priority be given to analysis of existing data and modelling studies (estimated cost approximately \$55,000 per year over four years).
- R9 The Committee recommends that research funding at an estimated cost of \$500,000 per year over 3 years, be allocated to support high priority projects, including any identified during the modelling studies.
- R10 The Committee recommends research, including modelling, to test hypotheses regarding human factors which may trigger or exacerbate population outbreaks of crown-of-thorns starfish (estimated cost \$250,000 over three years).
- R11 The Committee recommends an investigation to determine whether use of geological techniques of climate reconstruction can identify the frequency of occurrence of periods when factors including temperature and salinity resemble those prevailing at the outbreak of recent major crown-of-thorns starfish populations (estimated cost \$50,000 per annum over three years).
- R12 The Committee recommends research to evaluate the economic and social consequences of major populations of the crown-of-thorns starfish (estimated cost \$50,000 per annum for three years).
- R13 The Committee recommends that the Great Barrier Reef Marine Park Authority be recognised as the government agency responsible for reporting on and coordinating research and monitoring results on the crown-of-thorns in the Great Barrier Reef Region, with a responsibility to interact with funding agencies and research institutions to maximise efficiency in use of available funds and resources.

- R14 The Committee recommends that a senior scientist be appointed by the Great Barrier Reef Marine Park Authority on a five-year contract and supported with adequate funding (approximately \$85,000 per annum) to develop and coordinate a major program of research recommended in this report.
- R15 The Committee recommends that the Great Barrier Reef Marine Park Authority appoint an advisory committee to provide guidance to the research coordinator and advice to the Authority on development and coordination of research.
- R16 The Committee recommends that the various relevant research funding agencies be advised that crown-of-thorns starfish research is an area of national priority which should be taken into account in the funding of research.
- R17 The Committee recommends that the research questions identified by the Committee be publicised through the national and international scientific community.
- R18 The Committee recommends that specific research projects identified in this report and those defined in R8 and R9 be supported by allocation of an amount of approximately \$3 million over five years to the Great Barrier Reef Marine Park Authority to support a coordinated research program. This amount to be additional to funds available to crown-of-thorns starfish research through existing sources such as the Australian Research Grants Scheme, Marine Science and Technologies Grants and the program of the Australian Institute of Marine Science.
- R19 The Committee recommends that the Authority should continue its present information program and keep the public and the media informed on the situation regarding distribution and research relating to crown-of-thorns starfish.

APPENDIX 4. SUMMARY OF FINDINGS AND RECOMMENDATIONS BY PROFESSOR D.T. ANDERSON

1. The current management policy of the Great Barrier Reef Marine Park Authority for crown of thorns starfish control is soundly based and takes account of current knowledge of crown of thorns starfish populations on the Great Barrier Reef. The policy could be applied more extensively only if special funds were made available for this purpose.
2. The Great Barrier Reef Marine Park Authority has promoted appropriate research into crown of thorns management under the COTSAC research program and has fully evaluated the results of this research in relation to its current management policy. The causes of outbreaks of crown of thorns starfish are still unknown.
3. Ecological research and management-related research under the COTSAC program both support the view that local control techniques are available and could be effective, even though expensive, but large scale control or eradication is impracticable and unaffordable.
4. The COTSAC research program indicates that population fluctuations of the crown of thorns starfish have occurred in the past, but the scale of such fluctuations cannot be analysed in detail. The present phenomenon appears to have a long history.
5. The COTSAC research program has been defined, reviewed and operated in an efficient and productive manner, within the limits allowed by annual funding. A high degree of dedication is evident among the research workers and research managers involved in the program.
6. The provision of Federal funds for the COTSAC program on an annual basis has disadvantaged the program in various ways, primarily through the imposition of a need for rapid decision making and the corollary that the review committee for the program (COTSARC) has been unduly constrained by time considerations. Despite this, COTSARC has carried out its task as effectively as possible.
7. The COTSAC research program has led to significant advances in the understanding of the ecology of the crown of thorns starfish. As a result of this program, opportunities have now been created to investigate the broadscale ecology of the species in the Great Barrier Reef more deeply, and to better analyse its reproduction, dispersal, settlement and recruitment processes. Understanding of the causes and management of the crown of thorns starfish depends critically on the outcome of this research. Areas of future research should include:
 - * predation at all levels;
 - * population dynamics;
 - * effects of human activities, including agricultural run-off and fisheries; and
 - * biological control.
8. The research would benefit from an injection of supplementary research workers with suitable skills, especially in experimental biology. This could be obtained through 4-5 suitable post-doctoral appointments guaranteed for 3 years, and is critical to progress in the investigation of predation and population dynamics.
9. The crown of thorns starfish research program on the Great Barrier Reef should be continued for another 3-5 years at a dedicated and committed funding level of at least \$A1 million a year.

10. For the GBRMPA to run the program effectively, it needs the support of a review committee that could be active in determining the initial funding and annual renewal of all projects. Composition of the committee should include Professor Swan, 2 experts from GBRMPA, 2 experts from AIMS and 3 external (Australian-based) experts.
11. The review committee should meet at least 3 times each year, to review applications for funds, to receive and deliberate upon the reports of assessors on these applications, and to review progress of the program before the next round of applications.
12. In order to maintain a flow of information about the program to the wider community, Professor Swan should also be asked to chair a coordinating committee. This committee, meeting annually, could be informed about the progress of the program with a view to allowing input from other interest groups (e.g. tourism and state government). If comprised of 2 members of the scientific review committee and 4 members chosen from the Great Barrier Reef Consultative committee (GBRCC), the coordinating committee could report to the GBRCC annually on the research program.
13. A full time coordinator of the program should be appointed. This person would need to be ex officio a member of the scientific review committee and the coordinating committee. In anticipation of a continuation of a major part of the research program at AIMS, and the obvious need for coordination of this component within AIMS, the GBRMPA appointed coordinator would need to work closely with the responsible staff member(s) at AIMS.
14. The facilities and expertise of the Australian Institute of Marine Science are essential to the completion of the ecological research now required, but control of the program should remain with the Great Barrier Reef Marine Park Authority.
15. All projects funded under the cots research program should carry contractual obligations, including strict identification of the application of the funds within the project and an annual report of progress to the GBRMPA.

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