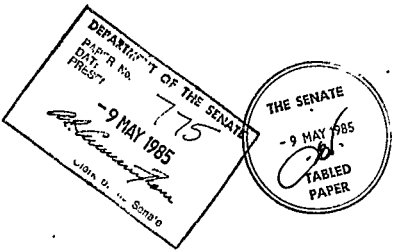

REPORT OF THE CROWN OF THORNS STARFISH ADVISORY COMMITTEE

11 January 1965

Errata Sheet

REPORT OF THE CROWN OF THORNS STARFISH ADVISORY COMMITTEE

11 January 1985

Report

P. 8 Chairman Professor K. J. C. Back
should read:
Chairman Professor K. J. C. Back A.O.

Australian Insitute of Marine Science
should read:
Australian Institute of Marine Science

P. 12 evaluation programs have.....
should read:
eradication programs have....

Attachment 2

P. 10 genetic heterogenety increases....
should read:
genetic heterogeneity increases..

Attachment 3

P. 1 quantitive survey techniques
should read:
quantitative survey techniques

REPORT OF THE CROWN OF THORNS STARFISH ADVISORY COMMITTEE

Table of Contents

Summary:

S1. 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.

S2. 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.

S3. 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.

S4. 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.

S5. 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.

S6. 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.

S7. 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.

S8. The Committee identified a number of research initiatives which should be taken immediately and considers that there is an urgent need for a co-ordinated program of crown of thorns starfish research in Australia. This is addressed in the Recommendations.

Recommendations

This section brings together the recommendations contained in the body of the report. The number of each recommendation is located in the right-hand margin. The section of the report where further supporting discussion is to be found and the page number is given in brackets.

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. R1(12)

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. R2(12)

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). R3(12)

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). R4(13)

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. R5(13)

The committee recommends a study of oral history of human use and of experience of the Great Barrier Reef (estimated cost $30,000). R6(14)

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). R7(14)

The committee recommends that priority be given to analysis of existing data and a modelling studies (estimated cost approximately $55,000 per year over four years). R8(14)

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. R9(15)

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). R10(15)

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 populations (estimated cost $50,000 per annum over three years). R11(15)

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).

R12(16)

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. R13(17)

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. R14(17)

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. R15(18)

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. R16(18)

The committee recommends that the research questions identified by the committee be publicised throughout the national and international scientific community (see Attachment 4). R17(18)

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. R18(18)

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. R19(19)

The indicative costs and a program of expenditure for the research program recommended by the committee are summarised in Table 1.

TABLE 1: Indicative costs and program of expenditure for research recommended by the committee

R.No.	Item	1984/85	1985/86	1986/87	1987/88	1988/89	Total
14	Coordinator and Support	20,000	106,000	106,000	106,000	87,000	425,000
1	Risk Analysis	35,000					35,000
4	Survey Workshop	25,000					25,000
8	Modelling Studies	15,000	55,000	55,000	55,000	40,000	220,000
3	Feasibility of biological control		55,000	55,000	55,000		165,000
6	Oral History		10,000	10,000	10,000		30,000
7	Surface Sediment Study	10,000	70,000	70,000	60,000		210,000
9	Priority Research		400,000	500,000	500,000	100,000	1,500,000
10	Hypothesis Testing		150,000	50,000	50,000		250,000
11	Geological Climatic Study		50,000	50,000	50,000		150,000
12	Socio-economic Study	10,000	40,000				50,000
	Annual Totals	115,000	936,000	896,000	886,000	227,000	3,060,000

OVERALL TOTAL $3,060,000

1. Background and Introduction

1.1 Earlier Committees

The current Committee is the fifth to have been convened since 1966 to consider the issues raised by the crown of thorns starfish. The Committees are listed in attachment 1. The earlier committees found that these issues are complex and that their resolution will require profound understanding of the organisation and functional relationships within the biological communities of the Great Barrier Reef. Each made recommendations regarding research requirements.

1.2 Between 1972 and 1975 the "Advisory Committee on Research into the Crown of Thorns Starfish" (the Walsh Committee) administered a research fund which supported 19 projects on crown of thorns starfish with total Commonwealth and Queensland government funding approaching $400,000. It concluded that there had been significant results from projects concerned specifically with A. planci and identified a number of desirable further studies:

- Investigation of the factors influencing cryptic behaviour of A. planci.
- Field observation and experimentation to investigate the movement, feeding and general behaviour of large populations of A. planci in all stages of growth. This field work should be supported by hydrographical monitoring.
- Further field observation and experimentation to identify predators of A. planci in Australian waters.
- More definitive information on both regrowth and resettlement of coral should continue to be obtained.
- Continued monitoring of population densities.

1.3 The Walsh Committee recommended that future research should be seen in the broad context of Great Barrier Reef ecological studies and that it should be financed from funds provided by the Australian Research Grants Committee, the Australian Institute of Marine Science and other similar bodies. The committee recommended that applicants compete for funds with others from all branches of science.

1.4 In 1980 the Great Barrier Reef Marine Park Authority (hereafter referred to as the Authority) convened an advisory committee on crown of thorns starfish, which met twice and recommended the following research program.

- Synoptic survey of A. planci and coral cover over the length of Great Barrier Reef.
- Repetition and extension of geological/sedimentological studies of previous crown of thorns populations.

- An historical study of previous outbreaks with particular emphasis on local accounts of major populations prior to 1960.

- Frequent and intensive field studies at Green Island Reef and Pixie Reef including trials of methods suggested for control of crown of thorns starfish.

1.5 The Current Committee

The current committee was convened in 1984 to review the situation in the light of developments subsequent to the report of the 1980 committee.

Members of the Committee were:

Chairman Professor K. J. C. Back
Vice Chancellor
James Cook University of North Queensland

Dr. Charles Birkeland
University of Guam, U.S.A.

Dr. R. Bradbury
Australian Institute of Marine Science

Dr. J. S. Bunt
Director
Australian Insititute of Marine Science

Professor R. Carter
Department of Geology
James Cook University of North Queensland

Dr. R. Endean
Reader, Department of Zoology
University of Queensland

Dr. B. Goldman
Director
Lizard Island Research Station

Mr. G. Kelleher
Chairman
Great Barrier Reef Marine Park Authority

Dr. J. S. Lucas
Senior Lecturer
Department of Zoology
James Cook University of North Queensland

Mr. R. G. Pearson
Director
Fisheries Research Branch
Department of Primary Industries
Queensland

Dr. P. Sale
Chairman
Australian Coral Reef Society

Professor K. P. Stark
Chairman
Great Barrier Reef Consultative Committee

Professor J. M. Thomson
Department of Zoology
University of Queensland

Secretary Mr. R. A. Kenchington
Great Barrier Reef Marine Park Authority

1.6 The committee met four times. Discussions covered all aspects of the situation raised by the presence of large populations of crown of thorns starfish in the Great Barrier Reef. Its terms of reference 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."

Each term of reference is dealt with below.

2. FIRST TERM OF REFERENCE

"TO REVIEW THE RESULTS OF RESEARCH INTO CROWN OF THORNS STARFISH AND RELEVANT ASPECTS OF CORAL REEF ECOLOGY, WITH PARTICULAR REFERENCE TO RESEARCH PUBLISHED OR CONDUCTED SINCE 1980."

2.1 The committee noted the reports of earlier committees and the recommendations by the Walsh Committee (1975) that future crown of thorns starfish research should be funded on the basis of applications which compete for funds with other branches of science.

2.2 The Committee noted that research conducted following the recommendations of the earlier committees has not resulted in resolution of the problem. Factors which contributed to this have been limited availability of research funds and skilled personnel, the nature of the research recommended and the major logistic problems of field research on the Great Barrier Reef.

2.3 The committee noted that research projects being conducted within the programs of universities and the Australian Institute of Marine Science addressed many issues which may have a bearing upon the relationship between the crown of thorns starfish and other components of reef communities; it concluded that the current level of research is unlikely to lead to a short term (3-5 years) resolution of the questions arising from presence of very large populations of crown of thorns starfish on the Great Barrier Reef.

2.4 A review of research published since 1980, prepared for the committee is given in attachment 2. One member of the Committee did not agree with the review. A list of current research projects relevant to crown of thorns starfish, of which the Committee is aware is listed in attachment 3.

2.5 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. The Committee does agree that on some affected reefs coral destruction has been marked. For example, in the best-documented case - Green Island Reef - over 90% of the hard coral tissue was consumed by A. planci between 1979 and 1981. 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.

3. SECOND TERM OF REFERENCE

"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".

3.1 In considering this term of reference the committee recognised that the ideal research objective would be an understanding sufficiently precise to allow the prediction of the occurrence and impact of the starfish and thus, if appropriate, to enable managers to modify the course of events.

3.2 Such an ideal may be unattainable in the foreseeable future. Its achievement could require a high level of understanding of virtually all aspects of reef ecology which is a long-term goal of fundamental research. Such research is in train with in the universities, the Great Barrier Reef island research stations and the long-term programs of AIMS*.

3.3 The committee identified research questions which would provide information to the Authority to assist it in the management of the crown of thorns starfish.

3.4 A number of specific research areas could effectively be addressed in 3-5 years programs to clarify issues relevant to management and public understanding of the phenomenon even though complete understanding may not be achievable in that time frame.

3.5 These areas are discussed below under headings:

1. Testing control measures
2. Extended monitoring
3. Earlier occurrences of large populations of crown of thorns starfish
4. Crown of thorns starfish and reef ecology
5. Testing hypotheses regarding the cause of crown of thorns starfish population outbreaks
6. Socioeconomic implications of the crown of thorns starfish.

3.6 Where provision is already made for measures recommended by the committee in the budgets of the Authority or another organisation, this is noted. Otherwise recommendations identify measures to be met from other funding sources.

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* At a late stage of the committee's deliberations the committee was informed of recent funding of some major research projects at the Australian Institute of Marine Science and James Cook University; however, details of these projects were not available before the committee's report was finalised.

3/7 Testing control measures:

3.7.1 The committee was advised that current Authority policy does not extend to large scale eradication of crown of thorns starfish but supports tactical or short-term control of crown of thorns starfish at locations where the need for control can be demonstrated, e.g. sites of importance for purposes of tourism or scientific research. Methods employed to date involve treatment of individual starfish by collection and removal or by injection with toxic chemicals. However, experience in Japan and the US Trust Territories is that attempted large scale evaluation programs have limited value for controlling major populations of starfish. In the absence of a more efficient technique, control even on a local scale is often not achievable. The committee noted comments of Professor Yamaguchi on the extensive Japanese programs to kill A. planci aggregations and his conclusion that the programs were ineffective.

3.7.2 The management relevant questions are:

- Is control of crown of thorns starfish on a regional scale justified?
- When is control of crown of thorns starfish on a local scale justified?
- What is the most effective means of controlling crown of thorns starfish on a local basis?
- Can more effective control measures be developed, particularly for large scale control if that is necessary?

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 (estimated cost $35,000). R1

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. R2

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). R3

3.8 Extended monitoring:

3.8.1 The committee noted that the size of the Great Barrier Reef was a major problem in assessing the threat imposed by an abundance of crown of thorns starfish, in planning management response and in understanding factors which may be significant in its distribution. This is due to serious logistic difficulties and to the high cost of surveying a valid sample of reefs in sufficient detail and frequency to detect changes with time.

3.8.2 The committee was advised that the Authority currently utilises a system of reef user reports backed by more precise and costly towed observer survey of a sample of reefs in order to monitor the distribution of major populations of crown of thorns starfish. These in turn are backed by detailed SCUBA searches along transect lines to obtain counts of starfish and more precise estimates of damage to coral communities. These techniques were developed in the 1970's to provide a balance between the conflicting objectives of precision on the one hand and covering a reasonable sample of reefs on the other.

3.8.3 The management relevant questions are:

- Can a more efficient and precise technique for monitoring crown of thorns starfish and reef condition be developed for systematic application in the Great Barrier Reef Region?

- What is the distribution of major populations of A. planci in respect of time and the geographic extent of the Great Barrier Reef?

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). R4

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. R5

3.9 Previous incidence of major crown of thorns populations

3.9.1 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.

3.9.2 Investigations should seek to establish whether major populations occurred prior to European settlement and, if they did, the time scales of previous episodes in order to indicate whether recent episodes represent an increase in frequency.

3.9.3 Authority funding has supported an initial study which has confirmed that crown of thorns skeletal elements can be readily distinguished from those of other related echinoderms.

3.9.4 The Authority has also supported an initial study of oral history of the Great Barrier Reef which suggests that this technique could produce valuable information on incidence of major populations of crown of thorns starfish and on human use and impact on the Great Barrier Reef.

3.9.5 The management relevant questions are:

What evidence is there for the occurrence of previous aggregations of crown of thorns starfish, both on an historic (200 years) and a geologic (15,000 years or more) time scale?

The committee recommends a study of oral history of human use and of experience of the Great Barrier Reef (estimated cost $30,000). R6

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). R7

3.10 Crown of thorns starfish and reef ecology

3.10.1 The present situation is that there is insufficient understanding of the relationships between crown of thorns starfish biology and the ecology of reef communities to enable scientists or managers to assess the consequences of particular crown of thorns starfish aggregations and to predict their development.

3.10.2 The committee developed an extensive list of questions which if answered should provide fundamental understanding of the crown of thorns starfish and its relationship to other components of reef ecology. The list which comprises more than twenty major research questions is at Attachment 4.

3.10.3 Each of these questions would require a major study costing from $50,000 to more than $250,000 annually over a three-year period. Given the high cost of these studies and the existing limitations of available research expertise it is recognised that resources cannot be made available to address each question simultaneously. There is no clear and objective means of assessing the relative priority of the various questions. Nevertheless it is clear that many aspects of existing research data have not been analysed and that such analysis and the development of a series of dynamic models based upon existing information would be of major value. These should assist in providing a basis for assessing the relative priority of individual research topics through their potential to improve descriptive and predictive capability.

3.10.4 The management relevant question is:

- Can models be developed to account for available field data on the Great Barrier Reef and to indicate short and medium term research projects which would provide information most critical to better modelling of the system?

The committee recommends that priority be given to analysis of existing data and a modelling studies (estimated cost approximately $55,000 per year over four years). R8

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. R9

3.11 Testing hypotheses regarding the cause of A. planci population outbreaks

3.11.1 An important issue in considering management of large populations of crown of thorns starfish is the possibility that they may be triggered or exacerbated by human activity.

3.11.2 This issue merits immediate support of quality research projects designed to develop and test hypotheses regarding the cause of major population outbreaks.

3.11.3 A management relevant question is:

- Is there evidence that outbreaks of A. planci have been *triggered or exacerbated by man?*

3.11.4 Several hypotheses have been advanced but not tested. These include collection of predators of adult or juvenile crown of thorns starfish and creation of environmental conditions, particularly temperature and salinity, which favour increased survival of starfish larvae.

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). R10

3.11.5 A management relevant question is:

- Is there a statistically significant relationship between A. planci outbreaks and environmental factors within and adjacent to the Great Barrier Reef Marine Park?

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 populations (estimated cost $50,000 per annum over three years). R11

3.12 Socioeconomic implications of the crown of thorns starfish

3.12.1 The Great Barrier Reef has been included on the World Heritage List. This clearly reflects that it has a very high intrinsic value which cannot be expressed simply in economic terms. Nevertheless the economic values of human uses are factors which can be measured and should be considered in managing the Great Barrier Reef.

3.12.2 There have been claims of economic costs as a consequence of the activity of large populations of crown of thorn starfish. There has been no assessment of socioeconomic costs and attitudes. Such an assessment is likely to be an important factor in decision making regarding management of the crown of thorns starfish. Initial assessment is likely to be achieved with economic studies being conducted by the Authority in the course of planning for Sections of the Great Barrier Reef Marine Park.

3.12.2 The management relevant questions are:

- What is the cost to the tourist industry resulting from the perception of potential tourists that the Great Barrier Reef is being seriously damaged?

- What is the cost to the Great Barrier Reef fishing industry of high levels of crown of thorns starfish populations?

- What is the cost to research programs attributable to the crown of thorns starfish?

The committee recommends research to evaluate the economic and social consequences of major populations of the crown of thorns starfish (estimated cost $50,000). R12

4. THIRD TERM OF REFERENCE

"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".

4.1 The committee concluded that for the purpose of management planning there is a need for the Authority to coordinate a major program of crown of thorns starfish research in Australia, but noted that there is a limited pool of expertise which can be called upon in establishing such a program. The committee noted that coordination of a program of research relevant to particular Authority needs would best be achieved by the appointment and financial support of a senior scientist operating with the guidance of an advisory committee appointed by the Authority for this specific task. The scientist and the advisory committee should report directly to the Authority and should liaise with research institutions in Australia and overseas.

4.2 The duties of the senior scientist should include

- ensure coordination, cooperation and collaboration between researchers and institutions conducting research on topics likely to be relevant to understanding and managing the crown of thorns starfish, including outbreaks or declines in populations of other species on the Great Barrier Reef;
- identify priority research needs and arrange for them to be met;
- establish and maintain close cooperation with crown of thorns research programs and projects overseas;
- in the third year of the proposed program arrange a conference of recognised international experts to review research progress and assess the situation regarding crown of thorns starfish on the Great Barrier Reef in the context of research and reports elsewhere in the Indo-Pacific Region.

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. R13

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 assistance and funding (approximately $85,000 per annum) to develop and coordinate a major program of research recommended in this report. R14

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. R15

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. R16

The committee recommends that the research questions identified by the committee be publicised throughout the national and international scientific community (see Attachment 4). R17

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. R18

5. FOURTH TERM OF REFERENCE

"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."

5.1 The committee, being composed largely of scientists, does not claim particular expertise in matters of general public information. Subject to that qualification the following conclusions were reached:

- The topic is clearly one of great interest to the public and the media. It is widely perceived as the most important issue in the Great Barrier Reef at present.

- The central issues are complex and unresolved. They are not easily treated in simplified or brief presentations, and over-simple models can be seriously misleading.

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. R19

ATTACHMENT 1

Committees of Inquiry into the Crown of Thorns Starfish

1. 1969/70 ad hoc committee of the Australian Academy of Science

   Report published:

   AUSTRALIAN Academy of Science. Acanthaster planci (Crown-of-thorns starfish) and the Great Barrier Reef. Report II. Canberra, AGPS, 1970: 20p.

2. 1971 Committee appointed by the Commonwealth and Queensland Governments on the Problem of the Crown-of-thorns starfish.

   Report published:

   WALSH, R.J., HARRIS, C.L., HARVEY, J.M., MAXWELL, W.G.H. THOMSON, J.M. & TRANTER, D.J. Rep. of the comm. appointed by the Comm. & Qld Govts on the problem of the Crown-of-thorns starfish (Acanthaster planci). Melb. CSIRO: Melbourne 45p.

3. 1971-75 Advisory Committee on research into the crown of thorns starfish.

   Report published:

   AUSTRALIAN Advisory Committee on Research into the Crown of thorns starfish. Report on Research sponsored by the Adv. Comm. on Res. into the Crown of thorns starfish. Canberra, AGPS, 1975: 39p.

4. 1980 Advisory committee on the crown of thorns starfish. Report to the Great Barrier Reef Marine Park Authority distributed on request.

5. 1984 Crown of thorns starfish advisory committee, the present committee

ATTACHMENT 2

A REVIEW OF RECENT RESEARCH AND LITERATURE ON ACANTHASTER PLANCI

In 1981, CSIRO published a book on the Ecology of Pests. Chapter 4 in this book was written by Don Potts about the "Crown-of-thorns starfish, man-induced pest or natural phenomenon?" This chapter constituted a thorough review of the literature on Acanthaster planci up to 1978.

The following is a review of subsequent research into the crown-of-thorns starfish and relevant aspects of coral reef ecology.

GENERAL BIOLOGY

Larval Biology

Substantive additions to the basic larval biology of Acanthaster planci have been published since 1978. Results from laboratory studies of particular relevance to our interests in factors regulating populations of A. planci were:

1. the determination of well-defined optimal levels and minimal or marginal levels of phytoplankton abundance for survivial, rapid development, and mean larval size of A. planci;

2. the finding that favourable conditions consist of not only adequate quantity of algae (concentration), but also quality (species composition) (Lucas, 1982).

The available data on phytoplankton concentrations in waters around the Great Barrier Reef indicate that they are generally too low or marginal for survivial and development of A. planci larvae. Lucas (1982) thus concluded that food availability must be a major factor determining survival of A. planci larvae in Great Barrier Reef waters.

The maximum filtration rates of larval A. planci were found to be in the late bipinnaria or early brachiolaria stages (Lucas 1982). The late bipinnaria stage is also the stage to which larvae can survive without food, although they normally start feeding in their early bipinnaria stage as soon as their alimentary canals are complete (Lucas 1982). Therefore, the late bipinnaria stage may be a crucial stage in the life-cycle, where food availability has a major influence on the success of the year-class.

Lucas et al. (1979) investigated the function of saponins found in eggs and larvae of A. planci. They found that planktivorous fishes detected and discriminated against saponins in gelatin particles at 2 to 4 orders of magnitude lower concentration than present in A. planci eggs or larvae. Therefore it seems likely that eggs and larvae are generally not eaten by planktivorous fishes. The potential of being preyed upon is probably chronic, producing a strong selection for saponins as an antipredatory material; but predation on eggs and larvae which possess saponins is probably not of major importance in determining the relative success of different year-classes.

Growth and Survival of Juveniles

Lucas (1984) found that juvenile A. planci underwent two phases of growth; a period of about 6 months of slow absolute growth while feeding on coralline algae and a later period of more rapid growth following a shift in diet to corals. These results corroborated those of Yamaguchi (1974). Lucas (1984) found that if A. planci juveniles did not have the appropriate corals available for the dietary transition, then the period of slow growth would be extended. Low temperature (about 20° C or lower) apparently decreased the growth rate and survival of juvenile A. planci. Therefore, even following conditions favorable for rapid growth and high survival rates of larvae, the ultimate abundance of adult starfish may still be strongly influenced by water temperature and by the distribution of A. planci recruits in relation to the availability of corals for their food (and by other factors such as predation).

Growth and Longevity of Adults

More than fifteen years ago, Chesher (1969) stated that Acanthaster planci has "an estimated life span of about 8 years". No data were given nor was any indication given of how this estimation was derived, but nevertheless extensive laboratory studies of Lucas (1984) confirm Chesher's estimation. Lucas found signs of senility, i.e., no further growth, even substantial shrinkage in body dimensions, and decreasing gonad size to the point of no further reproductive function, beginning in the fifth year and increasing through the eighth year. The fact that A. planci has a limited life span may be germane to the question as to why large populations sometimes disappear.

Cameron and Endean (1982) presented arguments for longevity in A. planci based on the complexity of the animal: spiny armature, venom, saponins, cetyl palmitate, etc. Kenchington's (1977) hypotheseis on the disappearance of A. planci a few years after their appearance depends on A. planci being short lived. The laboratory studies of Lucas (1984) support Kenchington's (1977) model in terms of the question of longevity.

Yamaguchi (1974) states that Acanthaster may not increase its size greatly after attaining its individual ultimate size as a mature animal (determinate growth). The data to support this view are still to be collected by monitoring the animal's growth in the laboratory.

Lucas (1984) reports that growth of A. planci in the laboratory is determinate.

Kenchington (1977), however, questioned determinate growth in A. planci by noting that all specimens 25 cm in diameter or larger are sexually mature, while some individuals reach over 60 cm in diameter. The 60 cm individuals must have continued growing long after reaching maturity.

Reproduction

Lucas (1984) found that A. planci began gametogenesis in the latter part of their second year, but gonad development was much greater in their third year. A. planci showed a definite seasonal pattern of gonad development and spawning in the laboratory where temperature was the only apparent environmental cue for this timing.

Conand (1983) measured reproductive output and morphometric parameters of A. planci populations from 50 locations around New Caledonia and the Loyalty Islands.

Feeding by Adults

As part of an excellent and extremely thorough review of perception of food by echinoderms, Sloan and Campbell (1982) described the role of dissolved mucoprotein from coral prey in stimulating feeding activities of an A. planci, a factor which might provide stimulus for other A. planci to approach and begin feeding in the same area, i.e., to form feeding aggregations. Jangoux (1982a) suggested that stomach eversion for feeding by A. planci is a chemosensorily induced reflex of the alimentary system because stomach eversion can be stimulated by adding food extracts or proteinaceous compounds to seawater surrounding the A. planci.

Lucas (1984) observed in his laboratory population that the appetite of A. planci has an intrinsic component which changed in both nature and intensity with age. At their "prime", Acanthaster planci fed more vigorously.

All aspects of feeding by Acanthaster planci were reviewed by Sloan (1980) and also by Jangoux (1982b).

r- or K- selection

In describing animals as "r-selected" and "K-selected" ecologists seek to distinguish between two different life-cycle strategies. "r-selected" animals show characteristics which increase their reproductive output. "K-selected" animals show characteristics which maintain population stability.

Moore (1978) and Cameron and Endean (1982) have debated whether A. planci is "r-selected" or "K-selected" (an "r-k-ic" topic [Vermeij 1978:170]). Terms such as "r-strategist", "opportunist", "stable", "cyclical", "ecological vacuum", "specialist", etc., are called "weasel words"* (yet another piece of ecological jargon) because the verbal definitions are pliable enough to allow a set of data to be used either as support or refutation of a model depending upon the wishes of the speaker. Unless the terms cited above are given operational definitions, both sides of the debate between Moore (1978) and Cameron and Endean (1982) are immune to refutation. Examples of operational definitions for "specialist" or "generalist" which provide an a priori avenue for statistical testing can be found in Birkeland and Neudecker (1981).

*This term probably comes from the ability of the researcher to "weasel-out" of any situation in which observations contradict his model.

Disease

In his laboratory population, Lucas (1984) observed a rapidly spreading necrosis which could be controlled by antibiotic treatments. Without treatment with antibiotics, the disease would kill A. planci within a few days. These findings may be germane to the question as to why dense aggregations of A. planci can disappear very quickly (Kenchington, Lucas and Smith, MS).

Physiology and Biochemistry

Recent physiological or biochemical studies involving Acanthaster planci have been presented by Yomo and Egawa (1978), Teshima et al. (1979), Komori et al. (1980), Mochizuki and Hori (1980), Sato and Ikekawa (1980), Yommo and Tokumoto (1981), Voogt (1982), Buznikov et al. (1982), Motokawa (1982), and Komori et al. (1983 a, b). These studies reflect the general scientific interest in A. planci that has been aroused by publicity. None of these studies has obvious application for understanding the ecology of A. planci.

Systematics

Blake (1979) moved Acanthaster planci (Family Acanthasteridae) from the Order Spinulosida (near Echinasteridae which includes Echinaster) to the Order Valvatida (near Oreasteridae which includes Culcita).

POPULATION DYNAMICS

Techniques

Studies of population dynamics of A. planci have been severely limited by failure to find a successful method for tagging the starfish. Glynn (1982c) presented a method for recognising individual starfish, based on arm and madreporite numbers and features of the aboral disc surface. This is useful for studying the behaviour and growth of A. planci in low density populations but is not suitable for high density populations because of the time required to identify each starfish.

Recruitment

Ebert (1983) wrote a thorough review of recruitmment of juveniles in echinoderms and concluded that, like A. planci, echinoderms in general vary greatly in recruitment success in both time and space. This highly variable recruitment seems typical of coral reef organisms as exemplified by molluscs (Frank 1969) and fishes (Doherty 1983). Of particular relevance to recent discussion of mechanisms of secondary infestations of A. planci,
Ebert (1983) reviewed variation in recruitmment of several species of echinoderms, including the starfish Asterias forbesi for which 25 consecutive years of data were available, and found no relation between abundance of adults and abundance of recruits. A relationship between adult density and percent fertilization is logical, but has not been demonstrated for any marine animal. It has also never been demonstrated that larval abundance is positively related to percent fertilization. If we could provide a measure of percent fertilization as a function of adult density, this would provide a quantitative aspect of the importance of aggregation in A. planci and would also deepen our understanding of secondary outbreaks.

Predation on Acanthaster planci

Glynn (1982a) published a study which presented evidence that the shrimp Hymenocera picta and the polychaete worm Pherecardia striata together kill enough A. planci to control the abundance of A. planci on reticulated pocilloporid reefs in Panama. This study is outstanding because it is the only quantitative study that indicates an influence of predators on A. planci abundance.

Causes of Primary Outbreaks*

Papers by Potts (1981) and Birkeland (1982) were in press at the same time. Both Potts and Birkeland favored terrestrial runoff as a cause of A. planci outbreaks, but Potts believed the aggregation model of Dana et al. (1972) was a more plausible mechanism because the larval survival hypothesis required the association of disturbance with the breeding season as well as a one of two year development lag. Birkeland (1982), however, argues that weather records provide evidence for the existence of the association of breeding season with the extra heavy rainfall prior to outbreaks and for three-year time lag. Potts (1981) emphasised survival of larvae because of favorable temperature and salinity conditions while Birkeland (1982) emphasised the importance of adequate food for larvae.

On the other hand, Potts (1981) pointed out that while the terrestrial runoff hypothesis evokes a natural process, it allows that the probability of outbreaks may be increased by human land-clearing activities for urban, industrial, agricultural or forestry development. While Birkeland (1982, 1983) recognised that this might happen in the future, he noted that there was no evidence of this having occurred to date. However, correspondence from M. Yamaguchi concerning the chronic A. planci situation in the Ryukyus at present does raise the question as to whether outbreaks might now be more frequent than they were in the past. (The chronic A. planci problem in the Ryukyus may actually be a result of secondary outbreaks rather than more frequent primary outbreaks.)

The past occurrence of outbreaks has been given further anecdotal documentation (Flanigan and Lamberts, 1981) and a comparative study of the importance of Acanthaster planci in the folk medicine and languages of high islanders in contrast to residents of atolls provides indirect evidence that A. planci has periodically been a problem around high islands but not around atolls (Birkeland, 1981).

Population Models

Antonelli and Kazarinoff (1984) have developed a model to describe the population fluctuations of Acanthaster planci and its coral prey. Antonelli and Kazarinoff took the viewpoint that predation of autotrophic coral polyps by A. planci is like the predation of plant communities by gregarious insects and may be similarly modelled. Because of

* Primary and Secondary Outbreaks. Some authors distinguish between primary outbreaks of A. planci, when there is an initial upsurge in population numbers due to exceptionally high survival rates of the developmental stages, and secondary outbreaks, which occur several years after the initial outbreak and which are seen as resulting from the high reproductive output of the primary outbreak producing intense recruitment in neighbouring reef areas.

the aggregation behaviour of A. planci (Ormond and Campbell, 1974) they included a quadratic co-operative term (i.e. an "autocatalytic" term) in the predation equation of the model. This quadratic co-operative term is very important in the model in that it makes possible the existence of stable limit cycles. Thus, according to this model, A. planci populations will show cycles of abundance resulting from their aggregation behaviour. Antonelli and Kazarinoff considered factors that affect the amplitude and orbital stability of the cycles. The model requires validation by testing against long-term data on A. planci and coral abundance, but, to date, there are no good sets of long-term population data.

We are aware of other biologists and mathematicians who are interested in modelling population variations of A. planci, viz Dr R. Bradbury (AIMS), Mr L. Marsh (James Cook University), Dr R. Moore (University of London) and Dr R. Ormond (University of York).

GREAT BARRIER REEF OUTBREAKS

A recurrence of abundant populations on the Great Barrier Reef in late 1979 and early 1980 was documented by Kenchington and Pearson (1982), Nash and Zell (1982), Endean (1982) and Cameron and Endean (1982).

Starfish populations

In 1980 there were large populations of crown of thorns starfish on reefs between about Lizard Island and Cairns (14.00°S and 17.00°S). The best documented and publicised of these was Green Island.

Since 1982 the occurrence of large populations of the starfish has been reported on reefs to 19°30'S which were previously reported to be free of significant numbers of the starfish. The best documented of these is John Brewer Reef which is also the site of a number of transects and sites being monitored by scientists for AIMS in a study of coral community development. Midshelf reefs between Cairns and Cooktown are now generally free from large populations of crown of thorns starfish.

Current reports indicate that many reefs between about 18°S and 19°30'S carry large starfish populations.

Ebert (1983) criticized the validity of the various conclusions of Laxton (1974) and Kenchington (1977) because of their sampling of various sites with single samples. Without continuity in sampling, a variety of interpretations of the data are equally plausible. Ebert's (1983) review clearly urges future studies to be directed towards following certain populations through time with replicate sampling.

LATITUDINAL VARIATION

The Great Barrier Reef covers a long enough latitudinal range that geographic variation in biology may come into effect. Ebert (1983) documented latitudinal variation in recruitment for particular species of echinoids and asteroids and postulated that latitudinal variation in growth rate, longevity, length of breeding season, and predictability of recruitment could provide alternative interpretations of Kenchington's (1977) data for A. planci.

However, results of electrophoresis studies by Nash (1983) in which Acanthaster planci populations over a 1200km range from Lizard Island to One Tree Island were examined indicated that A. planci on the Great Barrier Reef are members of one big panmictic population with a rather homogeneous genetic composition. An exception was one gene locus in a population at Green Island which was a remnant of a large concentrated population which had declined drastically.Natural selection may have been acting strongly during the phase of rapid population decline (Nash, 1983). It would be most interesting to continue electrophoresis studies to see if genetic heterogenety increases (natural selection relaxes) in expanding populations of A. planci, especially during outbreaks, and decreases (natural selection becomes more rigorous) when populations rapidly decrease in density.

GEOGRAPHICAL DISTRIBUTION

Piyakarnchana (1982) presented data on the distribution of A. planci in the Gulf of Thailand and suggested lack of food (corals) for adults and low salinity as limiting factors. He also speculated that the distribution of A. planci to some areas of the Gulf of Thailand may be prevented by current patterns.

Francis (1981) provided observations of A. planci in Tonga and Grosenbaugh (1981) provided observations on A. planci in Yap.

EFFECTS OF ACANTHASTER ON CORAL COMMUNITIES

This topic was reviewed by Menge (1982). Menge (1982) statistically analysed the data of Laxton (1974) and criticised Laxton's procedures.

DEFENCES AGAINST ACANTHASTER

The apparent co-evolution of several xanthid crabs and alpheid shrimps with pocilloporid corals has been treated in detail by Glynn (1980, 1982b). The latter reference is a thorough 68 page review of the subject. Symbiotic crabs and shrimp vigorously defend host pocilloporid corals against attack by A. planci, apparently in return for prolific production of high-quality mucus by the coral as food and

compact colony branching by the coral as shelter. Pocillorporids are highly favoured as food by A. planci in the absence of the crustacean symbionts.

CORAL REEF RECOVERY

Since the review of literature on the predator, A. planci, was written by Potts (1981), Pearson (1981) produced a review of literature on recovery of prey populations. Pearson's paper is a review itself, so it should be read directly; there is no point repeating it here. Suffice it to say that there was generally found to be a lag in recovery for several years as planulae settled and tiny remnant patches of colonies began to regenerate. During several years in this stage of recruitment of planulae, the number of small established colonies accumulated and the occupation of space by growth accelerated. After 10 years, a substantial amount of recovery had taken place in terms of coral cover of the substratum.

While Pearson (1981) was in press, Colgan (1981, 1982) was surveying the recovery of a coral population on Guam about 11 years after it was devastated (1% live coral cover) by an A. planci outbreak. His study was conducted in the same areas where Randall (1973a, b) surveyed the coral populations before and after the outbreak of 1968-1969. Colgan (1981, 1982) found that in terms of coral density, surface coverage, size class composition, and species richness, the coral population had nearly reached or exceeded the levels of these measurements of the population before the devastation by A. planci 11 years previous. Just as the coral population was reaching complete recovery in 1981, however, A. planci once again became abundant and started reversing the process of recovery. Colgan (1981, 1982) partitioned succession following the disturbance by A. planci into five stages: prevalence of filamentous algae, recruitment of coral planulae, growth form differentiation of corals, coral colony expansion, and competition between corals.

CONTROL PROGRAMS

A number of massive or expensive control programs have been undertaken in various places around the Pacific. All have killed many A. planci, but only one (at Miyake-jima) is considered to have been successful. In the Amami Island Group of the Ryukyu Islands (north of Okinawa), for example, a total of 1,999,768 Acanthaster planci were killed at a total cost of Y 227,120,000 (about A$1,000,000) or about Y 113 (A$0.50) each. In Sekisei Lagoon (Yaeyama Islands, south of Okinawa) 1,328,538 A. planci were killed at a cost of Y87,535,000 (about A$400,000) for 5,268 man-days effort over a 464 day period. (Dr Masashi Yamaguchi provided this information.) We do not have precise information for Ryukyu Islands near Okinawa, but the number killed and expenditure there must have been enormous. The total number of A. planci killed in the Ryukyu Islands in the past ten years was ca. 10 million (M. Yamaguchi, pers. comm.). After all that effort, which was to no avail in terms of overcoming the A. planci problem, an Acanthaster

workshop was held at the University of the Ryukyus. After a series of presentations of scientific papers, a general discussion of the problem was held. Yamaguchi concluded that efforts to kill aggregated A. planci were useless. Future efforts should be given more to intensive research into the true nature of the problem.

Perhaps the most successful Acanthaster planci eradication program was also the furthest from the equator (34°05'N), at Miyake-jima in the Izu Islands near Tokyo. A moderate outbreak began in late 1977 (Moyer, 1978) and was brought under control in late 1980. Jack Moyer, director of the Tatsuo Tanaka Memorial Biological Laboratory was appointed by the Tokyo Prefecture, the Miyake Island village government, and the Miyake Fishing Co-operative to co-ordinate a removal program. The Tokyo Prefecture and the Miyake governments provided funds and the fishing co-operative provided boats. Scuba divers were all volunteers. Professional fishermen were paid by the day, not by the catch. They had to report their catch every time and photographs were taken. No truly large specimens were observed, but many over 30cm in diameter were seen. The method of removal was to pull them from the water with steel hooks especially designed for the purpose. They were then allowed to die and rot on land. Some were used for fertilizer. The control program cost a total of Y1,000,000 equal to approximately A$4,000 at that time. About 3,500 A. planci were removed (i.e. it cost about A$1.00 per starfish) and the program was considered a success because the invasion ended.

Moyer (pers. comm.) was not certain that the removal program was solely responsible for the disappearance of A. planci. A decrease in water temperatures in the area over the past couple of years (possibly a result of El Nino) may have been also partially responsible.

Finally, Moyer (pers. comm.) noted that while the corals of Miyake-jima have been all but completely destroyed, as much as 80% of this loss probably results from predation by an outbreak of the gastropod Drupella rather than by the far less abundant asteroid Acanthaster.

In summary, efforts to control A. planci appear to have been successful in killing impressive numbers of A. planci, but usually unsuccessful in reducing the population to "normal levels". High density populations of A. planci eventually decline of their own accord and, during control programs, have simultaneously declined in nearby areas in which no control effort was made. Furthermore, it is questionable whether it is even feasible to effectively protect a small specified area (Kenchington and Pearson, 1982). "The inability of divers to exclude A. planci from an area as small as 1 hectare during peak infestation at Green Island reef suggests that such "physical" control on entire reefs would be impossible" (P. Tibbs, pers. comm., cited in Nash 1983:140).

A quantified assessment of three methods of control was provided by Kenchington and Pearson (1982). The Queensland Fisheries Service conducted test trials and found that 38 Acanthaster could be collected per hour by hand collection, 21 could be collected per hour by injecting Acanthaster with compressed air to float them to the surface, and 132 per hour could be killed by injection with $CuSO_4$. Such quantitative assessments are useful for making estimates of the costs of control programs being planned. It should however be noted that the long running control programs in Guam and the Trust Territory (Cheney, 1973) and Ponape, Eastern Caroline Islands (Wass, 1973) recorded less then 20 starfish per collector hour as usual. Program means in the Trust Territory ranged from 1.4 (Palau) to 5.2 (Truk) starfish per hour (Cheney, 1973).

The urgent need for controlling A. planci populations and the harm that will come to the coral reefs if A. planci is not controlled have been presented since Pott's (1981) review by Endean (1982, in press) and Cameron and Endean (1982).

OUTBREAKS OF OTHER SPECIES THAT HARM CORALS

Aggregates of the muricid gastropods Drupella fragum at Miyake-jima, Japan and Drupella rugosa at Mactan Island, Cebu, Philippines, were observed to result in widespread destruction of up to 35% of coral cover where Acropora was prevalent (Moyer et al, 1982). Acroporids and pocilloporids are the favoured prey of Drupella as is the case with Acanthaster. Moyer et al (1982) attributed these outbreaks of Drupella to terrestrial nutrient run-off by the same mechanism as is used to explain outbreaks of Acanthaster (Birkeland, 1982).

Terpios is an encrusting demosponge (Hadromerida: Suberitidae) which rapidly kills corals over large amounts of space (Bryan, 1973; Plucer-Rosario 1983) in American Samoa, Truk, Palau, Yap, Marianas (Guam, Rota, Aguijan, Saipan, and Pagan), Philippines (Cebu and Visayas), and Taiwan (Plucer-Rosario, 1983). Although it is less conspicuous, it may be more influential on coral communities than A. planci in the long-term (Plucer-Rosario, 1983; R.H. Randall, pers. comm.), because A. planci moves on after killing coral while Terpios keeps space occupied.

IN CONCLUSION

Forty-five publications relating to *Acanthaster planci* are identified in this review of post-Potts (1981) literature.

The break-down of these publications by topic is as follows

Topic	No. of publications
(a) Biochemical and related topics	10
(b) Theory of population fluctuations	7
(c) Asteroid or echinoderm reviews	7
(d) Coral mortality and recovery	5
(e) GBR outbreaks and occurrences	4
(f) Larval and adult biology	4
(g) Population studies	3
(h) Overseas locality outbreaks and occurrences	4
(i) Systematics	1
	45

Some comments on the above:

- Biochemical and Related Topics
  Almost a quarter of the papers are on biochemical and related topics reflecting the choice of *Acanthaster* as an interesting or topical subject.

- Theory of Population Fluctuations
  Debate over the causes of *Acanthaster* outbreaks continues between advocates of human interference causes (removal of predators of *Acanthaster*) (Cameron and Endean, 1982) versus advocates of natural causes (Birkeland, 1981, 1982, 1983;

Flanigan and Lamberts, 1981). Unlike other hypotheses, the climatic effects hypothesis of Birkeland is based on a statistical approach.

- Coral Mortality and Recovery
  Knowledge of long-term recovery of coral communities after the depredations of Acanthaster is substantially increased by several major publications (Colgan, 1981, 1982; Pearson, 1981).

- Larval and Adult Biology
  Few publications in this field (and three of these by Lucas), although there are many aspects still to be considered.

- Population Studies
  There has been a very substantial study by Glynn (1982a) on the dynamics of low density Panama populations. However, there are no new data on the dynamics of high density populations, although this is a glaring inadequacy in our knowledge of Acanthaster.

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CURRENT RESEARCH ON CROWN OF THORNS STARFISH

Project Title (date of completion)	Principal Researchers (institution)	Funding Source
1. History of incidence of crown of thorns on the Great Barrier Reef (Completed 1984)	B.J. Dalton (JCU) H. Reynolds (JCU)	GBRMPA
2. Metabolic studies of crown of thorns starfish (current)	K. Peckham (JCU)	Augmentative Grant - GBRMPA
3. An atlas of skeletal components of the crown of thorns starfish (completed 1984)	P.D. Walbran (JCU)	GBRMPA
4. Feasibility study localised crown of thorns control (current)	P. McGinnity (GBRMPA)	GBRMPA
5. Recolonisation of denuded reef areas (current)	V. Harriot (JCU)	GBRMPA
6. Monitoring crown of thorns (current)	P. McGinnity (GBRMPA)	GBRMPA
7. Surveys of crown of thorns and coral cover in Far Northern Section, Townsville, Whitsunday areas, Swain Reefs, Central Section (current)	A. Ayling (Sea Research)	GBRMPA
8. Temporal Variations in physiological parameters, genetics and the external symbionts of a high density *A planci* population.	J. Lucas (JCU) J. Shakle (CSIRO) J. Reichelt (JCU)	MS & T

CURRENT RESEARCH BEING UNDERTAKEN BY THE AUSTRALIAN INSTITUTE OF MARINE SCIENCE INTO CROWN OF THORNS STARFISH

Project Title (date of completion	Principal Research (Institution)	Funding Source
1 Population dynamics of the starfish.	P. Moran R. Reichelt	AIMS
i. Aquarium and field studies on adult starfish to develop a reliable field tagging method.	R. Bradbury	MST
ii Quantitative field surveys of the distribution and abundance of adults in the central Great Barrier Reef.		
iii Aquarium and field studies on the ecology of juveniles.		
iv Statistical reanalysis of the distribution of Acanthaster fragments in reef sediments.		
2. Dynamics of the coral community.	P. Moran T. Done R. Bradbury	AIMS
i Development of rapid, quantitive survey techniques	R. Reichelt (with LM Marsh of JCU)	Commonwealth Community Employment Program
ii Quantitative multi-species field surveys of the process of coral destruction and recolonisation on selected reefs in the Central GBR.		
iii Census of corals in permanent quadrats through time using field mapping and stereophotography.		
iv Discrete spatial simulation of the dynamics of recovery	(with DG Green of Australian National University).	
v Broad scale quantitative		

surveys of the extent of coral destruction and recovery on reefs of the central GBR.

3. Dynamics of prey-predator interaction.

i Theoretical modelling of the prey-predator interaction as a qualitatively stable cycle

R. Bradbury
R. Reichelt
P. Morgan

AIMS

(with LS Hammond of the Victorian Insititute of Marine Sciences).

ii Theoretical modelling of the effects of periodic forcing on the stability of the interaction.

(with PL Antonelli of University of Alberta).

iii Statistical analysis of the GBRMPA database on the phenomenon.

4. Ecosystem context.

i Quantitive field experiments on the secondary effects of the phenomenon on the reef fish community

R. Reichelt
R. Bradbury
W. Williams

AIMS

(with DR Robertson of the Smithsonian Tropical Research Institute).

ii Broad scale quantitive field surveys of the effects of the phenomenon on the fish community structure in the central GBR.

iii Theoretical predictive models of the whole ecosystem response using learning algorithms.

(with DG Green of Australian National University).

iv Policy studies of the ecological basis for rational management of the phenomenon.

RECENT GBRMPA RESEARCH RELATED TO CROWN OF THORNS STARFISH

Project Title (date of completion)	Principal Research (Institution)	Funding Source
Drift card study of Great Barrier Reef surface currents (December 1984)	John Collins (JCU)	GBRMPA
Flow Modelling in the Central Great Barrier Reef Region: a collaborative study (1986)	Dr. J.C. Andrews (AIMS) Dr. L. Bode (JCU)	AIMS JCU GBRMPA
Manta two survey analysis for Capricornia and Cairns Sections (Completed 1983)	Mr. J. Robertson (GBRMPA) Mr. M. Haywood (GBRMPA)	GBRMPA
Crown of thorns starfish clearance from Green Is. Reef (April 1981)	Mr. J. Hicks (QFS)	QFS GBRMPA
Boundary layer flows part patch reefs (June 1984)	Prof. P. Wilson (Sydney University)	GBRMPA
Planktonic despersal of larval corals (June 1984)	Mr. G. Bull (JCU)	GBRMPA
Analysis of visually dominant organisms data from manta tow coral surveys (November 1983)	Mr. G. Bull (JCU)	GBRMPA
Populations genetics of crown of thorns starfish (completed 1982)	W. Nash (JCU)	Augmentative Grant GBRMPA
Determinants of coral reef community structure: dynamics of communities dominated by the genus Acropora (December 1985)	Dr. C. Wallace Professor M. Pichon (JCU)	MST GBRMPA

Study for development and requirement of coral baseline and monitoring methodology (Marsh 1980)	Dr. T. Done (JCU)	GBRMPA
Manta tow survey of Capricorn-Bunker Reefs (August 1980)	Mr. L. Zell (GBRMPA)	GBRMPA
Manta tow survey of benthos and crown of thorns at reefs in the proposed Cairns Section of the Great Barrier Reef Marine Park. (August 1982)	Mr. W. Nash (GBRMPA)	GBRMPA
Circulation and sediment in platform well lagoons using One Tree Reef as an example (December 1979)	Ms. C. Luddington (Sydney University)	GBRMPA
Visual censusing of coral trout in the Cairns Section (June 1983)	Dr. A. Ayling	GBRMPA

Research questions identified by the Committee:

Larvae of crown of thorns starfish

- What is the relationship between physical conditions, food availability and larval survival?
- Where and when are favourable conditions likely to occur?
- What is the relationship between nutrient levels and production of food for larvae?
- How long do eggs and larvae stay in the water column in the field?
- Do larvae actively select water depths?
- To what extent do larvae 'ride' eddies and return to their natal reefs as opposed to being carried to more distant reefs?
- What role do predators play in determining population levels?
- What is the relationship between the numbers of larvae released into the plankton and the numbers that settle on a reef?
- Do they settle in huge numbers in small areas, if so, where and when?

Juvenile crown of thorns starfish

- Where do they normally occur?
- Can dense aggregations be located on a reef?
- What are their predators?
- What is their behaviour, especially concerning mobility and ability to aggregate?
- Is their field growth similar to that recorded in the laboratory?
- Are they subject to mortality other than from predators? e.g. through lack of food, disease etc.

Adult crown of thorns starfish

- What is the age structure of field populations?
- Do they migrate between reefs?
- Is growth in the field similar to that in the laboratories?
- Do they lose condition under crowding/feeding stress?
- What pathogens affect them under what conditions?
- Is there any decline in fertility (as opposed to fecundity) in large (old?) adults?
- What role do predators play in determining population levels?
- Why do some reefs remain free of large populations of crown of thorns starfish when nearby reefs carry them?

A. planci/reef community interactions:

- What are the probabilities of a destructive aggregation of A. planci observed in one location on a reef spreading throughout that entire reef, remaining to cause localised coral mortality, or disappearing with relatively little impact?
- What are the mechanisms governing the behaviour of such aggregations?

At the local, single reef and the large scale of the Great Barrier Reef:

- What are the short term (less than 3 years) effects of A. planci on hard coral cover?
- What are the short term (less than 3 years) effects of A. planci on the total reef community (e.g. fishes and other organisms)
- What are the long term effects of single or repeated episodes of A. planci on the total reef community?
- Is the nature of community development after A. planci intrinsically different to that following cyclone, flood or other forms of extensive coral mortality?

THE SENATE

ROLL 9-5-85

SENATORS—

1. [redacted]
2. [redacted]
3. [redacted]
4. BJELKE-PETERSEN
5. [redacted]
6. [redacted]
7. [redacted]
8. [redacted]
9. BUTTON
10. CARRICK, Sir John
11. [redacted]
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15. COLEMAN
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THE SENATE

ROLL 9-5-85.

SENATORS—

1. [illegible]
2. AULICH
3. [illegible]
4. BJELKE-PETERSEN
5. [illegible]
6. DOLIUS
7. [illegible]
8. [illegible]
9. BUTTON
10. CARRICK, Sir John
11. [illegible]
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14. COATES
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THE SENATE

ROLL 9-5-85

SENATORS—

1. ARCHER
2. AULICH
3. BAUME, Peter
4. BJELKE-PETERSEN
5. BLACK
6. BOLKUS
7. BOSWELL
8. BROWNHILL
9. BUTTON
10. CARRICK, Sir John
11. CHANEY
12. CHILDS
13. CHIPP
14. COATES
15. COLEMAN (Leave)
16. COLLARD
17. COLSTON
18. COOK
19. COONEY
20. CRICHTON-BROWNE
21. CROWLEY
22. DEVLIN
23. DURACK
24. ELSTOB
25. EVANS, Gareth
26. EVANS, Jack
27. FOREMAN
28. GEORGES
29. GIETZELT
30. GILES
31. GRIMES
32. GUILFOYLE, Dame Margaret
33. HAINES
34. HAINES
35. HARRADINE
36. HEARN
37. IRWIN
38. JESSOP
39. JONES
40. KINGARIFF
41. KNOWLES
42. LAJOVIC
43. LEWIS
44. McCLELLAND
45. McGIBBON
46. McINTOSH
47. McKIERNAN
48. McKLIN
49. MAGUIRE
50. MASON
51. MESSNER
52. MILLEN
53. PARER
54. PRIMMER
55. PUPLICK
56. RAE, Peter
57. RAY, Robert
58. REID
59. REYNOLDS
60. RICHARDSON
61. ROBERTSON
62. RYAN
63. SCOTT
64. SHEIL
65. SHORT
66. SIBRAA
67. TATE
68. TEAGUE
69. TOMLEY
70. VANSTONE
71. VIGOR
72. WALSH
73. WALTERS
74. WATSON
75. WITHERS
76. ZAKHAROV

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SENATE

(1)

198 5

9th day of May

Question, First Home Owners Amendment Bill 1985 Second Reading Amendment proposed by Senator Lewis that the words proposed to be added be added. — Senate / ~~Committee~~

NOES

SENATORS—

1. ARCHER
2. ~~AULICH~~
3. BAUME, Peter
4. BJELKE-PETERSEN
5. ~~BLACK~~
6. ~~BOLKUS~~
7. BOSWELL
8. BROWNHILL
9. BUTTON
10. CARRICK, Sir John
11. CHANEY
12. ~~CHILDS~~
13. CHIPP
14. ~~COATES~~
15. COLEMAN
16. COLLARD
17. ~~COLSTON~~
18. ~~COOK~~
19. ~~COONEY~~
20. CRICHTON-BROWNE
21. ~~CROWLEY~~
22. ~~DEVLIN~~
23. DURACK
24. ~~ELSTOB~~
25. ~~EVANS, Gareth~~
26. EVANS, Jack
27. ~~FOREMAN~~
28. GEORGES
29. GIETZELT
30. ~~GILES~~
31. ~~GRIMES~~
32. GUILFOYLE, Dame Margaret
33. HAINES
34. HAMER
35. HARRADINE
36. HEARN
37. HILL
38. JESSOP
39. ~~JONES~~
40. KILGARIFF
41. KNOWLES
42. LAJOVIC
43. LEWIS
44. ~~McCLELLAND~~
45. MacGIBBON (teller)
46. ~~McINTOSH~~
47. ~~McKIERNAN~~
48. MACKLIN
49. ~~MAGUIRE~~
50. MASON
51. MESSNER
52. MISSEN
53. PARER
54. ~~PRIMMER~~
55. PUPLICK
56. RAE, Peter
57. ~~RAY, Robert~~
58. REID
59. ~~REYNOLDS~~
60. ~~RICHARDSON~~
61. ~~ROBERTSON~~
62. ~~RYAN~~
63. SCOTT
64. SHEIL
65. SHORT
66. ~~SPIRA~~
67. ~~TATE~~
68. TEAGUE
69. TOWNLEY
70. VANSTONE
71. VIGOR
72. ~~WALSH~~
73. WALTERS
74. WATSON
75. WITHERS
76. ~~ZAKHAROV~~

Ayes, 35

Noes, 30

TELLER FOR THE NOES—SENATOR [signature]

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SENATE

1985

/

9 day of May

Question, First Home Owners Amendment Bill 1985 2° Amend by Sen. Lewis to add words

Senate

~~Committee~~

AYES

SENATORS—

~~1. ARCHER~~
2. AULICH
~~3. BAUME, Peter~~
4. BJELKE-PETERSEN
5. BLACK
6. BOLKUS
~~7. BOSWELL~~
~~8. BROWNHILL~~
9. BUTTON
10. CARRICK, Sir John
~~11. CHANEY~~
12. CHILDS
~~13. CHIPP~~
14. COATES
15. COLEMAN
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17. COLSTON
18. COOK
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22. DEVLIN
~~23. DURACK~~
24. ELSTOB
25. EVANS, Gareth
~~26. EVANS, Jack~~
27. FOREMAN
28. GEORGES
29. GIETZELT
30. GILES
31. GRIMES
~~32. GUILFOYLE, Dame Margaret~~
~~33. HAINES~~
~~34. HAMER~~
35. HARRADINE
36. HEARN
~~37. HILL~~
~~38. JESSOP~~
39. JONES
~~40. KILGARIFF~~
41. KNOWLES
~~42. LAIOVIC~~
~~43. LEWIS~~
44. McCLELLAND
~~45. MacGIBBON~~
46. McINTOSH
47. McKIERNAN
~~48. MACKLIN~~
49. MAGUIRE
~~50. MASON~~
~~51. MESSNER~~
~~52. MISSEN~~
~~53. PARER~~
54. PRIMMER
~~55. PUPLICK~~
56. RAE, Peter
57. RAY, Robert
~~58. REID~~ (Teller)
59. REYNOLDS
60. RICHARDSON
61. ROBERTSON
62. RYAN
~~63. SCOTT~~
~~64. SHEIL~~
65. SHORT
66. SIBRAA
67. TATE
~~68. TEAGUE~~
~~69. TOWNLEY~~
~~70. VANSTONE~~
~~71. VIGOR~~
72. WALSH
~~73. WALTERS~~
~~74. WATSON~~
~~75. WITHERS~~
76. ZAKHAROV

Ayes, 35

Noes, 30

TELLER FOR THE AYES—SENATOR N. A. Reid

10932/85

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SENATE

198.5

2

9th day of May

Question, National Welfare Fund Repeal Bill 1985 — 2° amendment (Jack Evans) — add words

Senate

~~Committee~~

AYES

SENATORS—

1. ARCHER
2. AULICH
3. BAUME, Peter
4. BJELKE-PETERSEN
5. BLACK
6. BOLKUS
7. BOSWELL
8. BROWNHILL
9. BUTTON
10. CARRICK, Sir John
11. CHANEY
12. CHILDS
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23. DURACK
24. ELSTOB
25. EVANS, Gareth
~~26. EVANS, Jack~~
27. FOREMAN
28. GEORGES
29. GIETZELT
30. GILES
31. GRIMES
32. GUILFOYLE, Dame Margaret
~~33. HAINES~~
34. HAMER
35. HARRADINE
36. HEARN
37. HILL
38. JESSOP
39. JONES
40. KILGARIFF
41. KNOWLES
42. LAJOVIC
43. LEWIS
44. McCLELLAND
45. MacGIBBON
46. McINTOSH
47. McKIERNAN (Teller)
~~48. MACKLIN~~
49. MAGUIRE
~~50. MASON~~
51. MESSNER
52. MISSEN
53. PARER
54. PRIMMER
55. PUPLICK
56. RAE, Peter
57. RAY, Robert
58. REID
59. REYNOLDS
60. RICHARDSON
61. ROBERTSON
62. RYAN
63. SCOTT
64. SHEIL
65. SHORT
66. SIBRAA
67. TATE
68. TEAGUE
69. TOWNLEY
70. VANSTONE
~~71. VIGOR~~
72. WALSH
73. WALTERS
74. WATSON
75. WITHERS
76. ZAKHAROV

Ayes, 6

Noes, 56

TELLER FOR THE AYES—SENATOR

10932/85

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SENATE

198 5

9th day of May

(2)

Question, Natural Welfare Fmt Repeal Bill 2nd R— amendment moved by Mr J. Evans

Senate

~~Committee~~

NOES

SENATORS—

1. ARCHER
~~2. AUSTIN~~
~~3. BAUME, Peter~~
4. BJELKE-PETERSEN
~~5. BLACK~~
~~6. DOLKUS~~
~~7. BOSWELL~~
~~8. BROWNHILL~~
9. BUTTON
10. CARRICK, Sir John
~~11. CHANEY~~
~~12. CHILDS~~
13. CHIPP
~~14. COATES~~
15. COLEMAN
~~16. COLLARD~~
~~17. COLSTON~~
~~18. CUOR~~
~~19. COONEY~~
~~20. CRICHTON-BROWNE~~
~~21. CROWLEY~~
~~22. DEVLIN~~
23. DURACK
~~24. ELSTOB~~
~~25. EVANS, Gareth~~
26. EVANS, Jack
~~27. FOREMAN~~
28. GEORGES
29. GIETZELT
~~30. GILES~~
~~31. GRIMES~~
~~32. GUILFOYLE, Dame Margaret~~
33. HAINES
~~34. HAMER~~
35. HARRADINE
36. HEARN
~~37. HILL~~
~~38. JESSOP~~
~~39. JONES~~
~~40. KILGARIFF~~
41. KNOWLES
~~42. LAJOVIC~~
~~43. LEWIS~~
~~44. McCLELLAND~~
~~45. MacGIBBON~~
~~46. McINTOSH~~
~~47. McKIERNAN~~
48. MACKLIN
~~49. MACOUBE~~
50. MASON
51. MESSNER
~~52. MILLEN~~
~~53. PARER~~
~~54. PRIMMER~~
~~55. PUPLICK~~
~~56. RAE, Peter~~
~~57. RAE, Robert~~
~~58. REID~~ Reid
~~59. REYNOLDS~~
~~60. RICHARDSON~~
~~61. ROBERTSON~~
~~62. RYAN~~
~~63. SCOTT~~
~~64. SHEIL~~
~~65. SHORT~~
66. SIBRAA
~~67. TATE~~
~~68. TEAGUE~~
~~69. TOWNLEY~~
~~70. VANSTONE~~
71. VIGOR
72. WALSH
~~73. WATTERS~~
~~74. WATSON~~
~~75. WITHERS~~
~~76. ZAKHAROV~~

Ayes, 6

Noes, 36

TELLER FOR THE NOES—SENATOR Mair Reid

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