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**A REVIEW OF THE  
CROWN-OF-THORNS STARFISH  
RESEARCH PROGRAM  
1989-1991**

**A REPORT TO THE GREAT BARRIER REEF MARINE PARK  
AUTHORITY**

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# A Review of the Crown-of-Thorns Starfish Research Program

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**Date of Submission:**

8 April 1991

**Terms of Reference:**

1. To review the Great Barrier Reef Marine Park Authority's crown-of-thorns starfish research program with reference to the recommendations made by Professor D. T. Anderson in his 1989 report to Senator Richardson.
2. To make recommendations on the provision of additional funds for the program.



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## Summary of Conclusions and Recommendations

1. *The COTS research program has operated in an efficient and productive manner during 1989-91 and has contributed significantly to the knowledge required for the use and enjoyment of the Great Barrier Reef in an ecologically sustainable manner. However, because of uncertainty over funding, some research projects started later than planned.*
2. *Significant additional progress is assured in the 1991-92 fiscal year, and continued support for the program into this third year is essential.*
3. *Some activities in the COTSREC program have the potential to contribute significantly to research in important areas outside the immediate scope of the program, including research on fisheries stocks and recruitment and on water quality.*
4. *The COTS monitoring program is providing exceptionally useful information. It is the key to identifying outbreaks rapidly and monitoring their spread, impact and decline. It also provides information essential to many other COTS research projects. Steps should be taken to guarantee funding of the COTS monitoring program at no less than the current (indexed) level of support at least until the cause(s) of outbreaks are known. The monitoring program should be reviewed regularly.*
5. *The COTS research program should also continue beyond the 1991-92 year, but at a level of support that reduces over a period of three years to fund a core program (as distinct from monitoring) of about half of the current (indexed) level. This program should be reviewed in three years.*
6. *The existing monitoring working group involving GBRMPA and AIMS should be responsible for reviewing the COTS monitoring program. This group should consider certain modifications to the monitoring program and report its conclusions to COTSREC before the end of 1991.*
7. *The GBRMPA COTS staff should be requested by COTSREC to develop, in consultation with researchers, contingency plans for research and funding to be activated in the event of a new COTS outbreak. Conclusions should be reported to COTSREC at the Committee's next meeting and the plan reviewed at each COTSREC meeting.*

8. *A contingency fund of \$400,000 should be sought from the Federal Government to be held in a trust fund and made available for core research in the event of an outbreak in the future. The fund should be used only when COTSREC and GBRMPA decide that an outbreak has clearly occurred.*
9. *Research on monoclonal antibodies and settling tubes should be given greater support.*
10. *No new research on COTS in the sedimentary record should be supported (other than, perhaps, modest pilot studies) unless new techniques show promise of characterising the dynamics of pre-1960 outbreaks with sufficient precision to challenge rigorously the hypothesis that human activities have caused or enhanced recent outbreaks. Proposals for research in this area could continue to be accepted and reviewed.*
11. *Support for hydrodynamic modeling should be phased out until existing model predictions have been field tested.*
12. *Screening and coordination of requests from researchers for assistance from the AIMS monitoring team should be undertaken by a group including the AIMS Project Manager, a member of the survey team and the GBRMPA Program Coordinator. Any problems with assessing priorities and resolving conflicts should be directed to the COTSREC Chairman.*
13. *COTSREC should provide and enforce guidelines for addressing COTSREC objectives in proposals and reports.*
14. *COTSREC should continue to review its funding priorities in order to reduce still further the number of projects supported.*

## Conduct of this Review

This consultancy was accepted on 1 March 1991, with an agreement to report to GBRMPA before the May meeting of the Crown-of-Thorns Starfish Research Committee (COTSREC).

I interviewed Professor John Swan, chairman of COTSREC in Melbourne on 4 March. From 5 through 7 March I interviewed the individuals listed below in Townsville. Drs Brian Lassig and William Gladstone provided me with numerous relevant documents and organised the interviewing. Their congenial efficiency was much appreciated. Either Dr Lassig or Dr Gladstone, or both, were present at the Townsville interviews.

### *Interviews*

#### *At the Offices of the Great Barrier Reef Marine Park Authority:*

Dr William Gladstone

Dr Donald Kinsey

Dr Brian Lassig

Mr Simon Woodley

#### *At James Cook University:*

Dr David Blair

Mr Lance Bode

Professor Howard Choat

Mr Glen De'Ath

Mr Ian Dight

Ms Leanne Fernandez

Professor Robert Henderson

Assoc. Professor David Hopley

Dr Maurice James

Dr Bruce Mapstone

Ms. Barbara Musso

Mrs Cecily Rasmussen

Ms Katrina Roper

Mr Richard Stump

Dr Hugh Sweatman

#### *At the Australian Institute of Marine Science:*

Dr Joe Baker

Dr John Benzie

Mr Lyndon DeVantier

Dr Terry Done

Mr David Johnson

Dr John Keesing

Mr Graeme. Kelleher

Dr David Klumpp

Mr Bruce Miller-Smith

Dr Peter Moran



## Background to this Review

In his 1989 report to DASETT on the crown-of-thorns starfish (COTS) program, Professor D. T. Anderson concluded that the Great Barrier Reef Marine Park Authority had promoted appropriate research on COTS, but suggested several modifications to the program and its funding.

1. He recommended that the existing COTS research committee, COTSARC, be disbanded and a new committee be formed, with Professor Swan continuing as chairman, to play a more effective role in determining, in consultation with GBRMPA, how best to spend research funds. Accordingly, the Crown of Thorns Starfish Research Committee (COTSREC) was established.
2. Anderson stated that the facilities and expertise of the Australian Institute of Marine Science were essential to the research program, but noted some difficulties in its relationship with GBRMPA. To overcome these, an inter-institutional agreement between the two organizations was drawn up. It formalised the responsibilities of each institution and relevant personnel; reporting procedures; allocations of funds; ownership of capital equipment and research information; the content of reports, and procedures for the disclosure of information, and dealing with potential conflicts. This arrangement is working well.
3. To understand better the causes of — and management options for responding to — COTS outbreaks, Anderson recommended continued research on the broadscale ecology of the species on the GBR, including improved analysis of its reproduction, dispersal, settlement and recruitment\* processes. He also identified four areas for future research:
  - predation at all levels
  - population dynamics
  - effects of human activities, including run-off and fisheries, and
  - biological control.

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\* Nowhere in the COTSREC documents at my disposal is "recruitment" defined. I presume it here means movement into adult populations. But in the marine science community it is equally commonly used as a synonym for "settlement". It would be useful to select, specify and stick to one or other of these meanings in future COTSREC documents.

The first three recommendations were acted upon. After careful deliberation it was decided, for sound practical reasons, not to fund biological control research.

4. Anderson recommended that 4 or 5 post-doctoral appointments be made in the program to bring in additional research workers with suitable skills, especially in the areas of predation and population dynamics, and that these appointments be guaranteed for three years. These appointments were made.
5. Anderson recommended that a full-time coordinator of the program be appointed. This was done; it has proved to be a very effective move.
6. Anderson recommended that all projects funded by the COTS research program should carry contractual obligations, including strict financial reporting and an annual report of progress to GBRMPA. This was acted upon.

Subsequently COTSREC set up three ad hoc working groups to refine the program's approach to:

- (a) monitoring COTS populations on the GBR
- (b) research on the biology of COTS
- (c) research on predation on COTS.

7. Anderson pointed out that provision of federal funds on an annual basis disadvantaged the program in a number of ways. In particular it imposed a need for rapid decision-making that unduly constrained the program. He recommended that the program be continued for another 3-5 years at a dedicated and committed funding level of at least \$1 million a year. Subsequently, funding was guaranteed for 1989-1990 (\$750 000) and 1990-1991 (\$1 million), with the provision of a third year's funding contingent upon a review of the program towards the end of the second year. This report is that review.

## Discussion

### First Term of Reference

To review the Great Barrier Reef Marine Park Authority's crown-of-thorns starfish research program with reference to the recommendations made by Professor D. T. Anderson in his report.

It would be inappropriate in an overview such as this to examine each research project funded and each new management initiative taken in the COTS research program. Rather I will focus on a number of important issues that have arisen or assumed greater importance since Professor Anderson's review. In general I am satisfied that those responsible for research and management in the program have taken up Professor Anderson's recommendations energetically and effectively, and that the program is clearly characterised by firmer direction and improved coherence and productivity.

In cases where Professor Anderson's recommendations were not acted upon, sound justification was given. I support COTSREC's attitude that a reviewer's recommendations are not written on stone tablets, and that, when subsequent careful deliberations suggest preferable alternatives, the latter should be acted upon. I expect COTSREC to respond to my recommendations in similar critical fashion.

As research findings accumulate, priorities inevitably shift. I believe the time has come to direct more emphasis to certain areas of the research program and less to others.

### Research Deserving Increased Support

#### *Pre-settlement survival*

A major focus of COTS research has been on identifying the life history stage(s) during which COTS populations may escape from the usual environmental controls over their numbers and create outbreaks. It has not been established whether the key events occur before or after the planktonic larvae settle to the bottom and metamorphose. To date most relevant



research has focussed on post-settlement factors, especially predation. Little field evidence has emerged, however, to support the notion that such factors are important in the development of COTS outbreaks\*

The emphasis on post-settlement phenomena is a consequence of several factors. The most important practical reason has been that techniques for studying pre-settlement stages in the animal's life history (i.e. the eggs and the planktonic larvae) have not been available. The inability to distinguish COTS larvae from the larvae of other starfish has prevented studies of the distribution, abundance and behaviour of the latter in the field. Also, the great difficulty in finding the tiny, cryptic juveniles soon after their settlement on the reef has prevented studies of the timing, distribution or magnitude of larval settlement.

Two promising techniques are being developed, supported by the COTSREC program, to overcome these major research bottlenecks:

1. The monoclonal antibody technique appears to hold great promise in enabling researchers to distinguish COTS larvae quickly and easily, even in formalin-preserved samples.
2. The settling-tube technique facilitates the collection and automatic preservation of larvae as they settle on the reef.

Both methods need more development before they can be used routinely. But, if their promise is borne out, they should, for the first time, provide researchers with effective tools to study pre-settlement phenomena. (Both techniques may also have important applications in unrelated research on fisheries stocks and recruitment.)

Under the circumstances, it was surprising to discover that both techniques are under development by the same graduate student, whose financial and technical support is not high. Until these techniques are perfected, however, much research that is vital to understanding COTS pre-settlement phenomena cannot proceed.

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\* Neither of the two references sometimes cited to support the idea that post-settlement predation is likely to be an important factor in COTS outbreaks are persuasive; one consists of what its author calls a "highly stylized model" and the other consists of a demonstration of interhabitat variation in predation pressure on sea urchins - not interannual variation. In addition, the widely accepted link between secondary COTS outbreaks on the GBR and upstream aggregations of adults suggests that secondary outbreaks, at least, are more likely to be the consequence of increased larval settlement than of increased post-settlement survival.

*I therefore recommend that research on monoclonal antibodies and settling tubes be given greater support, and that, to reduce delays, some of the unspent funds available due to the delayed starts of other projects be allocated for this purpose. Technical support appears to be of high priority.*

## Research for which Support should be Reduced

### *Reconstruction of past COTS dynamics through sediment analysis*

Studies of COTS skeletal fragments in GBR sediments suggest that COTS outbreaks may have occurred before 1960 (although there is some debate over the validity of the evidence). If such outbreaks did indeed occur, and if it could be shown that they occurred with comparable frequency and were of similar intensity to the outbreaks of the last 30 years, it could be concluded that recent outbreaks are not necessarily a consequence of human activity. However, existing research methods do not permit even cursory comparisons of the dynamics of past episodes with those of recent ones.

It has been suggested that a search should be made for locations where sediment cores yield better, less disturbed records of past events than do the cores that are presently available. Success here, coupled with the development of new and more sensitive analytical techniques, might yield the necessary precision to enable rigorous comparison of the dynamics of past and recent outbreaks.

The chances of achieving both goals appear at present, however, to be slim. Although locating appropriate coring sites and developing such methods are both worthy general research goals — of potential significance in a much wider context than that of the COTS program — it is doubtful whether COTS funds should be used to support anything other than modest pilot studies at this point. If promising sites and methods are both eventually found, then reactivation of more substantial COTS-related support for research in this area should, of course, be considered.

*I therefore recommend that no new research on COTS in the sedimentary record be supported, other than modest pilot studies, unless new techniques show promise of characterising the dynamics of pre-1960 outbreaks with sufficient precision to challenge rigorously the hypothesis that human activities have caused or enhanced recent outbreaks.*



## Issues in Need of Resolution

### (a) Monitoring

The monitoring program is by far the most expensive single item in the COTSREC program, but its value is unquestionable. It is essential that it be designed to maximise the provision of useful information. However, despite the dedication of the team responsible for it, and valuable improvements in manta-tow survey methodology in the past two years, important questions concerning the operation of the program remain unresolved.

No criticism is implied; the relevant questions are complex and several iterations of modification/trial/modification are likely to be needed over a number of years before the program approaches its optimum design. At present at least two different modifications of the program seem worth considering in this connection.

1. A "methodologically stratified" survey strategy, employing the existing manta-tow surveys plus belt-transect surveys by SCUBA divers, has been suggested. Such an approach could provide more detailed and accurate information on the localised distribution and abundance of COTS, as well as other elements of the reef community. It needs to be determined, however, whether logistics and the existing level of funding would support this approach, and whether the consequent reduction in the time available for the broader scale manta-tow surveys is an acceptable sacrifice.
2. Because the monitoring program systematically and repeatedly covers a very large number of sites over much of the the GBR, it provides an unparalleled opportunity to collect additional data of great value to other GBR research programs. Data on water quality, for example, could prove exceptionally useful for determining the impact of land-based activities on GBR water quality — a topic of particular concern to GBRMPA. Possibly a compact instrument package that measured several water quality parameters, or an automated water sampler that took many small samples for later analysis, could be designed to be towed behind the boat during manta tows.

Funds to support the development of such gear and its use during COTS monitoring should probably not come from COTSREC funds. But this is one of several instances where greater collaboration between the COTSREC program and other research programs could pay great dividends.

*I therefore recommend that the COTSREC ad hoc working group responsible for reviewing the monitoring program consider possible modifications to it, including those discussed above, and report to COTSREC before the end of 1991. Alternatively, a new permanent working group might be established for this purpose.*

The monitoring team has often accepted requests from various researchers to carry out work for them during their monitoring trips. These requests have been ad hoc and sporadic, and accepting them has sometimes proven excessively burdensome.

*I therefore recommend that a permanent committee be set up to screen and coordinate future requests for assistance from the monitoring team. The committee should include at least one representative from each of:*

- *the monitoring team*
- *GBRMPA*
- *AIMS COTS researchers*
- *JCU COTS researchers.*

**(b) Modeling of water movements on the GBR and dispersal of COTS larvae**

Modeling of water movements on the GBR has provided a physical explanation for some important features of the observed spread of *Acanthaster* outbreaks throughout the Cairns section of the GBR. Support is now being sought to extend this work to develop models capable of improved predictions of water movement and COTS larval dispersion under specific meteorological and hydrodynamic conditions. However, the fact that a model describes known phenomena is not proof of its predictive capabilities; it is possible to construct models that display some known characteristics of a system without actually representing that system. The predictive value of a model is not proved until its predictions have been tested. The COTS larval dispersion models have not as yet been tested by field research on the distribution and abundance of settling COTS larvae.

Another concern is raised by the existing model's prediction that "relatively small cross-shelf differences in the location of a patch of larvae due to differences in the time-dependent water velocities can, at a critical time and location, result in very different trajectories for the larval cloud" (Dight et



al, 1990, p. 13). Such behaviour seems chaotic (in the technical sense of the term) and appears to cast doubt on models ever being able to predict larval dispersal accurately.

Finally, the models are two-dimensional and assume that larvae behave like inert, neutrally buoyant particles. Yet in laboratory tanks COTS larvae display apparent positive phototropism, concentrating near the surface (Keesing, pers. comm.). If COTS larvae in nature also tend to distribute themselves non-randomly in the water column, two-dimensional modeling is not likely to predict their dispersal satisfactorily.

To test the existing models requires considerable field work involving studies of the distribution, dispersal and settlement of COTS larvae — research that, as discussed above, is only now beginning to appear feasible.

*I therefore recommend that COTSREC suspend funding for hydrodynamic modeling at the end of the 1990-91 fiscal year until such time as field studies suggest that their further development is justified.*

## Reviewing Priorities

Over the past six years increasingly fewer COTS research projects have been supported, while the average funding allocation per project has increased. During the COTSAC program (1985-89) 79 projects were supported at an average cost of \$38,000. During the two years of COTSREC (1989-91) 27 projects have been supported at an average cost of \$70,000 per project.

This trend reflects the refining of objectives and the tightening up of priorities as experience and research findings accumulate. Scope remains, however, for additional fine tuning of priorities. There is still a tendency, for example, to fund some minor programs because they cost little. Such programs cost virtually as much administrative time and effort, however, as the larger ones.

*I recommend, therefore, that COTSREC review, once more, its funding priorities with a view to reducing further the number of programs supported.*

Among the proposals and research reports to COTSREC that I read, there was substantial variation in the extent to which researchers made an explicit effort to show how their projects/results related to COTSREC priorities. Proposals/reports which gave this subject short shrift were not necessarily out of step with these priorities. But it is a useful exercise for researchers, and a valuable service to those who review their efforts, to consider this subject explicitly.

*Accordingly, I recommend that COTSREC provide and enforce brief but firm guidelines for addressing COTSREC priorities in proposals and reports.*

## Second Term of Reference

To make recommendations on the provision of additional funds for the program.

During COTS outbreaks, public pressure inevitably builds for the implementation of COTS research and control measures. Public pressure also wanes as the COTS populations wane. But one does not disband the army when the current war is over. Although COTS populations on the GBR are fast declining at present, elements of the COTS research program must be maintained if the response to another outbreak is to be significantly improved.

The response of the research community to the most recent outbreak in 1979 was much faster and more efficient than it was to the previous outbreak in the 1960s. But the slow process of approving and providing funding and of setting up and staffing research programs resulted in research in some essential areas not getting underway for a year or more, through no fault of COTSREC, GBRMPA or researchers.

As a result some valuable opportunities were lost; some types of research on COTS can only be carried out in the early stages of an outbreak.

Three things are necessary to ensure early identification of the next outbreak and an effective response to it:

1. The monitoring program must continue indefinitely.
2. There must be a core program of COTS research (as distinct from monitoring).
3. There must be a detailed plan of how to respond with maximum speed and effectiveness to a new outbreak.

## 1. Monitoring Program

It is not widely understood outside the scientific community that negative results are often as important as positive ones. Information on reefs where there are few or no COTS is imperative for identifying reefs where outbreaks appear imminent and in improving predictions of the timing and spread of outbreaks. Monitoring is therefore crucial for GBRMPA's (and the public's) overview of outbreaks; the monitoring program must continue indefinitely whether or not significant numbers of COTS are found in a given year. The program can also, as discussed above, provide invaluable spinoffs to other COTS and non-COTS research programs.

Current funding is just adequate to run the program effectively. (Additional funding would be needed if AIMS were to reduce its sizeable contribution to the program from its internal budget.)

*I therefore recommend that steps be taken to guarantee funding of the COTS monitoring program indefinitely and at no less than the current (indexed) level of support.*

## 2. Core Research Program

This report is being written near the end of the second year of the three-year program set up by Senator Richardson. According to his instructions, funding for the third year is contingent upon the conclusions reached in this report.

Research has not yet provided the answers to two critical questions:

- are COTS outbreaks entirely natural or attributable wholly, or in part, to human activity, and,
- can we be certain that outbreaks will not cause massive long-term changes to the Great Barrier Reef?

This is not due to any shortcomings in the research program. The scientific challenges posed by these complex questions are formidable. Although our understanding of the biology of COTS and the environmental impacts of COTS outbreaks has improved substantially, the answers to the key



questions are not yet even clearly in sight. There can be no argument that more research is needed if we are to answer these questions, and that one more year is by no means enough time, barring unexpected breakthroughs.

Some of this research can be carried out only during outbreaks. Because the most recent outbreak is waning, some important research projects must be reduced or suspended for the present. Other research projects can continue regardless of the status of COTS populations on the GBR, although some of the latter should be wound down as they come to the end of their productive phase over the next one or two years. Other programs should be enhanced. It is the role of COTSREC, not this reviewer, to make program-by-program decisions in this regard. But it is my responsibility to make an overall recommendation as to the extent that continued funding of the COTSREC research program as a whole is desirable.

*I conclude that the research program has been operated in an efficient and productive manner and that its continuation into the third year is essential. I recommend, furthermore, that the program be continued beyond the third year, but at a level of funding that reduces gradually over a period of three years (providing no new COTS outbreak occurs) to fund a core program at about one half of the current (indexed) level, and that this program be reviewed in two years.*

### 3. Contingency plans for a new outbreak

Funds for the first year of the current program were made available to GBRMPA in August 1989. The COTSREC-recommended program of research was approved in October. Ministerial approval to enter into contracts involving payment of more than \$50,000 was granted in November. Many projects were not begun until late 1989 or early 1990. The unavailability of suitable personnel for some projects meant that two projects did not begin for a further 12 months.

The continuing funding of a core program of COTS research (as distinct from monitoring) should reduce such delays in the event of another outbreak. But to assure the quickest and most efficient response, it is obviously desirable to have a contingency plan. (Past funding uncertainties have previously discouraged much attention being directed to this goal.)

This plan should identify:

1. Priority research projects to be activated or expanded in the event of an outbreak. (As noted earlier some key research cannot be carried out except during outbreaks.)
2. Mechanisms for quickly recruiting and deploying the necessary personnel.
3. Means of making funding available immediately in the event of an outbreak. One solution would be a \$400 000 contingency fund guaranteed by DASETT, to be used only when COTSREC (or a committee set up by COTSREC and DASETT) decided that an outbreak had clearly occurred. (The definition of what constitutes an outbreak has never been clearly formulated. Such a definition would need to be agreed upon for this purpose.)

*I therefore recommend that a committee with representatives from (at least) AIMS, JCU and GBRMPA be appointed by COTSREC, to establish contingency plans for research and research funding to be activated in the event of a COTS outbreak, and to report to COTSREC on their progress within a year.*







**REVIEW OF THE COTSREC RESEARCH PROGRAM  
1989-1991**

**Prepared for Dr R.E. Johannes by**

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**March 1991**

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## BACKGROUND

### Review of the COTSAC Program

In December 1988, following criticism in the media of the Great Barrier Reef Marine Park Authority's handling of the crown-of-thorns starfish (cots) issue, the then Minister for the Arts, Sport, the Environment, Tourism and Territories, Senator the Honourable Graham Richardson, requested a review of the Authority's crown-of-thorns starfish research program and policies. The research program had been recommended to the Authority by the Crown-of-thorns Starfish Advisory Committee (COTSAC), a body of experts convened by the Authority in 1984 for this purpose. Funding of \$3 million over 4 years for the program (1985/86 - 1988/89) was provided by the Federal Government. The program was reviewed annually by another advisory body established by the Authority, the Crown-of-thorns Starfish Advisory Review Committee (COTSARC). Summaries of this program are published (Moran and Johnson, 1990) and in press (Lassig, 1991).

The review for Senator Richardson was undertaken in January 1989 by Professor D.T. Anderson, Challis Professor at the University of Sydney. Terms of reference for the 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 or tourist interest.
2. To review the adequacy of the mechanism for defining, reviewing and operating the crown-of-thorns starfish program.

Anderson concluded that the research program had been defined, reviewed and operated in an efficient and productive manner and that the Authority's policy for crown-of-thorns starfish control (*ie.* intervention only in areas of special interest to tourism or science) was soundly based, taking into account current knowledge of starfish populations on the GBR (Anderson, 1989). He 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 Authority, the pattern of expenditure of these funds (see Appendix 1). On 30 March 1989 Senator Richardson notified the Authority's Chairman, Mr Graeme Kelleher, he had accepted the recommendations of Anderson's report.

### The Crown-of-thorns Starfish Research Committee (COTSREC)

Anderson recommended that Professor John Swan (who had chaired the COTSARC) continue as chairperson of the new advisory committee and that the committee include two representatives from the Great Barrier Reef Marine Park Authority, two from the Australian Institute of Marine Science (AIMS) and three external experts. Professor Swan convened two meetings of an "interim advisory committee" on 24 April 1989 and invited the Authority and AIMS representatives



to determine Terms of Reference for the new committee (Appendix 2) and to nominate the additional necessary members. Professor Ray Golding (Vice Chancellor of James Cook University) was invited to attend the second meeting later in the day to represent that institution (which had been heavily involved with the previous research program) in discussions of allocation of residual funds for the current financial year. It was agreed the committee be called the Crown of Thorns Starfish Research Committee (COTSREC).

Subsequently Professor Golding, Mr Robert Pearson (Queensland Department of Primary Industries and former member of COTSARC), Dr Keith Sainsbury (CSIRO) and Dr Peter Davies (BMR) were invited to join the COTSREC. All four accepted the positions.

The full COTSREC first met in July 1989 in conjunction with a workshop organised to facilitate discussion on future directions in the crown-of-thorns research program. About 30 scientists and managers (in addition to COTSREC members) attended the workshop and discussed current and future research in the areas of predation, terrestrial inputs and possible links with cots outbreaks, geological studies to determine past occurrences of cots, coral and starfish dynamics, recruitment, biology and controls.

Some elements of the future research program were decided (for subsequent recommendation to the Authority), but the committee recommended the formation of three working groups to detail projects in the areas of survey methodologies, biology and predation. The committee was to meet again in July to ratify working group recommendations and to determine a final research program, but was unable to convene at that time because of the national pilots' dispute. The meeting was postponed to September 1989, but again some interstate members were unable to travel to Townsville and so recommendations of the working groups were ratified by correspondence. A number of recommendations were agreed "in principle" with further details yet to be worked out by the Working Groups in consultation with researchers. These were completed by the end of October 1989.

### **The availability of funds and the start of research**

In the August 1989 budget it was announced that funds of \$750,000 were to be provided for crown-of-thorns starfish research in 1989/90 and \$1million in 1990/91. In response to Mr Kelleher's seeking assurance of the third year of funding (as recommended by Anderson), Senator Richardson replied "Although the Government's decision authorised funding for the program to 1990-91, I am happy for the Department and the Authority to operate on the basis that the program will continue into 1991-92. However, I would ask you that prior to entering the third year of the program, an assessment be carried out towards the end of the second year."

Funds for the first year of the program were made available to the Authority in August 1989. The COTSREC recommended program of research was approved at the Marine Park Authority's meeting on 13 October 1989. Ministerial approval to enter into contracts involving payment of more than \$50,000 (as required under S.56(a) of the Great Barrier Reef Marine Park Act, 1975) was granted on 9 November 1989.



All submitted proposals for funding which had not previously been peer reviewed were sent for review and returned to proponents for modification if required. Contracts were then drawn up with successful individuals and their institutions and the funds disbursed.

Many projects were thus not commenced until late 1989 or early 1990 (towards the end of the summer spawning and recruitment period for *A. planci*). The unavailability of suitable personnel for some projects meant that a couple of projects were not commenced until nearly 12 months later. Dr H. Sweatman, the postdoctoral fellow appointed by James Cook University for crown-of-thorns starfish predation studies took up his position as recently as September 1990.

### **The Australian Institute of Marine Science**

Anderson noted that the facilities and expertise of the Australian Institute of Marine Science were essential to the completion of crown-of-thorns starfish ecological research, but he highlighted a number of difficulties with the relationship between AIMS and the Authority. To overcome these problems, an Inter-Institutional Agreement was drawn up between the two organisations using the Australian Government Solicitor's office. The Agreement was established on 14 November 1989 and formalised aspects such as: the responsibilities of each institution and relevant personnel; reporting procedures; allocation of funds; ownership of capital equipment and research information; procedures for the disclosure of information; dealing with potential conflicts and the content of reports.

The Agreement was revised on 27 July 1990 to incorporate new or modified tasks (projects) for the second financial year of the program. Progress reports on the majority of research tasks were provided to the Authority on 30 April 1990 and 30 October 1990 as stipulated in the two Agreements.

While each Agreement contained a schedule for the payment of funds (quarterly in advance) a lengthy delay in funding was experienced at the beginning of the 1989/90 fiscal year (as discussed above). Some of the projects were on-going and funds were required to ensure the continuity of employment for staff. The authority provided \$75,000 (from unspent funds in the previous year) to cover the costs incurred during this hiatus in funding.

This delay in the provision of funds led to certain projects being deferred as there were insufficient funds to employ new staff. Nonetheless, selection procedures were conducted during this period so that staff could be appointed once additional funds were received.

The first major payment of funds was made in early December 1989. Within two weeks an additional two staff members had been appointed to undertake research into the survival of juvenile crown-of-thorns starfish. One of these, Dr J. Keesing, was appointed as a postdoctoral fellow to lead this research. Another postdoctoral fellow, Dr R. Babcock, was appointed in early January to lead investigations into the reproduction of the starfish. This research area had been highlighted previously by

a sub-committee comprising Dr L. Zann, Dr P. Moran, Assoc. Prof. J. Lucas and Dr J. Lawrence (University of South Florida).

### Structure of the Research Program

The crown-of-thorns starfish research program operates as a 'sub-program' within the Authority's Research and Monitoring Section. The budget for the program, as a special Federal Government fund, is run separately to the Section's general budget. The program is coordinated by the Program Coordinator who reports to the Research and Monitoring Section head (Mr Simon Woodley - Assistant Executive Officer). The coordinator liaises between researchers, their institutions and COTSREC members.

All research conducted by researchers at institutions other than AIMS are directly managed as individual projects by three Authority staff employed through the crown-of-thorns program. Two of these positions (the program coordinator and the Science 1) are 3 year appointments.

Individual projects are identified by a "Cost Code" number which is used for accounting purposes together with an abbreviated title.

The conduct of projects is covered by legal agreements between the Authority, the researchers and their institutions. Agreements specify project execution details, allocation of funds, reporting schedules and responsibilities. Progress reports are scheduled to be submitted by researchers for consideration by the COTSREC at its biannual meetings.

The crown-of-thorns starfish research undertaken at AIMS operates as a sub-program of the Authority's program. Under the AIMS' terminology, the sub-program is referred to as a "Study" and the individual projects as "Tasks". The crown-of-thorns Study forms a discrete project within the Reef Studies program.

At present the crown-of-thorns study comprises nine separate tasks. Each has a unique number that corresponds to that given in the main body of the Inter-Institutional Agreements. Eight of the Tasks involve research while the remaining Task provides administrative support to the others:

- Task 6.1.1:** Broadscale surveys of the crown-of-thorns starfish and its effects on corals along the Great Barrier Reef.
- Task 6.1.2:** Field surveys of juvenile crown-of-thorns starfish
- Task 6.1.3:** Analysis of coral colonies, populations and communities: interpretation of outbreak history and projection of recovery.
- Task 6.1.4:** Assessment of the utility of mitochondrial DNA as a genetic marker in crown-of-thorns starfish (*A. planci*).
- Task 6.1.5:** The role of predation in factors influencing the survival of small juvenile *Acanthaster planci* cultured in the laboratory.



- Task 6.1.6:** Investigations of factors affecting the reproduction and larval dispersal and nutrition of the crown-of-thorns starfish.
- Task 6.1.7:** Project support and administration.
- Task 6.2.1:** Investigation of the trophodynamic implications of outbreaks of the crown-of-thorns starfish.
- Task 6.2.2:** Impact of crown-of-thorns starfish on interactions among space occupants of coral reefs: predictive models of coral reef community structure.

The overall structure of the Study is presented in Figure 1 in the form of an organisational flow chart. Each of the tasks has a Leader who is responsible for controlling the resources of that task as well as ensuring that the task objectives are completed as efficiently and effectively as possible. The Task Leaders report to the Project Manager who is responsible for coordinating and managing the entire Study (including all research, personnel and resources). The Project Manager in turn reports to the Director of AIMS and liaises with the Program coordinator at the Authority.

In all, there are presently 13 staff employed in the Study: two are postdoctoral fellows (Tasks 6.1.5 and 6.1.6), nine are professional officers (Task 6.1.1 has 5 survey team members and a database manager; Tasks 6.1.5, 6.1.6 and 6.2.1 have one each). There are also two Ph.D. students in the Study (Tasks 6.1.6 and 6.2.1). The professional officers connected with Tasks 6.1.6 and 6.2.2 were appointed on contract, for 9 and 6 months respectively. All other staff were appointed according to the terms and conditions of the Institute and continued employment was subject to renewed funding.



## LIST OF PROJECTS : STATUS AND PROGRESS

A full list of projects supported through the COTSREC program are given in the following section. The projects are grouped into categories regarded by COTSREC as priority research areas:

- \* Coral/starfish dynamics
- \* Biology
- \* Hydrodynamics, recruitment and terrestrial inputs
- \* Predation
- \* Geology

### CORAL/STARFISH DYNAMICS

<b>Cost Code</b>	F10110
<b>Title</b>	An integrated study of hard coral regeneration and juvenile crown-of-thorns starfish at Green Island.
<b>Investigators</b>	Mr D. Fisk (Consultant)
<b>Objectives</b>	(i) to provide quantitative and qualitative data on the nature of recovery of hard coral communities; (ii) to search in detail in specific habitats where <i>A. planci</i> are predicted to occur and to provide correlative evidence of the importance of food availability and habitat type on settlement patterns.
<b>Budget</b>	1989-90           \$23,000 1990-91           \$27,430
<b>Duration</b>	November 1989 -
<b>Status</b>	Monitoring of corals and starfish continuing.
<b>Progress</b>	Elements of this long-term monitoring project were originally funded through the COTSAC research program. All components of the project (coral settlement panels, substrate mapping, line transects to measure coral recovery and belt transect searches for <i>A. planci</i> ) are continuing as planned. The major field trip in November-December 1990 was successfully completed and a second minor trip will be undertaken in late March.

All winter settlement panels have been retrieved but not yet analysed. All quadrats have been re-mapped and colonies re-measured. Growth of individual plate colonies are reaching diameters greater than 1m. Growth and recruitment of smaller colonies and of massive species under the live coral canopy have appeared to have slowed down from previous years (prior to the well formed canopy of many of the quadrats). These data are not analysed in detail at present. Line transect data of coral recovery is not yet analysed but it is expected that coral cover estimates will exceed maximum figures recorded in 1989.

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<b>AIMS Task No.</b>	6.1.1
<b>Title</b>	Broad-scale surveys of the crown-of-thorns starfish and its effects on corals along the Great Barrier Reef.
<b>Investigators</b>	Dr P. Moran (AIMS)



<b>Objectives</b>	(i) to assess and summarise the broadscale distribution and effects of the crown-of-thorns starfish within the last 8-9 years;
	(ii) to develop a scientific understanding of the broad spatial and temporal dynamics of the crown-of-thorns starfish and its hard coral prey.
<b>Budget</b>	1989-90 \$203,123
	1990-91 \$220,221
<b>Duration</b>	December 1985 -
<b>Status</b>	102 reefs surveyed (1990/91), annual report underway.
<b>Progress</b>	This Task continues to progress as planned. A total of 168 reefs were surveyed along the GBR between June 1989 and May 1990. The results of these surveys were presented in a Technical Report by Baker <i>et al.</i> (1990). A synthesis of the results was produced shortly after as required under the Agreement established between the Authority and AIMS.

In general, the surveys have proceeded as planned for this fiscal year (1990/91). To date, 102 reefs have been surveyed and only those in the Whitsunday and Pompey Sectors remain. If these surveys are successful then 136 reefs will have been surveyed by the end of the fiscal year. The perimeter of the majority of these reefs has already been digitised and work on the Technical Report is underway. A paper which describes the pattern of movement of the outbreaks of the last 10 years is in preparation.

Apart from surveying reefs staff have also been involved in several other activities:

- \* Manta video: this was trialled once and a number of problems were encountered. Based on these experiences this technique is considered not to be a viable alternative to the current technique since in order to gain the required resolution the viewing width can only be 2m.
- \* Bias with respect to coral cover: considerable time (ca. 40 days) was spent in assisting Ms L. Fernandes in the field. This work was completed towards the end of 1990.
- \* ROV: unfortunately the ROV purchased by AIMS has experienced several technical problems which have prevented its use by survey team members. This has since been rectified and a field trial is planned for the middle of the year. Survey team members spent an average of 100 days at sea during 1990.

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<b>AIMS Task No.</b>	6.2.1
<b>Title</b>	Investigation of the trophodynamic implications of outbreaks of the crown-of-thorns starfish.
<b>Investigators</b>	Dr D. Klumpp (AIMS)
<b>Objectives</b>	to determine the effects of outbreaks of crown-of-thorns starfish on some or all of the following <ul style="list-style-type: none"> <li>(i) primary production and biomass of epilithic algal communities;</li> <li>(ii) composition and abundance of the herbivorous fish community;</li> </ul>



- (iii) processes of herbivory in selected fishes, including feeding rates;
- (iv) abundance and feeding rates of invertebrate grazers such as echinoids, turbinids and trochids and mesograzers;
- (v) standing stocks and quality of detritus in the water column and in benthic habitats;
- (vi) microbial biomass and production;
- (vii) zooplankton abundance, production and feeding rate.

**Budget**  
 1989-90 nil  
 1990-91 \$13,500

**Duration** December 1990 -

**Status** Student appointed, field work underway.

**Progress** This Task began in December 1990 with the appointment of a postgraduate student (Mr Tony Hart) to undertake the research. To date progress has been rapid. A preliminary research plan has been devised and will be submitted in final form for the consideration of COTSREC. Field work has already commenced and one cruise has been successfully completed. Cages to be used for experimental manipulations in the field are presently being constructed at AIMS and are expected to be deployed in April.

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**AIMS Task No.** 6.2.2

**Title** Impact of crown-of-thorns starfish on interactions among space occupants of coral reefs: Predictive models of coral reef community structure.

**Investigators** Dr C. Johnson (Griffith University)

- Objectives**
- (i) to investigate the nature and outcomes of interactions among corals, coralline algae and turfs on 'healthy' and reefs affected by crown-of-thorns;
  - (ii) to construct 'rules of assembly' from these empirical data (augmented by published work), and thence predictive spatial models (cellular automata) of dynamics of coral reef community structure for 'healthy' and affected reefs;
  - (iii) to compare among model predictions and test their predictions at larger spatial and temporal scales than the scale at which empirical data were collected;
  - (iv) to evaluate if biological interactions are important in structuring benthic reef assemblages, and if so, at what scales, and thus if the concept of 'assembly rules' is valid for coral reef communities;
  - (v) to evaluate the utility of predictive models of community structure on coral reefs.

**Budget**  
 1989-90 nil  
 1990-91 \$5,000

**Duration** June 1990 -

**Status** Samples (stage 1) processed, further work contingent on additional funding.

**Progress** This Task began in June 1990. It is part of a larger program of research which was conducted by Dr Craig Johnson (now at the University of Queensland) when he was a postdoctoral fellow at AIMS. The main objective of this Task was to complete analysis of samples collected as part of experiment 1 (reciprocal transfers). Ms Kaye Walker was appointed on a short-term contract in mid-June to undertake the analyses. Unfortunately, the funds were insufficient to enable Ms Walker to complete them in the time available. Consequently, a small amount of additional funds (ca. \$3,000) was used to extend the contract into mid-December, thereby allowing her time to complete the work. It is likely that she will continue this work throughout much of 1991 with funds obtained from the University of Queensland. This should be sufficient to complete all of the analyses.

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**Cost Code** F10139

**Title** Development of a robust method for determining the status of individual reefs with respect to outbreaks of crown-of-thorns starfish.

**Investigators** Assoc. Prof. H. Marsh and Ms L. Fernandes (JCU)

**Collaborators** Drs P. Moran (AIMS) and T. Done (AIMS)

**Objectives**

- (i) to increase the robustness of the regression equations for estimating the proportion of crown-of-thorns starfish sighted during manta tow surveys;
- (ii) to quantify the biases associated with manta tow estimates of live and dead coral cover;
- (iii) to use these results and the AIMS manta tow data base to develop an unambiguous method of classifying individual reefs with respect to whether or not they are experiencing or have recently suffered major disturbance consistent with an outbreak.

**Budget**

1989-90	\$11,500
1990-91	\$28,000

**Duration** April 1990 -

**Status** Final analysis being conducted.

**Progress** This project is the second part of an investigation aimed at addressing criticisms of the AIMS manta tow technique, *viz.* its precision and accuracy. The first part of the project (biases associated with estimating starfish numbers) was funded through the COTSAC program. During this second phase (to quantify biases associated with manta tow estimates of live and dead coral cover), additional observations have also been made on cots estimations. The number of observations in the database used to generate regression equations has increased from 69 to 131 and includes a wider variety of combinations of conditions. The regression model of sightability on variables that can be readily measured in the field explains approximately 41% of the variability and includes one of the observers, structural complexity and visibility as the most significant independent variables. The AIMS manta tow team now records these variables.

Preliminary examination of the data for live and dead coral cover estimates indicates there is reasonable agreement within and between the observers. Of the total number of comparisons both inter- and intra-observer for the same sites at different or the same times, in 22.5% of cases there was a difference in live coral



cover estimates and in 12.7% of cases there was a difference in dead coral cover estimates.

Final analysis is expected to be completed by mid-March and a final report completed by the end of April 1991.

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<b>Cost Code</b>	F10140						
<b>Title</b>	Surveys of benthic biota in the Cairns Section of the GBR Marine Park.						
<b>Investigators</b>	Dr B.D. Mapstone, Prof. J.H. Choat, Dr H.D. Marsh (JCU) and Dr A. Ayling (Consultant)						
<b>Objectives</b>	<ul style="list-style-type: none"> <li>(i) to determine the variation in abundances of the following taxa at several spatial scales:           <ul style="list-style-type: none"> <li>a. large <i>A. planci</i>, massive poritid corals and giant clams;</li> <li>b. benthic organisms and non-living substrata, with particular emphasis on live corals;</li> <li>c. fish with medium to great mobility over short periods, including <i>Plectropomus</i> spp., lutjanids, chaetodontids, and possibly also some lethrinids, haemulids, scarids and labrids;</li> <li>d. fish with restricted home-ranges and relatively low mobility over short intervals, such as most of the pomacentrids and some labrids.</li> </ul> </li> <li>(ii) to conduct detailed surveys of <i>A. planci</i> and coverage by living corals on reefs in the northern region of the Cairns Section of the GBR, specifically that region delineated by the ribbon reefs that is suspected of being the primary area of genesis of cots outbreaks;</li> <li>(iii) to estimate the effects on the abundances of the above organisms of the zoning strategies implemented by the Great Barrier Reef Marine Park Authority.</li> </ul>						
<b>Budget</b>	<table border="0" style="width: 100%;"> <tr> <td style="width: 30%;">1989-90</td> <td style="width: 30%;">\$35,000</td> <td style="width: 40%;">(plus \$90,565 R&amp;M Section)</td> </tr> <tr> <td>1990-91</td> <td>\$20,000</td> <td>(plus \$20,000 R&amp;M Section)</td> </tr> </table>	1989-90	\$35,000	(plus \$90,565 R&M Section)	1990-91	\$20,000	(plus \$20,000 R&M Section)
1989-90	\$35,000	(plus \$90,565 R&M Section)					
1990-91	\$20,000	(plus \$20,000 R&M Section)					
<b>Duration</b>	January 1990 -						
<b>Status</b>	Field work for 1989/90 completed, analysis and reporting in progress.						
<b>Progress</b>	Field work for 1990/91 in progress. Very few cots have been recorded from any of the 24 reefs surveyed in 1989/90 or the 30 reefs so far surveyed in 1991. Average densities are only slightly greater than zero.						

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<b>Cost Code</b>	F10141
<b>Title</b>	Crown of thorns and coral trout density on three Central Section reefs: 1983-1989.
<b>Investigators</b>	Drs A.M. and A.L. Ayling (Consultants)
<b>Objectives</b>	(i) to resurvey, six years after first being surveyed, three reefs affected by crown-of-thorns starfish to obtain



information on starfish, coral trout and chaetodontid densities as well as hard coral cover.

**Budget** 1989-90 \$6,090  
1990-91 nil

**Duration** October 1989 - January 1990

**Status** Completed.

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**AIMS Task No.** 6.1.3

**Title** Analysis of coral colonies, populations and communities: interpretation of outbreak history and projection of recovery.

**Investigators** Dr T. Done (AIMS)

**Objectives** (i) to understand the significance of recent crown-of-thorns starfish outbreaks in relation to the population dynamics of coral communities, for the time period from present up to 200 years into the future;  
(ii) to resurvey sites to provide estimates of recruitment and survivorship of massive coral colonies, thereby improving the utility of previous model projections.

**Budget** 1989-90 \$20,000  
1990-91 nil

**Duration** June 1989 -

**Status** Field work complete, analyses underway.

**Progress** Originally this Task was due to be completed by October 1990. However, due to other commitments the Task Leader was unable to prepare the draft final report for the Authority. Submission of this document has since been deferred until June 1991 with the Authority's approval.

All field work connected with this Task has been completed and the data have been checked and stored. An additional cruise was needed to complete the field work due to the effects of cyclone Ivor. The data are presently being analysed and the report will be completed by June 1991.

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**Cost Code** F10137

**Title** Impact of the crown-of-thorns starfish (*Acanthaster planci*) on the community structure, demography and morphology of massive corals.

**Investigators** Mr L.M. DeVantier (AIMS)

**Objectives** (i) to obtain precise information on the effects of predation by *A. planci* on the population structures of approximately 100 species of massive coral.

**Budget** 1989-90 \$18,000  
1990-91 \$5,000

**Duration** August 1989 -

**Status** Field work completed, data analyses underway. Final report being compiled.

**Progress** Funding for this project is in the form of a postgraduate stipend for Mr DeVantier to complete his Ph.D. The stipend is managed through AIMS and Mr DeVantier is jointly supervised by Dr Terry Done (AIMS) and Assoc. Prof. R. Endean (University of Queensland). At the time funding was first granted

(August 1989), the work had been underway (part-time) for 3 years. Although the thesis was originally intended to be submitted mid-1990, Mr DeVantier has extended his field data collection and is now expected to submit his thesis by mid-1991.

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## BIOLOGY

<b>Cost Code</b>	F10142
<b>Title</b>	Age determination in <i>Acanthaster planci</i> (L.).
<b>Investigators</b>	Assoc. Prof. J.S. Lucas and Mr R. Stump (JCU)
<b>Objectives</b>	(i) to assess three potential methods of age determination in <i>A. planci</i> : <ol style="list-style-type: none"> <li>a. pigment band counts and determination of cyclicity from mark and recapture exercises using tetracycline as a skeletal marker;</li> <li>b. accumulation of age pigment (lipofuscin) in pyloric caeca quantified from recaptured individuals;</li> <li>c. skeletal and somatic morphometry.</li> </ol>
<b>Budget</b>	1989-90           \$33,750 1990-91           \$41,000
<b>Duration</b>	December 1989 -
<b>Status</b>	Five of six planned field collections completed. Laboratory analyses to be completed by September 1991.
<b>Progress</b>	The application of the skeletal banding technique for age determination is now being evaluated for several populations of <i>A. planci</i> under different environmental conditions in the Pacific Region. Reduced funding in 1990/91 meant that the researchers were unable to undertake proposed work in remote locations, but arrangements were made for volunteers to collect specimens.

Assistance (vessel and divers) from the Armed Forces is being sought to help in a large scale collection of starfish from Davies Reef in April 1991. It is hoped that a large enough number of recaptures of marked individuals (660 have been marked with tetracycline and released) will be made to obtain sufficient samples in each pigment band/age class for analysis.

The work is progressing according to schedule and additional funding will be required next financial year to complete the study.

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<b>AIMS Task No.</b>	6.1.6
<b>Title</b>	Reproductive biology of the crown-of-thorns starfish.
<b>Investigators</b>	Dr R.C. Babcock (AIMS)
<b>Objectives</b>	(i) to obtain a more precise quantitative picture of the reproductive biology of <i>Acanthaster</i> populations during the spawning season; (ii) to obtain a more precise picture of starfish behaviour and reproductive biology during the spawning season based on field observations; (iii) to examine the role of pheromones in the aggregation and spawning behaviour of <i>Acanthaster</i> ;



- (iv) to examine the effects of population density on reproductive seasonality and synchrony;
- (v) to determine if there are latitudinal variations in the reproductive seasonality of populations in the central GBR and at the southern extremity of their distribution in the GBR region;
- (vi) to assess gamete viability in individuals of different nutritional states;
- (vii) to establish potential longevity of diluted sperm;
- (viii) to measure *in situ* fertilization rates for artificially spawned starfish at varying densities and in differing conditions;
- (ix) to determine *in situ* fertilization rates for naturally spawning starfish.

**Budget**

1989-90	\$40,417
1990-91	\$105,727

**Duration** January 1990 -

**Status** Spawning observed, samples being processed.

**Progress** This Task began in January 1990 with the appointment of Dr Babcock. Initially he was engaged in developing a detailed research plan which was submitted for external peer review. Considerable time was spent in making plans for the 1990/91 spawning season. Unfortunately, the Navy withdrew its support (*ie.* labour and vessels) necessitating significant rationalisation of shiptime. Sufficient time at sea during the spawning season was obtained on AIMS's boats after using shiptime from Task 6.1.2.

While the withdrawal of Navy support limited the scope of what could be done in the field, this research proved to be entirely successful. A mass spawning of about 100 starfish was recorded and a variety of important factors (*eg.* fertilisation success, density, distance, behaviour) were recorded. This also is a World first.

Laboratory investigations of spawning pheromones have produced inconclusive results as no clear pattern in sperm chemotaxis could be identified using normal techniques. Preliminary studies using oxygen electrodes indicate that it may still be possible to demonstrate this effect. These experiments are planned for the end of 1991. The recent decline in salinity in aquaria has forced the cancellation of several experiments on aggregation of starfish.

Research into the use of monoclonal antibodies as potential markers for larvae has progressed steadily. At present, plankton samples are being tested for the presence of larvae of crown-of-thorns starfish. Deployment of settling tubes was partially successful. A number of tubes were damaged/lost as a result of the effects of cyclone Joy. Most contained large quantities of sediment which will considerably extend the time required for processing.

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<b>AIMS Task No.</b>	6.1.4
<b>Title</b>	A pilot study to assess the utility of mitochondrial DNA as a genetic marker in crown-of-thorns starfish ( <i>A. planci</i> )
<b>Investigators</b>	Dr J.A.H. Benzie (AIMS)



<b>Objectives</b>	(i) to establish the methodologies for extraction of mitochondrial DNA from crown-of-thorns starfish;
	(ii) to assess its utility as a genetic marker in the starfish.
<b>Budget</b>	1989-90 \$5,500
	1990-91 nil
<b>Duration</b>	December 1989 -
<b>Status</b>	Samples processed, technical problems.
<b>Progress</b>	This Task originally was due to be completed in June 1990 however, because of delays in the construction and renovation of Institute laboratories the completion date has been put back a year (to June 1991).

Processing of ripe ovary and pyloric caeca was undertaken towards the end of 1990. The results to date have indicated zero or low yields of mitochondrial DNA. Extraction conditions are being modified by changing EDTA concentrations in an attempt to increase yields that have been inadequate to date for population genetic work. Changing EDTA levels has not been successful so far, but the experiments used relatively low salt concentrations in precipitation steps and this factor may have affected yield. This series of experiments is being repeated with a high salt extraction step and should be completed by May 1991. A major problem is that DNA when obtained is highly degraded, and it is clear this is the result of a strong nuclease activity. total DNA extracts with stringent conditions still undergo degradation although this is less than in standard procedures.

If appropriate procedures can be developed for extracting mitochondrial DNA, then several populations will be tested during the next spawning season when gonad tissue will be available. The expected completion date for completion of tests on extraction procedures is May 1991.

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<b>Cost Code</b>	F10104
<b>Title</b>	Crown-of-thorns population dynamics in Fiji.
<b>Investigators</b>	Dr L.P. Zann (GBRMPA) and Ms V. Vuki (USP)
<b>Objectives</b>	(i) to monitor annual recruitment of juvenile <i>A. planci</i> on Suva Reef;
	(ii) to monitor growth and mortality of the recruits (if any significant settlement should occur);
	(iii) to monitor adult populations for the onset of disease;
	(iv) to monitor changes which have occurred in designated cross reef transects;
	(v) to examine reef community structure in a selection of 'control' reef sites away from urban disturbance for subsequent monitoring.
<b>Budget</b>	1989-90 \$5,000
	1990-91 \$4,000
<b>Duration</b>	October 1985 -
<b>Status</b>	Long term monitoring continuing; 1990/91 sampling to be undertaken in June/July 1991.
<b>Progress</b>	Results of this long-term monitoring study (13 years to date) were published in the recent special edition of Coral Reefs (see publications). The research was funded under the COTSAC program while Dr Zann was acting coordinator of the research program and has continued with COTSREC funding.

The study is unique in providing such a long time series of annual cots recruitment patterns and details of a recorded mass mortality of juveniles. Attempts at similar monitoring on the GBR have failed because of an inability to locate large numbers of juvenile starfish (see AIMS Task 6.1.2). Continued monitoring of study sites to record starfish population dynamics, including annual recruitment and benthic changes is intended.

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#### HYDRODYNAMICS, RECRUITMENT AND TERRESTRIAL INPUTS

**Cost Code** F10119

**Title** Anthropogenic influences on nearshore coral reefs, via mainland runoff, and correlations with spatial and temporal patterns in *Acanthaster planci* population explosions.

**Investigators** Mrs C. Rasmussen and Assoc. Prof. D. Hopley

**Objectives**

- (i) to ascertain the exact effect of enhanced phosphate levels on coral colony growth;
- (ii) 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.

**Budget**

1989-90	\$10,000
1990-91	nil

**Duration** March 1987 -

**Status** Thesis being written.

**Progress** This research was initially funded through the COTSAC program as a Ph.D. project and continued (for its fourth year) with COTSREC funding. The study has focussed on the scale and extent of terrestrial runoff and its effects on coral growth. Data analysis is nearly complete and writing-up is well underway. The thesis is expected to be submitted in June 1991.

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**Cost Code** F10143

**Title** Modelling approach to hydrodynamics and the large-scale larval dispersal of *Acanthaster planci*.

**Investigators** Dr M.K. James, Mr L. Bode and Mr I. Dight (JCU)

**Objectives**

- (i) to develop a database of digitized data, incorporating bathymetry, coastline, islands, reef barriers and *A. planci* habitat, at a meso-scale resolution, along with software for the automatic generation and nesting of computational grids.

**Budget**

1989-90	\$36,000
1990-91	\$30,000

**Duration** November 1989 -

**Status** Sensitivity analyses of the model are complete and the bathymetry of the Cairns Section of the GBRMP has been digitised.



**Progress** The larval dispersal and reef connectivity patterns established during previous studies (partially supported with COTSAC funds) have been subjected to sensitivity analysis and found to be generally robust against variations in simulation sample size, initial dimensions of the larval cloud, number of particles used to simulate a cloud of given spatial extent, and the method used to simulate temporal variation in the wind-forced component of the hydrodynamics.

Results to date emphasise the great importance of temporal variation of the hydrodynamics, especially modulation by a time-varying wind-field and the inertial response of the water mass. There is a strong need for further work on incorporating these effects in models of larval dispersal at all scales, particularly if reliable predictions are required of specific spawning and dispersal events.

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**AIMS Task No.** 6.1.2  
**Title** Field surveys of juvenile crown-of-thorns starfish.  
**Investigators** Dr P. Moran (AIMS)  
**Objectives** (i) to locate extensive, high density populations of juvenile crown-of-thorns starfish on reefs in the southern half of the Central Section of the Great Barrier Reef Marine Park.  
**Budget** 1989-90 \$11,000  
 1990-91 nil  
**Duration** December 1989 -  
**Status** 1990 surveys cancelled, report underway.  
**Progress** Field surveys to locate extensive, high density populations of juvenile crown-of-thorns starfish were undertaken during November 1989. A total of 51 sites were surveyed on 14 reefs (located just south of the main concentration of adult starfish). Despite this intensive effort only 14 small starfish were found (at a cost of about \$1,200 each). A Technical Report on the results of this research is almost completed.

A further series of surveys was planned for the following year (December 1990) however, they did not go ahead as the shiptime designated for this Task was used to support higher priority research efforts (Task 6.1.6). These changes were undertaken with the approval of the Authority.

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**Cost Code** F10149  
**Title** The physical oceanography of the GBR during and prior to crown-of-thorns starfish outbreaks.  
**Investigators** Dr K.P. Black (VIMS)  
**Objectives** (i) to examine the available physical oceanographic data in relation to cots outbreaks on the GBR throughout the known history of the starfish since 1981 and, in particular, during and prior to outbreaks:  
 a. to determine currents  
 b. to determine sea temperatures and salinities  
 c. to determine wind strengths and directions.  
**Budget** 1989-90 nil



**Duration** 1990-91 \$13,500  
**Status** February 1991 -  
 Progress report received, project expected to be completed in June 1991.

**Progress** A list of all the oceanographic data available has been compiled and all records from the central GBR over the cots spawning seasons (October - February) retained. The data is currently being analysed to produce a time series of records (although there are gaps in the records and limited consistency in the location of measurements). Two new phases of the project have been initiated to circumvent this problem:

- \* a meso-scale (2.1km grid) numerical hydrodynamic model of the GBR is being established. The work is well advanced as the bathymetry for all of the Central and Cairns Sections of the GBR has been prepared and checked and two of the three large model grids covering this region have been simulated. This model will assist the project by making it possible to spatially interpolate and relate measurements at different locations in the central GBR.
- \* Dr Burrage at AIMS has developed procedures to specify the variability in currents on the GBR using sea levels measured at Townsville. This technique will allow hindcasting currents back to the 1960s. Drs Black and Burrage will collaborate in the use of this technique to specify currents in the central GBR and thereby greatly expand the available data set.

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## PREDATION

**Cost Code** F10106  
**Title** Database of *A. planci* outbreaks in the South Pacific.  
**Investigators** Dr L.P. Zann (GBRMPA) and Mr L. Bell  
**Objectives** (i) to identify any commonalities among widely separated geographic areas which have been subjected to crown-of-thorns outbreaks, with a view to 'testing' the "predator removal hypothesis".

**Budget** 1989-90 \$5,000  
 1990-91 \$4,000

**Duration** April 1986 -  
**Status** Project continuing; surveys of Western Samoa will conclude late 1991. Final report to be submitted in February 1992.

**Progress** This project was commenced with COTSAC funds and is continuing with support from COTSREC program. The project is attempting to document cots outbreaks throughout the South Pacific (using a variety of techniques (reconstructed from geological studies of lagoonal sediments, from folklore and oral history of fishermen, and from published and unpublished reports) and relate these to possible causal mechanisms (eg. fishing pressure, weather, terrestrial runoff).

Information on the following areas has been collected - Vanuatu, Fiji, Tonga, Cook Islands, Western and American Samoa. The researcher is currently in Western Samoa (on leave until September 1991) and is continuing to add to the database.

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<b>AIMS Task No.</b>	6.1.5				
<b>Title</b>	The role of predation in factors influencing the survival of small juvenile <i>Acanthaster planci</i> cultured in the laboratory.				
<b>Investigators</b>	Mr J. Keesing (AIMS)				
<b>Objectives</b>	<ul style="list-style-type: none"> <li>(i) to establish and operate a facility to rear large numbers of post-settlement <i>A. planci</i>;</li> <li>(ii) to identify likely predators of small juvenile <i>A. planci</i> from field surveys of known habitats;</li> <li>(iii) to undertake laboratory experiments on the survival of juvenile <i>A. planci</i>;</li> <li>(iv) to conduct pilot experiments in the field on the survival of juvenile <i>A. planci</i>;</li> <li>(v) to conduct detailed field experiments on the survival of juvenile <i>A. planci</i>.</li> </ul>				
<b>Budget</b>	<table> <tr> <td>1989-90</td> <td>\$67,271</td> </tr> <tr> <td>1990-91</td> <td>\$93,639</td> </tr> </table>	1989-90	\$67,271	1990-91	\$93,639
1989-90	\$67,271				
1990-91	\$93,639				
<b>Duration</b>	December 1989 -				
<b>Status</b>	Culturing successful, field work underway.				
<b>Progress</b>	This Task began towards the end of 1989. Considerable time has been spent in devising and refining the necessary procedures and facilities for rearing large numbers of larvae and undertaking experimental manipulations in the field. Overall, progress in this Task has been good despite the many technical and logistic problems. Extensive field surveys of benthic fauna have been undertaken and over half of the samples have been sieved and sorted. Several different laboratory experiments also have been conducted which have investigated the survival of juvenile starfish and their growth on different substrata. More recently, two batches of larvae were successfully reared to settlement. There are now about 10,000 small starfish being kept in the system - a World first. Two main lessons were learnt from this exercise: (a) rearing was productive but labour intensive, (b) success of the operation could be further enhanced if the factors that were critical in the rearing process could be identified.				

Two successful deployments of small starfish using caging techniques have been made in the last few weeks. These have produced a number of preliminary results (see Major Research Findings). Recent wet weather has reduced the salinity (ca. 19ppt, normally 35 ppt) in aquaria hampering laboratory experiments.

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<b>Cost Code</b>	F10144
<b>Title</b>	Feeding studies on potential fish predators of post-settlement <i>Acanthaster planci</i> .
<b>Investigators</b>	Dr H. Sweatman (JCU)
<b>Objectives</b>	<ul style="list-style-type: none"> <li>(i) to examine stomach and intestinal contents of exploited fishes that feed on benthic invertebrates from reefs with high densities of <i>A. planci</i> ;</li> <li>(ii) to conduct experimental studies on the digestive rates and gut transit times of lethrinids (potential <i>A. planci</i> predators);</li> </ul>



- (iii) to determine what constitutes lethal damage to *A. planci*;
- (iv) to determine the effects of sublethal damage on *A. planci*.

**Budget**                    1989-90                    \$50,000  
                                   1990-91                    \$50,000

**Duration**                September 1990 -

**Status**                    Submitted research proposal currently under review.

**Progress**                Dr Sweatman was recruited as a postdoctoral fellow for this project from the Smithsonian Tropical Research Institute (Panama). Delays in recruiting and relocation meant that Dr Sweatman did not take up his position at James Cook University until September 1990. The submitted proposal describes three aspects to the study:

- \* Analysis of gut contents of the reef-associated, benthic feeding, commercially important species of emperor, *Lethrinus miniatus* taken at sites where there are currently populations of *A. planci*;
- \* Studies of gut transit times and digestion in *L. miniatus* to look at:
  - the time that skeletal elements of *A. planci* remain in the gut, which is necessary to estimate feeding rates from gut contents;
  - the appearance of *A. planci* remains after varying degrees of digestion;
- \* Studies of healing and regeneration in *A. planci* to be able to assess:
  - the extent of damage that would be lethal,
  - the effects that sublethal damage has on subsequent reproduction.

The latter studies will be undertaken as a post-graduate research project and supported from Dr Sweatman's funds.

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**Cost Code**                F10145

**Title**                        The biology and ecology of the giant triton, *Charonia tritonis*, with particular reference to its role as a predator of the crown-of-thorns starfish *Acanthaster planci*.

**Investigators**            Dr W. Gladstone (GBRMPA)

**Objectives**                (i) to investigate the behaviour (period of activity, refuges, searching and feeding) of *Charonia tritonis*, in aquaria and opportunistically in the field;

                                  (ii) to establish feeding rates of captive *C. tritonis* on *A. planci* and other asteroids in the aquarium;

                                  (iii) to monitor growth rates of the captive specimens over two years;

                                  (iv) to identify suitable field techniques appropriate for censusing *C. tritonis*;

                                  (v) to undertake pilot field studies to determine if a functional response exists between *C. tritonis* and *A. planci*.



**Budget**                    1989-90                    \$10,000  
                                   1990-91                    \$5,000

**Duration**                January 1990 -

**Status**                    Field collection of tritons continuing. Awaiting availability of experimental facilities at AIMS.

**Progress**                This project was originally proposed by Dr Zann (former coordinator of the crown-of-thorns research program. Project management commitments and staff shortages delayed commencement of the project and it has since been taken over by Dr Gladstone. Arrangements to house collected tritons at AIMS have been made, but experimental facilities are not yet prepared. Time lapse photographic equipment to be used to record feeding behaviour has been developed and tested.

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**Cost Code**                F10146

**Title**                    Modelling to assess the impact of predators on crown-of-thorns starfish populations.

**Investigators**        Dr H.I. McCallum (Univ. of Qld) and Dr R. Bradbury (NRIC)

**Objectives**            (i) to develop and analyse models of the coral-starfish interaction in close association with field workers;  
 (ii) to assist in the design of the experimental program by indicating which parameters associated with predation are of most impact in determining the effect of predators on starfish;  
 (iii) to provide an indication of the level at which predation is likely to be of significance in the starfish-predator interaction, providing guidance on numbers of replicates required and sample sizes;  
 (iv) to interpret the outcome of experimental studies and surveys and determine the consequences of observed results for starfish population dynamics;  
 (v) after each stage of the field work, to refine models and provide guidance for the next step in the experimental program.

**Budget**                    1989-90                    \$23,037  
                                   1990-91                    \$22,000

**Duration**                February 1990 -

**Status**                    First stage of tactical modelling completed.

**Progress**                Two "tactical models" to examine the impact of predation on adult starfish and coral cover, given a known larval settlement, have been developed. Best estimates of the various parameters for these models (predator feeding rates, coral growth rates *etc.*) have been extracted from the existing literature. The models have been used to generate surfaces predicting the starfish mortality rate given a range of possible predator consumption and attack rate. These surfaces will provide guidance as to the predator types and predator densities that may be of significance in *Acanthaster* population biology. A "strategic model" of larval interchange between reefs has been developed, which indicates the possibility of very complex "chaotic" population dynamics.

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**Cost Code**                F10138

<b>Title</b>	Survey of marine scientists and other experts for anecdotal observations of crown of thorns predation.
<b>Investigators</b>	Marine Bio Logic (Consultants)
<b>Objectives</b>	(i) to survey, by questionnaire, up to 200 scientists and frequent reef users working on Australian coral reefs, to document observed cases of <i>A. planici</i> predation.
<b>Budget</b>	1989-90 \$2,000 1990-91 nil
<b>Duration</b>	September 1989 - January 1991
<b>Status</b>	Completed.

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#### GEOLOGICAL PERSPECTIVES

<b>Cost Code</b>	F10148
<b>Title</b>	<i>Acanthaster</i> feeding on coral reefs: the implications for bioerosion.
<b>Investigators</b>	Prof. J.H. Choat and Ms B. Musso (JCU)
<b>Objectives</b>	(i) to investigate the process of bioerosion in corals killed by <i>Acanthaster</i> feeding.
<b>Budget</b>	1989-90 nil 1990-91 \$15,000
<b>Duration</b>	October 1990 -
<b>Status</b>	Field work underway.

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<b>Cost Code</b>	F10150
<b>Title</b>	Geological working group
<b>Investigators</b>	Dr Kinsey (Chairperson), Drs Moran and Pandolfi (AIMS), Assoc. Prof. Hopley and Dr G. De'Ath (JCU), Dr Davies (BMR), Dr Lassig (GBRMPA)
<b>Objectives</b>	(i) to recommend to COTSREC a research program that addresses the issue of crown-of-thorns skeletal elements in reef sediments as potential indicators of past population densities and outbreaks; (ii) to initiate pilot studies to investigate potentially fruitful areas of research in this regard.
<b>Budget</b>	1989-90 nil 1990-91 \$20,000
<b>Duration</b>	November 1990 -
<b>Status</b>	First meeting held, second meeting scheduled in March 1991 to determine appropriate pilot studies.
<b>Progress</b>	A number of actions were decided at first meeting for members to follow up and report on at the second meeting:

- \* investigation of possibilities for using organic traces of cots on massive corals as evidence of previous outbreaks;
- \* analysis of potential outcomes and consequences of these analyses with an appropriate action plan for future directions pending success/failure of preliminary steps;



- \* investigation of possibilities for accurate dating of cots spicules using alternative dating techniques (eg. Caesium and free amino acids);
- \* preparation of a description of necessary taphonomic/calibration required to detail sedimentological processes that affect interpretations of spicule presence in core samples;
- \* organisation and design of intensive surface sediment sample collection from a reef off Townsville with a documented cots history, focussing on cryptic locations that have not previously been sampled;
- \* analysis of data collected by Professor R. Henderson for within reef spatial distribution of skeletal elements to be interpreted in view of known biological data of cots distribution on these reefs;
- \* further analysis of Professor Henderson's data for Myrmidon Reef;
- \* checking on the potential of ANU's newly acquired dating equipment capable of dating very small quantities of material.

Proposed pilot studies from this background information will be initiated this financial year and full-scale research in promising areas funded in 1991/92.

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## EDUCATION

**GBRMPA Cost Code** F10103  
**Title** GBRMPA Aquarium interactive display.  
**Investigators** Mr B. Kettle (Consultant)  
**Objectives** (i) to develop an interactive display, based on an Apple Macintosh computer, to provide public information on the crown-of-thorns starfish, the research program and management issues.

**Collaborators** GBRMPA Staff  
**Budget**

1989-90	\$6,000
1990-91	\$5,000

**Duration** October 1989 -  
**Status** Basic display completed and in use.  
 More detailed responses being planned.  
**Progress** Public information and education are regarded by the Authority as important, integral aspects of the crown-of-thorns research program. The interactive program (using a Macintosh donated to the aquarium) currently in use provides a general overview of the crown-of-thorns phenomenon, including the starfish's biology, ecology, behaviour, current research and management issues. This second phase of the project will expand on the detail in each of these areas. The revised, expanded program should be completed by June 1991.

Authority staff have also prepared a "cots pack" containing slides, printed material and a video for distribution to Queensland schools. The package will be distributed to six schools this month on a trial basis, with more widespread distribution planned in the future, subject to feedback from the initial recipients.

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## MAJOR RESEARCH FINDINGS

The following results have been obtained from projects supported by COTSREC funds since June 1989. They are given in point form and grouped within the categories established by COTSREC as priority areas of research.

### Coral/starfish Dynamics

- (a) About a third (31.5%) of all reefs surveyed since 1982 have experienced outbreaks of crown-of-thorns starfish in the last 10 years. The estimated percentage of reefs which have experienced outbreaks over the entire GBR is  $18\% \pm 4\%$ .
- (b) The number of outbreaking populations on the GBR is declining. The proportion of reefs with outbreaks (at the time of survey) rose from 7% in 1985/86 to 16% in 1988/89 and then dropped to around 4% during 1989/90.
- (c) the starfish has mainly affected reefs between Lizard Island and Townsville over the last 10 years.
- (d) The proportion of reefs with outbreaks in the Townsville region has steadily declined over the last few years (75% in 1985/86 to 13% in 1989/90). In contrast, the proportion of outbreaking populations in the region immediately to the south (Cape Upstart) has increased from 5% in 1985/86 to 37% in 1989/90. The data provide the first direct evidence of the southward drift hypothesis put forward by Kenchington (1977).
- (e) Recent analyses of the database (incorporating historical surveys and user reports) indicate:
  - \* that the second series of outbreaks on the GBR began in an area of reefs between Cairns and Cooktown during 1979 and 1980.
  - \* after that time the outbreaks moved to the south of Cairns (at a rate of approximately 0.67 degrees/year) and to the north of Cooktown (at a rate of about 0.23 degrees/year).
  - \* the direction of both the southern and northern drifts followed the line of mid-shelf reefs. The pattern of movement of the southerly drift is more dispersed either side of the drift path.
  - \* The southerly and northerly drifts have now slowed to about 0.24 and 0.04 degrees/year respectively.
- (f) Surveys within the Cairns region have recorded noticeable coral recovery on some reefs. At the present time however, this is still patchy. Widespread damage due to cyclones has been recorded on a number of reefs in the Far Northern Section of the GBR.

- (g) Almost 20% of reefs with outbreaks (at the time of survey) were considered to be seriously affected (*ie.* reefs with an average dead coral cover of greater than 30%).
- (h) Outbreaks of crown-of-thorns starfish produce an estimated 11% increase in the cover of dead coral on reefs. This represents over a threefold increase in the amount of dead coral.
- (i) 59% of the variability in the proportion of starfish counted by manta towed observers is explained by reef topography, presence of branching coral communities, proportion of cryptic starfish, observer bias and underwater visibility.
- (j) In 22.5% and 12.7% of manta tow estimates of live and dead coral cover respectively, there was intra- and inter-observer bias.
- (k) In 9.5% and 4.4% of live and dead coral cover estimates, respectively, there was discrepancy between manta tow and video (ground truthing) techniques.
- (l) Recruitment of corals was greater in the presence of turf algae inside fish territories, rather than outside the territories where grazing pressure is high. At present it has not been determined whether the higher levels of coral recruitment are due to the presence of turf algae, the resident fish or a combination of both.
- (m) Growth of turf algae inhibits the spread of crustose coralline algae. The latter suffers from high mortality when transferred into fish territories.
- (n) Good coral recovery is continuing at Green Island and is expected to be higher than the 1989 maximum of 42% cover.
- (o) Faster growing *Acropora* species continue to dominate Green Island coral communities, but there is a visible increase in the abundance and size of faviids and other massive corals.
- (p) Crown-of-thorns starfish at Green Island are estimated to be 3-4 year old and are aggregated in two areas with the highest coral cover.
- (q) For massive corals, there is substantial variability in growth within species and between reefs. Radial growth rates of massive corals ranged from a maximum of approximately 2 cm/year for species of *Porites* (Poritidae), 1 cm/yr for species of *Goniopora* (Poritidae), *Lobophyllia* (Mussidae) and *Galaxea* (Oculinidae) to a minimum of about 0.5 cm/yr for most other taxa including the majority of faviids.
- (r) Partial and total colony mortality via predation, overgrowth or sedimentation reduced the mean growth of massive coral populations to less than their radial growth rates.
- (s) Massive corals on reefs unaffected by crown-of-thorns starfish exhibited adult-dominated population structures with most colonies being >10 cm and



many >50cm in diameter. The large corals are likely to be at least 50 years old. By contrast, massive coral populations on reefs which have experienced major outbreaks of *A. planci* were generally dominated by recruits <10 cm in diameter.

- (t) Massive coral communities subject to intense predation by *A. planci* declined in both species richness and abundance for up to four years following outbreaks. For example, approximately 60% of massive corals were killed outright on Holbourne Island Reef during the *A. planci* outbreak and about half of the surviving corals sustained injury to >30% of their colony surfaces. The initial high survival of remnants of many species declined over the first four years following the outbreak, with a 50% loss in the first year, due to overgrowth by other sessile benthos and predation by residual starfish populations.
- (u) Partial predation of massive corals by *A. planci* can result in distinctive growth anomalies on these colonies. the continued growth of remnant coral patches is generally three-dimensional (*ie.* there is little spread back across the dead coral surfaces).
- (v) Reefs which experienced major outbreaks generally exhibited low detectable recruitment for 3 years following predation. After 3 years, recruitment rates in most reef areas increased markedly, principally via the appearance of fast-growing acroporids and pocilloporids. Apart from poritids, recruitment by massive corals remained comparatively low 4 years following outbreaks. Increasing recruitment became apparent 5-7 years following predation, particularly for *Porites*, the faviids and mussids.
- (w) Reefs which experienced less intense massive coral predation exhibited substantial recruitment by massive corals 2-3 years after outbreaks. Results suggest that starfish outbreaks of different intensity can have quite different ecological effects, favouring either opportunists or slow-growing species.
- (x) Initial simulations of coral recovery on reefs subject to major outbreaks indicate that populations of most taxa of massive corals are unlikely to restore large colonies under an intense, recurrent outbreak regime with a return period of <20 years, irrespective of rates of recruitment in the interim period.

## Biology

### Reproduction

- (a) About 100 crown-of-thorns starfish were observed spawning in synchrony at approximately 0930 on Friday 7 December 1990 at Davies Reef. Most of the starfish were aggregated, occurring in small clusters of 2-3 individuals over a distance of about 100m. Prior to spawning the starfish sought prominent locations, climbing onto coral heads and rocky outcrops. Most adopted a bell-shaped posture when releasing gametes.

- (b) Another three starfish (all males) were observed to spawn approximately 10 days after this event.
- (c) The following results were obtained in relation to Gonad Index (*ie.* ratio of gonad tissue body size):
- \* it increased slowly (to about 10%) until a few weeks before the mass spawning event.
  - \* it then increased rapidly reaching a maximum of about 20%.
  - \* it was larger in females than males.
  - \* it had declined by about 50% after the mass spawning event.
  - \* a further increase and decline was recorded, suggesting that another mass spawning event may have taken place. However, none was observed.
- (d) Fertilisation success was high (80% - 90%) between individuals located within a few metres of each other. This figure declined to about 60% at 10m, 40% at 16m, 30% at 30m and 20% at 60m.
- (e) Extracts of gonads were found to induce spawning of several individuals.

### Growth

- (f) Primary spine growth occurs in aboral spine ossicles by elongation from the base of the ossicle at the junction with the pedicel ossicle which together forms the spine appendage.
- (g) Morphometric analyses from time-series population subsamples show annual growth in spine ossicles obtained from the mean spine length of individual starfish, but no significant growth in whole body diameter for the population. This suggests that body size frequency analyses, the traditional age determination method used for this species, is unreliable for post-maturity populations.
- (h) Quantification of fluorescent age pigments in chloroform and methanol extracts obtained from pyloric caecum tissues show no correlation with spine ossicle length or spine pigment bands. Seasonal cell turnover in this tissue is likely to reduce the accumulation of these pigments with age.
- (i) There is a strong negative correlation between the number of spine pigment bands and fecundity which has been adjusted to remove the confounding influence of body size. Individuals with long spines and >2 pigment bands have significantly lower fecundity for similar body sizes.



## Hydrodynamics, recruitment and terrestrial inputs

- (a) A total of 14 juvenile crown-of-thorns starfish, ranging in size from 5 to 15cm in diameter, were observed during surveys carried out on 14 reefs between Townsville and Shute Harbour. Small feeding scars were found to be unreliable indicators of the presence of these small starfish. About 32% of all scars were directly attributed to the activity of the gastropod *Drupella*.
- (b) Larval dispersal and reef connectivity patterns have provided a physical explanation for:
- \* the general southward spread of *A. planci* outbreaks;
  - \* the high incidence of outbreaks on mid-shelf reefs;
  - \* the high susceptibility of particular reefs to repeated outbreaks; and
  - \* the apparent cessation of outbreaks in the southern part of the Central section of the GBR.
- (c) Hydrodynamic models have also led to the identification of a region which is proposed to be the source of *Acanthaster* outbreaks which from time to time propagate southwards.
- (c) Varying the initial dimensions of the particle cloud can produce noticeable differences in the relative strengths of connections between a source reef and each of its sink reefs.
- (d) Alternative approaches to simulating the effect of temporal variation of the wind can sometimes produce substantial differences in the trajectories in individual dispersal events.
- (e) Monitoring of cots on Fijian reefs has provided a number of important observations:
- \* recruitment was very patchy in time and space;
  - \* macroscale recruitment events resulted in outbreaks over many thousands of hectares over 100km of coastline whereas localised but intensive mesoscale events resulted in concentrated aggregations over areas of several tens of hectares;
  - \* a very low level of recruitment occurred in most years, but three intensive, macroscale recruitment events occurred in 1977, 1984 and 1987 and two localised but intensive recruitment events occurred in 1982 and 1983.
  - \* annual recruitment between 1975-89 had no overt relationship with rainfall events as proposed in the terrestrial run-off hypothesis on the cause of primary outbreaks.
  - \* growth and mortality rates within monitored cohorts were highly variable;
  - \* longevity of cohorts ranged from 2-8 years;
  - \* there is no invariable pattern or process involved in the population dynamics of *A. planci* and a single explanation of the phenomenon is unlikely.

## Predation

- (a) Mass culturing techniques produced approximately 10,000 juvenile starfish during the 1990/91 spawning season. This represents an order of magnitude increase over the previous year. In general, it was found that while the survival of larvae was high only a low proportion ever attained the competency to settle.
- (b) The rate of survival of newly settled starfish was found to increase with age in the laboratory. Mean survival rates for starfish aged 14 days, 50 days and 420 days (after settlement) over a period of 100 days was 10%, 48% and 84% respectively. Subsequent survival to 220 days was high for all ages. These results suggest that mortality of juvenile starfish is probably high initially after settlement but that it stabilises to a lower level.
- (c) Losses of small starfish (1-2cm diameter) were significant when exposed to benthic treatments containing crabs. No direct predation however, was observed.
- (d) Natural coral rubble habitats are likely to contain a range of hazards which result in the death of significant numbers of small starfish. Recovery of these starfish after 6 days in the field cages containing natural coral rubble (and attached epibiota) was 62% compared with 92% in control cages.
- (e) The growth rate of juvenile crown-of-thorns starfish varied enormously over a four month period. Food type accounts for this large difference. Those that were fed *Seriatopora hystrix*, *Pocillopora damicornis*, *Stylophora pistillata* and *Acropora formosa* achieved the most superior growth rates (6-8 mm/month), while those fed *G. retiformis*, *P. lichen* and *P. lutea* grew slowest (0.2-0.7 mm/month).
- (f) Approximately 10 species of animal have been observed to prey upon *A. planci* in the field by a large number of scientists and other reef experts. The most prominent predator is clearly the giant triton, *Charonia tritonis*, with maori wrasse, *Cheilinus undulatus*, being the second most common predator.
- (g) The low frequency of observed predation events (one every 72 hours on 'outbreaking reefs' and one every 1,284 hours of diving on 'non-outbreaking reefs') indicates that long periods of time are required to produce substantial numbers of field observations and this may be a constraint in future predator studies.
- (h) In Western Samoa, according to anecdotal reports, outbreak episodes probably occurred prior to the first documented outbreaks in 1969 (possibly 1916, 1932/33 and 1950), suggesting recent fishing pressure (of predators) may not be a valid explanation of outbreaks in that area.



## FUTURE RESEARCH DIRECTIONS

The following discussion outlines possible future directions of research currently being funded through the COTSREC program as well as some new areas that warrant investigation. Many of the currently funded projects were envisaged as three year studies.

The list is not exhaustive, but is intended as a guideline to indicate major directions and to highlight the need for continuity of funding. COTSREC, at its scheduled meeting in May 1991, will be re-evaluating research priorities and future directions.

Annual broadscale surveys of the GBR have been conducted for almost 6 years. Over that time there has been an appreciable increase in our understanding of the extent of the crown-of-thorns problem. Regular and standardised monitoring of large ecosystems are critical both for improved scientific understanding and management.

It is just as important to monitor crown-of-thorns starfish when they are present in low numbers as well as when there are large (outbreaking) populations. Consequently, the monitoring that is underway needs to continue even though the activity of the starfish is declining. Consideration therefore needs to be given to perhaps broadening the basis for monitoring and building it within a framework of the general requirements of the Authority. This will require a firm commitment for substantial funds in the long term. Research currently being funded from the Research and Monitoring Section's budget together with COTSREC funds (Mapstone *et al.*) is investigating methodologies that will provide the necessary information most effectively and efficiently. While the manta tow technique is appropriate for broadscale reconnaissance, other methodologies (*eg.* line and belt transects) are necessary to obtain the precision required for most management purposes.

Further studies to investigate the influence of observer training, learning and experience on estimates of starfish abundance, live and dead coral cover may help to improve the precision of the manta tow technique.

Similarly monitoring of coral recovery and crown-of-thorns starfish recruitment on Green Island reef (Fisk) is now in its fifth consecutive year and requires a long-term commitment. There are no comparable whole-reef studies on the GBR on this time scale in this amount of detail. Ongoing monitoring in future years is essential to follow the dynamics of the slower growing massive corals and less opportunistic species.

Initial delays in funding and recruiting suitable personnel has meant that most projects have been underway for just over 12 months. Some time-critical projects (*eg.* AIMS Tasks 6.1.5 and 6.1.6) were not able to make full use of the 1989/90 spawning season. Indeed, the season had almost passed by the time these projects were fully operational. This has retarded their progress by almost a year since it was hoped they could make use of that spawning season to undertake preliminary experiments and test facilities. Many of these were subsequently conducted in the 1990/91 season. Given this and the fact that research is expected to be completed by

June 1992 (the current commitment from the Federal Government for future cots research) it is suggested that funding be given to extend these projects so that they are able to make use of the spawning season in the 1992/93 fiscal year. Such extensions would have substantial benefits in terms of results produced and in the light of substantial funds already invested.

On a more pragmatic level, a commitment exists to fund a number of projects for a maximum period of three years. In some cases (eg. AIMS Task 6.2.1, the Choat & Musso study of bioerosion and Dr Sweatman's postdoctoral fellowship) the commitment extends beyond the duration of the presently assured funds (1991/92).

In the first two years of its operation, COTSREC has given priority to research investigating the role of predation in regulating crown-of-thorns population densities over other proposed hypotheses. With recent research suggesting significant impacts on the Reef from terrestrial runoff, there is increasing evidence for alternative explanations of outbreaks, including enhanced survivorship of starfish larvae as a result of increased nutrient levels in the GBR lagoon. Earlier experimental work in this area was inconclusive and there is a need to expand on this work to investigate larval nutrition. Research in this area is planned for 1991/92, however, it is unlikely that the issue will be resolved in the remaining 12 months of the COTSREC program. The scale of the task necessitates funding in the order of \$100,000 over a minimum period of two years.

The Geological Working Group established by COTSREC is having its second meeting later this month. A budget of \$20,000 was allocated to the group for its operations and to commission pilot studies aimed at resolving this most contentious question. The Authority's current management policy that widespread controls should not be attempted until it can be shown that human activity is responsible for causing or exacerbating outbreaks relies heavily on the acquisition of evidence for previous outbreaks over geological time. Further research in this area will be undertaken in 1991/92 following pilot studies, but it is likely these will require funding into the following fiscal year.

Large-scale hydrodynamic modelling has provided a physical explanation of many of the observed (coarse) patterns of cots outbreaks. Further testing of these models, in particular attempting to resolve apparent anomalies in the general southward spread of outbreaks and prediction of the outcomes of specific spawning and dispersal events, is envisaged. Extension of the models to the Central Section of the Marine Park would also be extremely instructive, given the predominance of affected reefs in this area.

Hydrodynamic modelling on finer (reef) scales has further assisted our understanding of dynamics (larval retention and recruitment). Linking of large and fine scale models (or compressing large-scale hydrodynamic data at a finer scale of resolution) is regarded as a critical area for future research.



## ADMINISTRATION AND FINANCE

Funds of \$750,000 and \$1 million (indexed) have been provided by the Federal Government for the Authority's crown-of-thorns research program in 1989/90 and 1990/91 respectively. Salaries of the three Authority staff (Coordinator, Project Manager and Science 1) are paid out of this allocation, as are operational costs of the COTSREC, its working groups and workshops.

Budget allocations for projects are given in Table 1. Allocations to AIMS appear as a single line item and are broken down in Table 2.

A total of \$1,033,685 was allocated for crown-of-thorns research at AIMS for the 1989/90 (\$459,000) and 1990/91 (\$574,685) fiscal years. During 1989/90 the Authority also allocated \$16,000 for the Ph.D. project being undertaken by Mr L. DeVantier (which is administered by AIMS) and another \$5,000 was allocated to support research within Task 6.2.2 (Impact of crown-of-thorns starfish on interactions among space occupants of coral reefs: predictive models of coral reef community structure) from unspent funds.

AIMS' crown-of-thorns budget allocation over the last 18 months have been spent mainly in the following areas:

1. Approximately 60% was spent on salary-related items: this includes \$407,762 for base salaries; \$8,721 for diving allowances; \$22,635 for compulsory superannuation (calculated as 3% of gross salaries); and \$3,924 for recreation leave fare entitlements. Funding was insufficient to allow staff to join the commonwealth Superannuation Scheme.
2. About \$23,453 was spent on meeting the costs associated with travel for staff to undertake field research. Of this amount, \$11,184 was used by Dr. Keesing to undertake collaborative research in Japan.
3. A further \$44,995 was spent on stores and consumables for all projects within the Study. A relatively small amount of capital equipment (\$10,007) was purchased to upgrade the seawater system used to hold starfish and culture larvae.
4. The Study puts a large drain on the resources of AIMS. To offset this, on-costs are paid (ca. 20% of base salary) to cover infrastructure costs. To date, about \$85,006 (11.5%) has been paid in the form of on-costs to the Institute.
5. A significant amount of funds (\$18,785) was used in the maintenance and hire of vehicles to transport staff to and from the Institute. This is a requirement of all externally funded projects and is part of the terms and conditions of employment for all staff.
6. Other significant areas of expenditure to date include contract labour (\$32,710), research grants (\$30,000), external ship charter (\$14,750) and publications (\$9,432).

**Table 1.** Funds allocated to projects under the Authority's COTSREC research program during the 1989/90 and 1990/91 fiscal periods. A dash indicates where funds were not requested or allocated.

Cost Code	Project	1989/90	1990/91	Total
	GBRMPA staff salaries	95,500	110,000	205,500
F10024	Publications	5,000	2,500	7,000
F10077	Travel & subsistence <sup>a</sup>	20,000	20,000	40,000
F10094	Chairperson's retainer	5,000	5,000	10,000
F10099	Incidentals <sup>a</sup>	8,000	10,000	18,000
F10102	AIMS component	459,000	574,685	1,033,685
F10103	Interactive aquarium display (Kettle)	6,000	5,000	11,000
F10104	Population dynamics Fiji (Zann)	5,670	4,000	9,670
F10106	Pacific databases (Zann)	5,213	4,000	9,213
F10110	Green Island monitoring (Fisk)	23,000	27,430	50,430
F10119	Mainland runoff (Rasmussen & Hopley)	10,000	-	10,000
F10137	Massive coral dynamics (DeVantier)	18,000	5,000	23,000
F10138	Predation anecdotes (Kettle)	2,000	-	2,000
F10139	Manta tow bias (Marsh et al)	11,500	28,000	39,500
F10140	Cairns section survey (Mapstone et al)	35,000	20,000	55,000
F10141	Coral trout surveys (Ayling)	6,090	-	6,090
F10142	Age determination (Lucas & Stump)	33,750	41,000	74,750
F10143	Large scale models (James)	36,000	30,000	66,000
F10144	Fish predation post-doc (Sweatman)	50,000	50,000	100,000
F10145	Triton ecology (Gladstone)	10,000	5,000	15,000
F10146	Predation models (McCallum)	23,037	22,000	45,037
F10147	Fund raising feasibility study (Curran)	10,000	-	10,000
F10148	Bioerosion (Choat & Musso)	-	15,000	15,000
F10149	Oceanography review (Black)	-	13,500	13,500
F10150	Geology working group (Kinsey)	-	20,000	20,000
<b>TOTAL</b>		<b>877,760<sup>b</sup></b>	<b>1,012,115</b>	<b>1,889,875</b>

<sup>a</sup> Unspent funds from these items have been re-allocated to research projects, *eg.* AIMS Crown-of-thorns Study Tasks 6.1.1 (to maintain continuity) and 6.2.2 (subsidiary funding) or carried over into following fiscal periods as unspent, uncommitted funds.

<sup>b</sup> The total allocation from the Federal Government for 1989/90 was \$750,000. Cash carried forward from the previous year (the COTSAC program) totalled \$159,564. Of this total, \$52,519 was committed to the completion of eleven COTSAC projects, the remaining uncommitted \$107,075 was added to the 1989/90 COTSREC budget to give a total of \$857,075. The difference between this figure and the total budget for 1989/90 shown above (-\$20,685) was carried over into 1990/91 for payment from that year's budget.



**Table 2.** Funds allocated to Tasks within the AIMS Crown-of-thorns Study during 1989/90 and 1990/91 fiscal periods. A dash (-) indicates where funds were not requested.

Task No.	1989/90		1990/91		Total	
	GBRMPA	AIMS	GBRMPA	AIMS	GBRMPA	AIMS
6.1.1	203,123	72,000	220,221	80,000	423,344	152,000
6.1.2 <sup>a</sup>	-	9,600	-	-	-	9,600
6.1.3	20,000	35,690	-	-	20,000	35,690
6.1.4	4,000 <sup>b</sup>	4,051	-	4,216	4,000	8,267
6.1.5	67,271	10,500	93,639	19,500	160,910	30,000
6.1.6	40,417	-	105,727	19,500	146,144	19,500
6.1.7	146,764	39,871	155,098	51,717	301,862	91,588
6.2.1	-	-	13,500 <sup>c</sup>	115,394	13,500	115,394
6.2.1	-	-	10,000 <sup>d</sup>	-	10,000	-
<b>TOTAL</b>	<b>481,575<sup>e</sup></b>	<b>171,712</b>	<b>598,185<sup>f</sup></b>	<b>290,327</b>	<b>1,079,760</b>	<b>462,039</b>

<sup>a</sup> support for this project covered within Task 6.1.1

<sup>b</sup> funds carried forward into 1990/91 due to delays in research

<sup>c</sup> funds carried forward from previous fiscal year

<sup>d</sup> \$5,000 from previous fiscal period, remainder provided by GBRMPA from unspent funds

<sup>e</sup> total allocation by GBRMPA \$459,000; additional \$16,000 given to support Ph.D. research by DeVantier, \$6,575 uncommitted funds

<sup>f</sup> total allocation by GBRMPA \$574,685

The Institute also puts considerable resources into the Study. Notional figures for each project are given in Table 2. Most of this support comes in the form of shiptime, computing, staff and stores. Over the last 18 months the Institute provided 250 days of shiptime (39 cruises) for research tasks within the Crown-of-thorns Study. Approximately 85% of this time was allocated on the RV Sirius. The Institute also provides large amounts of specialised equipment (*eg.* Remote Operated Vehicle, computers spectrophotometers, freeze dryers) without charge. As well, it has paid for the visits of several scientists from overseas (*eg.* Dr J. Lawrence, University of South Florida) under its Visiting Investigators Program.



## REPORTS AND PUBLICATIONS

The following reports and publications report on research conducted with financial support through the Authority's crown-of-thorns starfish research program and from the AIMS crown-of-thorns Study. Some studies were commenced prior to the COTSREC program (in most cases with funding through the COTSAC program), but all reports were published after June 1989.

**AIMS (1990)** Report of field surveys of juvenile crown-of-thorns starfish. Final report to GBRMPA, March 1990. 23pp.

**Antonelli, P.L. (1990)** Applied Volterra-Hamilton systems of Finsler type: increased species diversity as a non-chemical defense for coral against the crown-of-thorns. In: Bradbury, R.H. (ed.), *Acanthaster* and the coral reef: a theoretical perspective. Springer-Verlag, Berlin. pp220-235.

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**Antonelli, P.L., Kazarinoff, N.D., Reichelt, R.E., Bradbury, R.H. and Moran, P.J. (1990)** A diffusion-reaction transport model for large-scale waves in crown-of-thorns starfish outbreaks on the Great Barrier Reef. In: Bradbury, R.H. (ed.), *Acanthaster* and the coral reef: a theoretical perspective. Springer-Verlag, Berlin. pp45-53.

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**Babcock, R.C. (1990)** Spawning behaviour of *Acanthaster planci*. *Coral Reefs* 9: 124.

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- Black, K.P., Gay, S.L. and Andrews, J.C.** (1990) Residence times of neutrally-buoyant matter such as larvae, sewage or nutrients on coral reefs. *Coral Reefs* 9: 105-114.
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## APPENDIX 1

COMPILATION OF THE  
MAJOR FINDINGS AND RECOMMENDATIONS OF ANDERSON'S REVIEW OF  
THE CROWN OF THORNS STARFISH RESEARCH PROGRAM

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 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.

## APPENDIX 2

MEMBERS OF THE CROWN-OF-THORNS STARFISH RESEARCH COMMITTEE  
(COTSREC)

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