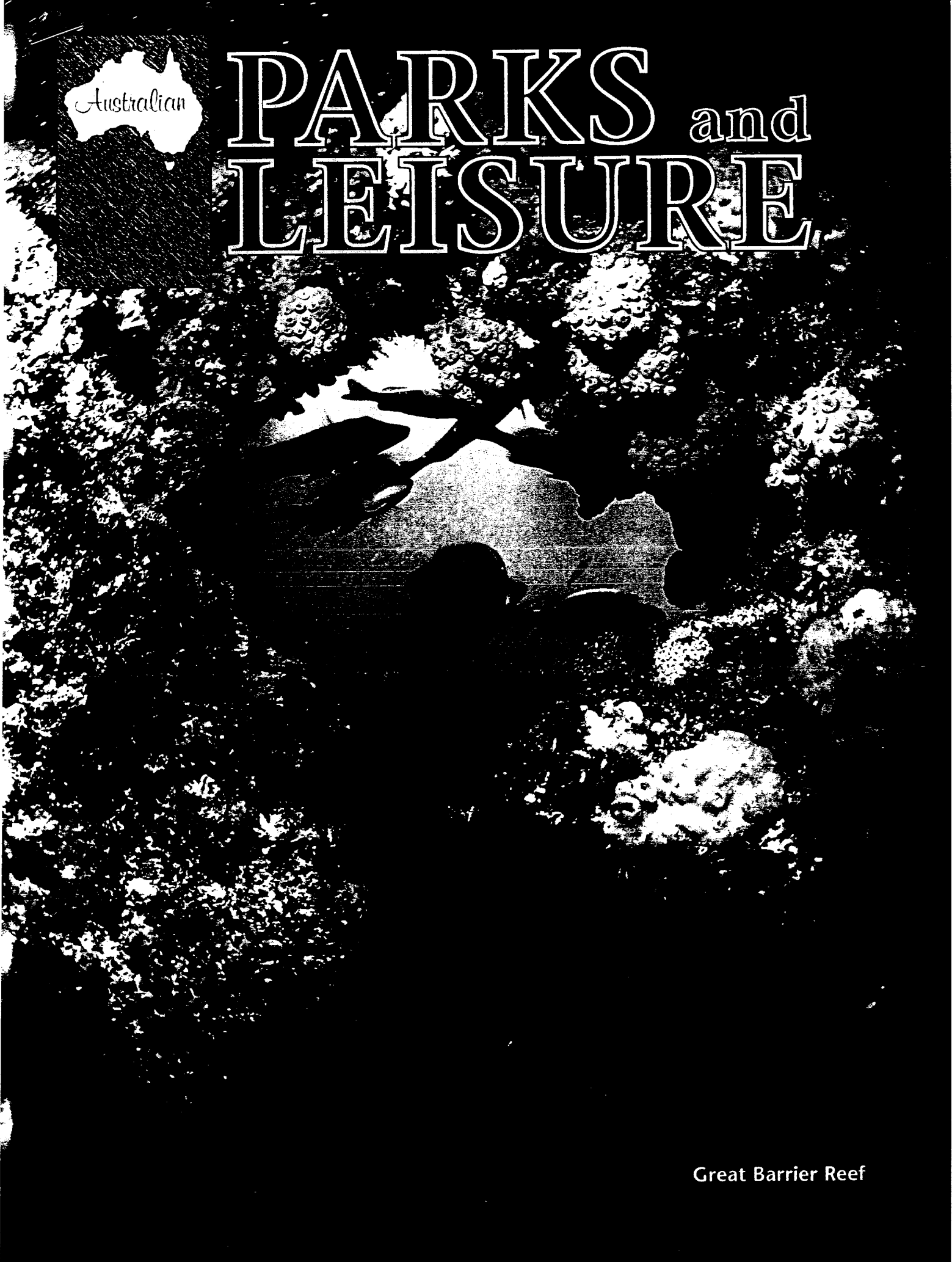


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Great Barrier Reef

VOLUME 1, No. 3

Registered by Australia Post PP 232100/00045

MARCH 1999

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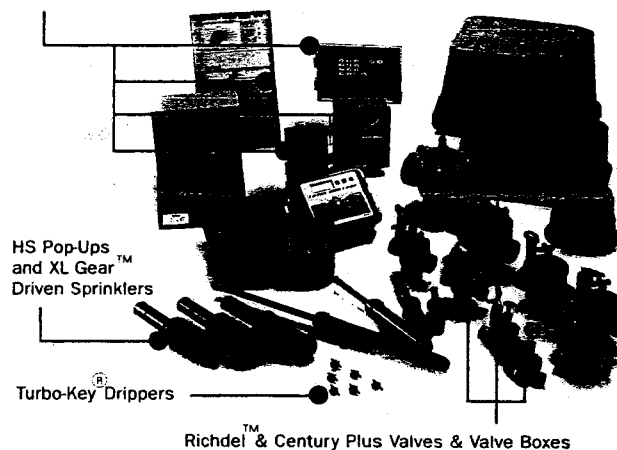
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What do
you mean

"There's an outbreak of
crown-of-thorns starfish
on the Great Barrier Reef?"

Leanne Fernandes
Peter J. Moran and
Helene Marsh

INTRODUCTION

Large aggregations of the Crown-of-Thorns starfish (*Acanthaster planci*) have caused extensive coral mortality in reef systems in Australia as well as around the Indo-Pacific region (Devaney and Randall 1973, Birkeland 1982, Moran 1986, Yamaguchi 1986). Such population aggregations have been labelled "outbreaks", synonymous with aggregations of insects also termed "outbreaks" (Chesher 1969, Barbosa and Schultz 1987). The term "outbreak" has been defined based mainly upon the criterion of population density or size (Endean and Stablum 1975, Pearson and Garrett 1976, Barbosa and Schultz 1987). However, many workers recognise the inadequacy of a single criterion upon which to identify an outbreak (Potts 1981, Moran 1986, Keesing and Lucas 1992, Moran and Death 1992b). Since 1985, the Australian Institute of Marine Science (AIMS) has used more comprehensive criteria in an informal decision-making process classifying outbreak and non-outbreak populations of Crown-of-Thorns starfish (Moran et al 1988). Extensive research has since been conducted, and management decisions made, in Australia based on outbreaks of starfish as defined by experts at AIMS (Moran and Davies 1989, Birkeland and Lucas 1990).

As for insect outbreaks, biological classification schemes which distinguish the threshold between outbreak and non-outbreak populations of Crown-of-Thorns starfish have received little attention. This is partially due to a dearth of comparative data on non-outbreaking populations of the species in question (Nothnagle and Schultz 1987, Birkeland and Lucas 1990). Outbreaks also vary spatially and temporally (Dana et al. 1972, Moran 1986, Berryman 1987, Reichelt et al. 1989, Moran and De'ath 1992). Consequently, there is no generally accepted biological definition of the threshold for

outbreaks of Crown-of-Thorns starfish (Moran 1986). Although the biological definition remains elusive, working definitions of outbreaks have been developed and used for summarising the distribution and status of different starfish populations.

To date, the working definitions of Crown-of-Thorns starfish outbreaks have been many, ambiguous and/or limited. For example, Chesher (1969) provided seven different and inconsistent descriptions of normal versus outbreak populations of Crown-of-Thorns starfish (Dana et al. 1972). Bass et al. (1989a), Bass et al. (1989b) and Baker et al. (1990) defined an outbreak somewhat ambiguously: "large numbers of starfish (generally greater than 40 per reef) and extensive hard coral mortality". The meaning of "extensive" was not clarified, the size of reef was not considered and sometimes the threshold of 40 was not applied. Other workers have specified a number of Crown-of-Thorns starfish per unit area even though the techniques used did not sample any measured area (Pearson and Endean 1969, Dana et al. 1972). Recently, Moran and De'ath (1992b) suggested that average counts of 0.22 starfish per manta tow (covering roughly a 200m long by 10m wide area) on a reef may be indicative of an outbreak. They also noted that the abundance of starfish per se is not necessarily a reliable indicator of an outbreak (Moran and De'ath 1992b).

Despite these problems, descriptions of the distribution and abundance of outbreaks of Crown-of-Thorns starfish, and other outbreaking species, are used to inform managers as well as the general public and government agencies (Great Barrier Reef Marine Park Authority 1984, Great Barrier Reef Marine Park Authority 1985, Berryman and Stenseth 1989, Pedigo 1989). Researchers also use the data to identify the pattern of outbreaks and to direct further studies aimed at understanding the phenomenon (Barbosa and Schultz 1987, Moran et al. 1988; Dight et al. 1990; Reichelt et al. 1990, Moran et al. 1992). It is important that the working definition of outbreak be made transparent,

rigorous and repeatable. The present research fulfils this need.

We developed a system for classifying reefs on the Great Barrier Reef (GBR), Australia, in terms of the population status of *Acanthaster planci*. The definition documents and formalises the expert-opinion based on a classification system used by the AIMS for almost a decade. As such, it introduces transparency to the term "outbreak" as used in the substantial amounts of work on the phenomenon in Australia. This study provides a framework upon which to build definitions of Crown-of-Thorns starfish outbreaks in all parts of the world and a basis for comparison with outbreaks in different areas or with surveys using different methods.

METHODS: DEFINING THE BASIS FOR THE DECISION CRITERIA

Data used

We used information from reefs surveyed by the AIMS Crown-of-thorns Study Broadscale Survey team using the manta tow technique (Baker et al. 1991). This technique involves towing snorkel divers behind a dinghy around the perimeter of each reef. During each two minute tow a snorkeller visually records information on Crown-of-Thorns starfish abundance and coral cover (Moran et al. 1989). These data have been used, informally, for many years to determine the status of reefs with regard to starfish outbreaks on the GBR (Johnson et al. 1988; Moran et al. 1988).

All data from complete, standard AIMS manta tows collected between 1985 and 1990 were used in the formalisation of the decision process and generation of Table 1 (622 records). Details of the manta tow method are described in Moran et al. (1989).

Reef classification with regard to outbreaks of Crown-of-Thorns starfish

The categories of reef classification which AIMS have used are:-

Active outbreak (AO) = the reef is supporting an active outbreak of starfish. This category indicates

relatively large numbers of starfish causing extensive hard coral mortality.

Recovering (RE) = the reef is recovering from an outbreak. This refers to post-outbreak reefs where extensive areas of dead hard coral remain and possibly above normal numbers of residual starfish.

No outbreak (NO) = the reef shows no evidence of an outbreak (Bass et al. 1989a; Baker et al. 1990).

We retained these categories as the classification alternatives as they satisfy the needs of the users of the data (e.g. managers, public, scientists) and provide for consistency. One aim is to clarify the ambiguity of the adjectives used in the definitions (e.g. relatively large, extensive).

Criteria by which Crown-of-Thorns starfish surveys of reefs are categorised

Since 1985, AIMS used several criteria informally to identify outbreaks populations of starfish: the number of starfish in relation to the size of the reef; total number of *A. planci* per reef; estimates of live and dead coral cover; and the degree of aggregation of Crown-of-Thorns starfish. We retain these criteria but used statistical estimates to formalise the population parameters:

- 1) the mean number of starfish per manta tow is used as an index of the total number of starfish on a reef in relation to the size of the whole reef and
- 2) on each reef the variance to mean ratio (VMR) of the number of Crown-of-Thorns starfish per manta tow is used as an index of the degree of aggregation of starfish on the reef.

Data on live coral cover and dead coral cover was recorded by manta towed observers within the following levels:

These levels were used directly within

0	0
1	1-10
2	11-30
3	31-50
4	51-75
5	76-100

the formalised decision key. Definitions of live and dead coral cover are provided in Moran et al (1989) and Fernandes (1991).

Determining threshold values of the decision criteria

Classification of reefs with regard to outbreaks depends upon the Crown-of-Thorns population size and coral cover. The levels at which one distinguishes between one classification and another is by application of "threshold" values.

Of the total data used to define thresholds of the decision criteria, 134 records had been classified, using the informal assessment process, as AO reefs, 240 as RE reefs (of which 58 had counts of *A. planci*) and 248 as NO reefs (of which 123 had counts of *A. planci*). Investigation of the level of each of the decision criteria within each category of "outbreak" status enabled us to formally identify and define the decision criteria which had been used. For example, we found that all of the reefs labelled as active outbreak averaged more than 0.5 Crown-of-Thorns starfish per manta tow. Thus, 0.5 Crown-of-Thorns starfish per manta tow on a reef became one of the thresholds of the decision criteria in the decision key. Other thresholds were developed similarly. The decision criteria and thresholds were organised in the form of a key and adjusted until they matched both the process used by the expert (project leader and second author) and the recorded classifications.

Some discrepancies were noted between the formalised decision criteria developed and the actual classification of reefs. For example, one reef with a count of no Crown-of-Thorns starfish was labelled as an outbreaking reef due to data collected on SCUBA by the AIMS BroadScale Survey team during that same field trip. Consequently, where external data sources influenced the categorisation of a reef, explicit reference to those sources is required in the decision key.

Distinguishing between reefs which should be categorised as recovering versus categorised as having no

current evidence of an outbreak can be difficult. Previous surveys of reef can indicate whether that reef has suffered from an outbreak or not. If this data is not available, one can compare the live and dead coral status and Crown-of-Thorns starfish populations with "no outbreak" reefs in the same sector of the GBR and cross shelf position (inner, mid and outer shelf (Table 1). If the reef in question has more starfish and dead coral and less live coral than the "no outbreak" reefs, for example, then it would be classified as a recovering reef. The sectors and cross shelf position referred to are those used by AIMS (Baker et al 1991, Moran et al 1991). A summary of conditions on "no outbreak" reefs in each of the different sectors and cross shelf positions on the Great Barrier Reef is outlined in Table 1.

Comparing the decision key with the previous classification system

The decision key was applied to empirical data. The ease of application was considered in terms of the clarity of the questions posed and the possibility of answering the questions unambiguously. The purpose of the key was to define the decision rules which experts at AIMS have used to classify reefs. If the classification achieved by the key matched that arrived at by expert assessment then the key serves its purpose. In all 622 cases, classification by the formalised key matched that achieved by expert opinion. The decision rules had, therefore, been correctly identified and formalised.

RESULTS

The decision key illustrated in Fig. 1 is the result of application of all the information available on reefs of the Great Barrier Reef (GBR) which were manta towed by the AIMS BroadScale Survey team (1985-1990). In distinguishing reefs which are recovering and reefs which have no evidence of an outbreak, using the second last question in the key, the 95% confidence limits in Table 1 should be used. Thus, the condition "Total COTS > No outbreak" asks: Is the present number of Crown-of-Thorns starfish more than the upper

95% confidence limits of no outbreak levels? In testing the key, the decision criteria were found to be clear and unambiguous.

The use of the key can best be understood by application. For this purpose we provide hypothetical (but realistic) data for five reefs in Table 2. Reefs Alpha and Beta classify quickly to active outbreak and no outbreak status. These reefs are typical of the majority of reefs found on the GBR. Data presented for reefs Gamma, Delta and Epsilon are less typical and far more ambiguous. For reef Gamma, the variance to mean ratio indicates that the starfish were aggregated and the mean number of starfish per manta tow are borderline indicating a possible classification as "active outbreak". However, by the decision key, the total number of starfish and dead coral cover in the presence of starfish are both less than the threshold. Given that there is no other information on this reef it is classified as "no outbreak". For reef Delta, three of the four criteria required for classifying a reef as supporting an outbreak are marginally satisfied at the second branch of the decision tree thus the reef can be unambiguously labelled as "active outbreak". Reef Epsilon does not have an outbreak but does have previous reliable information (in the form of previous AIMS manta tow data) indicating that an active outbreak did occur here recently. The distinction to be made now is whether the reef is in recovery or whether it no longer has evidence of an outbreak. As there is no standard AIMS manta tow data on this reef prior to outbreak status, data are compared with reefs in the Townsville sector and mid-shelf position (Table 1). This comparison indicates that, although the starfish population seems to be within normal levels, the live and dead coral cover has not yet recovered to normal levels. The live coral cover is normally higher and dead coral cover should be lower. Thus, reef Epsilon is a "recovering" reef.

DISCUSSION

The decision key introduces consistency and transparency to the classification system used by experts at AIMS for labelling reefs with

regard to outbreaks of Crown-of-Thorns starfish on the Great Barrier Reef (GBR). The framework and criteria of the decision tree can be transferred to other parts of the world which support populations of Crown-of-Thorns starfish. The specific thresholds within criteria used here are applicable only to: (a) the AIMS manta tow sampling technique and (b) the GBR. With different data sampling techniques a different proportion of the population may be sampled thus demanding different threshold levels for criteria such as "Mean number of Crown-of-Thorns starfish counted per manta tow on a reef". For example, if the starfish data were collected using SCUBA gear then relatively higher counts of starfish per unit search effort would define an outbreak within this decision key. This is due to the larger proportion of starfish which would be available and counted using this technique (Fernandes 1990, Moran and De'ath 1992a). Keesing and Lucas (1992) mention that feeding rates of Crown-of-Thorns starfish vary between regions. Consequently, different absolute numbers of starfish might be considered an outbreak in different regions based upon the amount of coral mortality associated with each population. Thus, the thresholds within the criteria used, including coral cover criteria, would need to be generated based on local information.

Crown-of-thorns starfish tend to occur most often in either very high or extremely low densities (Dana et al. 1972, Moran 1986, Moran and De'ath 1992b). The key will be most useful when intermediate densities of starfish are found and borderline decisions must be made. The key assists in clarifying the "grey" areas of the decision-making process.

This key will facilitate exploration of the utility and validity of the, previously undocumented, AIMS classification scheme for outbreaks of Crown-of-Thorns starfish on the GBR. As suggested by Keesing and Lucas (1992), there may be room for improving the criteria used. Perhaps the thresholds of the criteria should be altered. Moran and De'ath

(1992b) suggest that an average density of 0.22 starfish per manta tow might be a more appropriate density of starfish to define an outbreak. They calculate this to equal 1500 starfish counted by SCUBA dives per km². This is higher than the 1000 starfish km⁻² number suggested by Keesing and Lucas (1992) especially considering that Moran and De'ath referred to SCUBA estimates and Keesing and Lucas to absolute numbers. Our suggested average density of starfish counted per manta tow within an outbreak is greater still than that suggested by Moran and De'ath (1992b) (i.e. 0.5 or 1.0). However, if a smaller population is aggregated with high dead coral cover then the reef would still be classified as supporting an active outbreak by the present classification scheme. Use of coral cover criteria, as we have done, was recommended by Moran and De'ath (1992b) to mitigate potential misclassifications.

By clarifying the working definition used by researchers and managers on the Great Barrier Reef, we hope to stimulate a more critical assessment of the biological meaning of *Acanthaster planci* outbreaks and to facilitate international understanding and comparison of research results.

ACKNOWLEDGMENTS

Thanks to the AIMS COTS Survey and Broadscale Survey manta tow teams and the crews of the RV Sirius, RV Basten and RV Harry Messel who all contributed to the data collection in various ways. Many thanks also to Glen De'ath, Terry Done and Sandra Romano for their constructive comments and V. Baker for extracting information from the AIMS Reef Ecology Database. The work was funded by the Great Barrier Reef Marine Park Authority and COTSREC.

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REFERENCES

- Baker, V.J., Bass, D.K., Christie, C.A., Miller, I.R., Miller-Smith, B.A., Thompson, A.A. & Mundy, C.N. (1990). Broadscale surveys of Crown-of-Thorns starfish on the Great Barrier Reef: 1989 to 1990. The Crown-of-thorns Study. Australian Institute of Marine Science, Townsville.
- Baker, V.J., Moran, P.J., Mundy, C.N., Reichelt, R.E. & Speare, P.J. (1991). A guide to the Reef Ecology Database. 1. Description of data. The Crown-of-thorns Study. Australian Institute of Marine Science, Townsville.
- Bass, D.K., Davidson, J., Johnson, D.B., Miller-Smith, B.A. & Mundy, C.N. (1989a). Broadscale surveys of Crown-of-Thorns starfish on the Great Barrier Reef: 1987 to 1988. The Crown-of-thorns Study. Australian Institute of Marine Science, Townsville.
- Bass, D.K., Davidson, J., Johnson, D.B., Miller-Smith, B.A., Mundy, C.N., Thompson, A.A. & Baker, V.J. (1989b). Broadscale surveys of Crown-of-Thorns starfish on the Great Barrier Reef: 1988 to 1989. The Crown-of-thorns Study. Australian Institute of Marine Science, Townsville.
- Barbosa, P. and Schultz J.C. (eds.) (1987). *Insect outbreaks*. Academic Press, New York.
- Beryman, A.A. (1987). The theory and classification of outbreaks. In *Insect Outbreaks* (P.Barbosa & J.C.Schultz, eds.), pp. 3-27. Academic Press Inc., New York.
- Beryman, A.A. & Stenseth, N.C. (1989). A theoretical basis for understanding and managing biological populations with particular reference to the spruce bark beetle. *Holarctic Ecol.* 12, 387-394.
- Birkeland, C. (1982). Terrestrial runoff as a cause of outbreaks of *Acanthaster planci* (Echinodermata: Asteroidea). *Mar. Biol.* 69, 175-185.
- Birkeland, C. & Lucas, J.S. (1990). *Acanthaster planci*: Major management problem of coral reefs. CRC Press, Boca Raton, FL.
- Chesher, R.H. (1969). *Acanthaster planci*: Impact on Pacific coral reefs. Report to the U.S. Dept. of Interior No. PB187631, Westinghouse Electric Co., Pittsburgh, PA.
- Dana, T.F., Newman, W.A. & Fager, E.W. (1972). *Acanthaster* aggregations: interpreted as primarily responses to natural phenomena. *Pacific Science* 26, 355-372.
- Devaney, D.M. & Randall, J.E. (1973). Investigations of *Acanthaster planci* in southeastern Polynesia during 1970-1971. *Atoll Res. Bull.* 169, 1-23.
- Dight, I.J., James, M.K. and Bode, L. (1990). Modeling the larval dispersal of

- Acanthaster planci* II. Patterns of reef connectivity. *Coral Reefs* 9, 125-134.
- Endean, R. and Stablum, W. 1975. Population explosions of *Acanthaster planci* and associated destruction of the hard coral cover of reefs of the Great Barrier Reef, Australia. *Environ. Conserv.* 2:247-256.
- Fernandes, L. 1990. Effect of the distribution and abundance of benthic target organisms on manta tow estimates of their abundance. *Coral Reefs* 9, 161-165.
- Fernandes, L. (1991) Development of a more robust method for determining the status of individual reefs with respect to outbreaks of Crown-of-thorns starfish (*Acanthaster planci*). Final report to the Great Barrier Reef Marine Park Authority, Townsville, Australia.
- Fernandes, L., Marsh, H., Moran, P.J. and Sinclair, D. (1990) Bias in manta tow surveys of *Acanthaster planci*. *Coral Reefs* 9, 155-160.
- Great Barrier Reef Marine Park Authority (1984). An information kit on the Great Barrier Reef Marine Park. Great Barrier Reef Marine Park Authority, Townsville, Australia.
- Great Barrier Reef Marine Park Authority (1985). The Crown-of-thorns Reef notes. Great Barrier Reef Marine Park Authority, Townsville, Australia.
- Johnson, D.B., Bass, D.K., Miller-Smith, B.A., Moran, P.J., Mundy, C.N. & Speare, P.J. (1988). Outbreaks of Crown-of-Thorns starfish (*Acanthaster planci*) on the Great Barrier Reef: results of surveys 1986-1988. *Proceedings of the Sixth International Coral Reef Symposium* 2, 165-69.
- Keesing, J.K. and Lucas J.S. (1992) Field measurement of feeding and movement rates of the Crown-of-Thorns starfish *Acanthaster planci* (L.). *J.Exp.Mar.Biol.Ecol.* 156, 89-104.
- Moran, P.J. (1986). The *Acanthaster* phenomenon. *Oceanogr. Mar. Biol.* 24, 379-480.
- Moran, P.J., Bradbury R.H. & Reichelt, R.E. (1988). Distribution of recent outbreaks of the Crown-of-Thorns starfish (*Acanthaster planci*) along the Great Barrier Reef: 1985-1986. *Coral Reefs* 7, 125-127.
- Moran, P.J. & Davies S. (1989) *Acanthaster planci*: an annotated bibliography. 3rd Edn. Australian Institute of Marine Science, Townsville.
- Moran, P.J. & De'ath, G. (1992a). Suitability of the manta tow technique for estimating the relative and absolute abundances of Crown-of-Thorns starfish (*Acanthaster planci* L.) and corals. *Aust. J. Mar. Freshwater Res.* 43, 357-78.
- Moran, P.J. & De'ath, G. (1992b). Estimates of the abundance of the Crown-of-Thorns starfish *Acanthaster planci* in outbreaking and non-outbreaking populations on reefs within the Great Barrier Reef. *Mar. Biol.* 113, 509-15.
- Moran, P.J., De'ath, G., Baker, V.J., Bass, D.K., Christie, C.A., Johnson, D.B., Miller, I.R., Miller-Smith, B.A., Mundy, C.N. & Thompson, A.A. (1991) Broadscale surveys of Crown-of-Thorns starfish and corals along the Great Barrier Reef: 1982-1990. The Crown-of-thorns Study. Australian Institute of Marine Science, Townsville.
- Moran, P.J., De'ath, G., Baker, V.J., Bass, D.K., Christie, C.A., Miller, I.R., Miller-Smith, B.A. & Thompson, A.A. (1992). Patterns of outbreaks of Crown-of-Thorns starfish (*Acanthaster planci* L.) along the Great Barrier Reef since 1966. *Aust. J. Mar. Freshwater Res.* 43, 555-68.
- Moran, P.J., Johnson, D.B., Miller-Smith, B.A., Mundy, C.N., Bass, D.K., Davidson, J., Miller, I.R. & Thompson, A.A. (1989). A guide to the AIMS manta tow technique. The Crown-of-thorns Study. Australian Institute of Marine Science, Townsville.
- Nothnagle, P.J. & J.C. Schultz. (1987). What is a forest pest? In *Insect Outbreaks* (P.Barbosa & J.C.Schultz, eds.), pp. 59-80. Academic Press Inc., New York.
- Pearson, R.G. & Endean, R. (1969). A preliminary study of the coral predator *Acanthaster planci* (L.) (Asteroidea) on the Great Barrier Reef. Queensland Department of Harbours and Marine, *Fisheries Notes* 3, 27-55.
- Pearson, R.G. & Garrett, R.N. (1976). *Acanthaster planci* on the Great Barrier Reef: general surveys. 1972-1975. *Biol. Conserv.* 9, 157-164.
- Pedigo, L.P. (1989). *Entomology and pest management*. McMillan Publishing, New York.
- Potts, D.C. 1981. Crown-of-thorns starfish: man induced pest or natural phenomenon? In *The ecology of pests* (R.L. Kitching & R.E. Jones eds.). Commonwealth Scientific and Industrial Research Organization, Melbourne.
- Reichelt, R.E., Bradbury, R.H. & Moran, P.J. (1989). The Crown-of-Thorns starfish, *Acanthaster planci*, on the Great Barrier Reef. Paper presented at the Conference on Population Dynamics of Outbreaking Species, Edmonton.
- Reichelt, R.E., Bradbury, R.H. & Moran, P.J. (1990) Distribution of *Acanthaster planci* outbreaks on the Great Barrier Reef between 1966 and 1989. *Coral Reefs* 9, 97-103.
- Yamaguchi, M. (1986). *Acanthaster planci* infestations of reefs and coral assemblages in Japan: a retrospective analysis of control efforts. *Coral Reefs* 5, 23-30.

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What do you mean "There's an outbreak of crown-of-thorns starfish on the Great Barrier Reef?"

From page 16

Fig. 1. Decision key to classify individual reefs with regard to crown-of-thorns starfish outbreaks on the Great Barrier Reef. The key is based on manta tow survey data as collected by the Australian Institute of Marine Science.

Table 1. Summary of the characteristics of reefs on the Great Barrier Reef (1985-1990) which have been classified as having no evidence of an outbreak (NO). This data is used for distinguishing "outbreak" from "recovering" reefs if there is no standard AIMS manta tow data of pre-outbreak conditions available for the reef being keyed out. n = sample size; COTS = numbers of Crown-of-Thorns starfish; CL = confidence limits; VMR = variance to mean ratio; DCC = dead coral cover category (from 0 to 5); LCC = live coral cover category (from 0 to 5).

Sector of GBR (as in Baker et al 1991)	Cross shelf position (n)	Mean COTS/tow	95%CL mean COTS/tow	Mean total COTS/reef	95%CL total COTS/reef	Mean VMR/reef	95%CL VMR/reef	Median DCC/reef (range)	Median LCC/reef (range)
Cape Grenville	n/a (34)	0.023	0.020	0.706	0.546	0.380	0.271	1 (1-3)	2-3 (1-4)
Princess Charlotte Bay	n/a (36)	0.012	0.011	0.750	0.682	0.220	0.153	1 (0-1)	2 (1-4)
Cooktown/Lizard Island	Inner (9)	0	0	0	0	0	0	1 (1-2)	2 (1-3)
	Mid (35)	0.013	0.009	0.571	0.464	0.324	0.213	1 (1-2)	2 (1-3)
	Outer (19)	0	0	0	0	0	0	1 (0-1)	2 (1-2)
Cairns	Inner (11)	0	0	0	0	0	0	1 (1)	2 (1-3)
	Mid (15)	0.004	0.006	0.2	0.21	0.2	0.21	1 (0-1)	2 (1-4)
	Outer (10)	0	0	0	0	0	0	1 (0-1)	2 (1-3)
Innisfail	Inner (13)	0	0	0	0	0	0	1 (0-2)	3 (1-4)
	Mid (2) ¹	0	0	0	0	0	0	0-1	1-2
	Outer (10)	0.001	0.003	0.100	0.196	0.100	0.196	1 (1)	1-2 (1-3)
Townsville	Inner (5)	0	0	0	0	0	0	1 (1)	2 (2)
	Mid (17)	0.139	0.076	8.588	4.649	1.330	0.455	1 (0-2) n=13	2 (2-3) n=13
	Outer (17)	0.010	0.017	0.471	0.715	0.209	0.284	1 (0-1) n=15	2 (2-3) n=15
Cape Upstart	Inner (0) ²	-	-	-	-	-	-	-	-
	Mid (45)	0.036	0.026	1.800	1.101	0.763	0.485	1 (0-3)	2 (1-3)
	Outer (18)	0.006	0.006	0.222	0.198	0.222	0.198	1 (1-2)	2 (1-4)
Whitsundays	n/a (76)	0.013	0.015	0.474	0.484	0.293	0.286	1 (0-2)	2 (1-4)
Pompey Complex	n/a (65)	0.005	0.005	0.292	0.291	0.134	0.091	1 (0-2)	3 (1-4)
Swains	n/a (100)	0.048	0.023	1.370	0.566	0.614	0.206	1 (0-3)	3 (1-5)
Capricorn Bunker	n/a (30)	0.004	0.006	0.400	0.655	0.111	0.122	1 (0-3)	3 (2-5)

¹ Due to insufficient data for "no outbreak" midshelf reefs in the Innisfail sector, use data of midshelf reefs in the Cairns sector for comparison.
² Due to insufficient data for "no outbreak" inner shelf reefs in the Cape Upstart sector, use data of inner shelf reefs in the Townsville sector for comparison.

Reef name	Total COTS	Mean COTS	VMR	Median DCC on tows with COTS	Median DCC	Median LCC	Other data	Status
Alpha	330	11.4	17.1	2	2	1	-	Active outbreak
Beta	0	0	n/a	n/a	1	3	-	No outbreak
Gamma	15	0.5	11.2	1	1	2	-	No outbreak
Delta	19	0.7	3.6	2	2	1	-	Active outbreak
Epsilon (midshelf reef, Townsville sector)	5	0.1	0.9	2	2	1	Previous AIMS manta tow data on outbreak (source, date)	Recovering

Table 2. Example of data used to classify reefs with regard to outbreaks of Crown-of-Thorns starfish and of the application of the decision key. COTS = numbers of Crown-of-Thorns starfish; CL = confidence limits; VMR = variance to mean ratio; DCC = dead coral cover category (from 0 to 5); LCC = live coral cover category (from 0 to 5).



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