Western Indian Ocean J. Mar. Sci. Vol. 5, No. 1, pp. 105–113, 2006

Short Communication

Observations on the Behaviour and Character of an *Acanthaster planci* (L.) Aggregation in a High-Latitude Coral Community in South Africa

Louis Celliers and Michael H. Schleyer
Oceanographic Research Institute, P.O. Box 10712, Marine Parade, 4056, South Africa.

Key words: Crown-of-thorns starfish, coral communities, high-latitude reefs, Sodwana Bay, South Africa

Abstract—The aggregation of *Acanthaster planci* (crown-of-thorns starfish) and their predation on corals is a well-publicised phenomenon that has affected many coral reefs but, after three decades of research, is still not well understood. These animals were first observed on the marginal reefs of South Africa during the early 1970s and since then have been reported on all the major South African reefs, as well as those in southern Mozambique and the Bazaruto Archipelago. However, during the 1990s an *A. planci* population aggregated on Two-mile Reef (TMR) at Sodwana Bay, South Africa. This event, which was limited to the fore-reef of TMR, lasted for most of the 1990s. Furthermore, it appears evident that the high-latitude, marginal nature of the South African coral communities influenced the behaviour of the starfish. Morphometric data are presented to model relationships between *A. planci* age and body diameter. The aggregation was transient, peaked in numbers betweeen 1994 and 1996 and then declined until *A. planci* became locally extinct. The cause of this spot outbreak remains unknown.

INTRODUCTION

No recent events, with the exception of coral bleaching, have had a greater influence on the global degradation of coral reefs than *Acanthaster planci* (crown-of-thorns starfish) outbreaks (Moran 1986; Endean and Cameron 1990). *A. planci* are carnivorous starfish found throughout the Indo-Pacific region, their main prey being hard corals. A characteristic trait of *A. planci* is their ability to aggregate on coral reefs and feed indiscriminately on hard corals (Moran 1986). Such an aggregation of starfish has been termed an "outbreak" and is a well-publicised phenomenon (Moran & De'ath 1992; Seymour & Bradbury 1999).

The high-latitude coral communities along the east coast of South Africa have been relatively protected from major disturbances (Schleyer 2000; Schleyer & Celliers 2000). The global importance of marginal reef systems such as the high-latitude reefs of South Africa is vested in their role as indicators of the effects of climate change (Buddemeier & Kinzie 1998; Kleypas *et al.*, 1999). A 1993 study on the taxonomy and ecology of the South African reefs concluded that no biologically unacceptable levels of damage or degradation of coral communities were evident (Riegl *et al.* 1995). However, during the early and mid 1990s an *A. planci* aggregation was resident on one of the local reefs (Schleyer 1998), followed by limited coral bleaching in 1998-2000 (Schleyer & Celliers 2000; Celliers & Schleyer 2002). These animals were first recorded on these marginal reefs during the early 1970s (Heydorn 1972) and again during the early 1990s (Schleyer 1998). Since then, they have been reported on all the major South African reefs

Corresponding Author: LC
E-mail: louis@ori.org.za

as well as those in southern Mozambique and the Bazaruto Archipelago (Schleyer 2000; Rodrigues *et al.* 1999).

This study expands the geographical knowledge base of *A. planci* aggregations and their influence on the dynamics and structure of coral communities, while examining some behavioural aspects, food and habitat preferences, predators, and aspects of their population dynamics. The South African aggregation is compared to those found elsewhere in the world.

MATERIALS AND METHODS

Study area

The coral communities in the province of KwaZulu-Natal are grouped together in northern, central and southern reef complexes and all fall between 27 and 28°S along the east coast of South Africa. The underlying reef structure consists of Pleistocene sandstone formed *ca.* 3780 years B.P (Ramsay & Mason 1990) and the reefs vary in size, topography, depth and distance from the shore. The study site was located on Two-mile Reef (TMR) in the central reef complex at Sodwana Bay.

The South African coral communities represent the southernmost distribution of this fauna on the east coast of Africa and consist of a non-accumulative veneer of coral growth on submerged sandstone structures (Ramsay 1996). These communities are rich in species and constitute a biodiversity peak south of the equator, in spite of the high-latitude and marginal nature of the environment (Benayahu 1993; Riegl *et al.* 1995; Celliers 2001).

Morphometric data

Records of the *A. planci* aggregation on the fore-reef of TMR included the outbreak location, date, absolute abundance, and limited morphological information that always included whole body diameter of the animals. The progression of the aggregation was monitored annually between 1993 and 1997, and biannually between 1998 and 2002. Data were collected during daylight hours and only adult *A. planci* specimens were measured. Whole body diameters were recorded *in situ* and were measured as the greatest length across the aboral surface from arm-tip to arm-tip. Measurements were recorded to the nearest 0.5 cm.

Video sampling of coral communities

Coral communities in the area affected by *A. planci* feeding were quantified using a modified quadrat and rapid digital video sampling method (English *et al.* 1994; Aronson & Swanson 1997). Twenty-two duplicated transects were collected from north to south along the fore-reef edge of TMR. A spacer bar was used to maintain a fixed distance between lens and the subject during filming, thus standardising the frame-size at 0.35 m^2. Data were extracted from the digital images using a process of non-random point intercept sampling (regular, linear point sampling), as described by Carleton and Done (1995). Ten fixed pattern point intercept markers were evenly distributed on the screen, maximising distance from the nearest neighbour, as well as the edge of the screen.

RESULTS AND DISCUSSION

Unfortunately, most of the starfish and coral data were collected in this study after the estimated peak of the *A. planci* aggregation which ruled out the possibility of a direct before-after comparison in coral community structure. Even so, the results from the coral community surveys showed measurable *A. planci* predation in terms of a reduction in hard coral cover. Further observations also provided some clues as to the behaviour of the starfish in an environment marginal for coral community development. *A. planci* is normally absent or very scarce on South African reefs and further studies of this nature will be dependent on the vagaries of ocean current to provide larval settlement for the next event of this nature. It is for this reason that this study is of value and, until the next opportunity presents itself, these results represent the most detailed information on *A. planci* in this environment. Furthermore, the *A. planci* population is referred to as an aggregation or spot-outbreak rather than a true "outbreak". These terms are not necessarily mutually exclusive but, in this study, all starfish counts were near

absolute for the entire reef area and, at its peak, the population was numbered in hundreds rather than thousands or hundreds of thousands as has been the case on reefs elsewhere in the world: 80,974 in the Cook Island 1973; 220,000 and 12,908,100 in the Ryukyus Islands, Japan 1957 and 1970-1983 respectively; 226,750 in the Caroline Island, Micronesia 1969-1972; etc. (see Moran, 1986).

Recreational SCUBA divers and dive operators first observed the aggregated *A. planci* during 1993 and scientific monitoring of this event was initiated in 1994 by the Oceanographic Research Institute based in Durban, South Africa. The *A. planci* aggregation was observed only on the fore-reef and upper fore-reef of TMR at Sodwana Bay. The fore-reef has a complex topography with a steep profile, gullies, crevices and small reef outcrops, and locating the starfish in this environment was difficult and time-consuming. The largest number of starfish counted at any one time was in September 1994 (200+ individuals; M.H. Schleyer, pers. obs.). The majority of the recorded sightings were made in the southern region of the reef (Fig. 1 (iv) - south of 27°31.26'S latitude), while only isolated sightings were made north of 27°31.00'S latitude (Fig. 1 (ii)). According to the distribution records and the coral community survey (see Fig. 2), two regions on the fore-reef remained relatively free of *A. planci* during the outbreak (Fig. 1 (i) - 27°31.16'S to 27°31.25'S and (iii) 27°31.88'S to 27°30.00'S). No data were recorded in 1997 due to a lack of funding.

After reaching maximal abundance (n = 200+) during 1994, the aggregation of *A. planci*, located then in the southern section of the reef, appeared to divide into two groups (Fig. 1 (ii and iv)). The observed population size and projected temporal progression of the *A. planci* aggregation on the fore-reef of Two-mile Reef at Sodwana Bay, South Africa is presented in Table 1.

A noteworthy behavioural trait of the *A. planci* aggregation on TMR was the apparent seasonal dispersion of individuals (Schleyer 1998). Field observations suggested that the population dispersed or sought shelter with the onset of winter (May-September), and aggregated during summer (November-March). Unfortunately, the monthly or two-monthly survey dives only commenced in 1998, yielding data in the subsequent four *A. planci* surveys (June, Sept and Nov 1998 and Jan 1999) to support this observation. As *A. planci* is a metabolic conformer, seasonal variation in mean temperatures as high as 10°C at Sodwana Bay (Celliers & Schleyer 2002) probably affected the movement and behaviour of the starfish. Cold water lethargy in winter may have reduced their feeding voracity, reducing their movement and causing their apparent dispersal if they took shelter. A patchy feeding pattern on the hard corals was noted in the study area (Fig. 2). Patches of reduced hard coral cover were reconcilable with the *A. planci* distribution over the study period.

The fore-reef as an *A. planci* habitat

Even though hard corals were not abundant on the fore-reef of TMR, their diversity was relatively high, eliminating the possibility of strong preferential predation by the starfish (Table 2). Observations revealed that the starfish preferred hard coral prey with a high tissue to skeleton ratio. Soft corals, and even sponges, were occasionally preyed upon.

Although *Porites* species were consumed, *Alveopora* spp., *Montipora* spp. and corals of the family Faviidae appeared to be the preferred prey of the starfish. *Acropora* spp. are generally scarce on most deeper reefs in South Africa and, if present, are small and caespitose. *Porites* outcrops were regularly spaced on small bommies offshore of the fore-reef of TMR (5-10 m distant, 24-28 m deep) and were not included in the analysis. Hard coral species that attained a diameter of >1 m were *Astreopora myriophthalma*, *Alveopora spongiosa* and, occasionally *Hydnophora exesa*. The remaining hard corals on the fore-reef were generally < 0.5 m in diameter. Soft corals of the family Alcyoniidae, including the genera *Sinularia* (13.7 %), *Lobophytum* (5.7 %) and *Sarcophyton* (4.1 %), were more abundant than hard corals.

The lack of numerically abundant prey usually associated with *A. planci* feeding, particularly *Acropora* and *Montipora* spp., may have introduced a limiting factor through food scarcity, causing the decline in starfish numbers over the

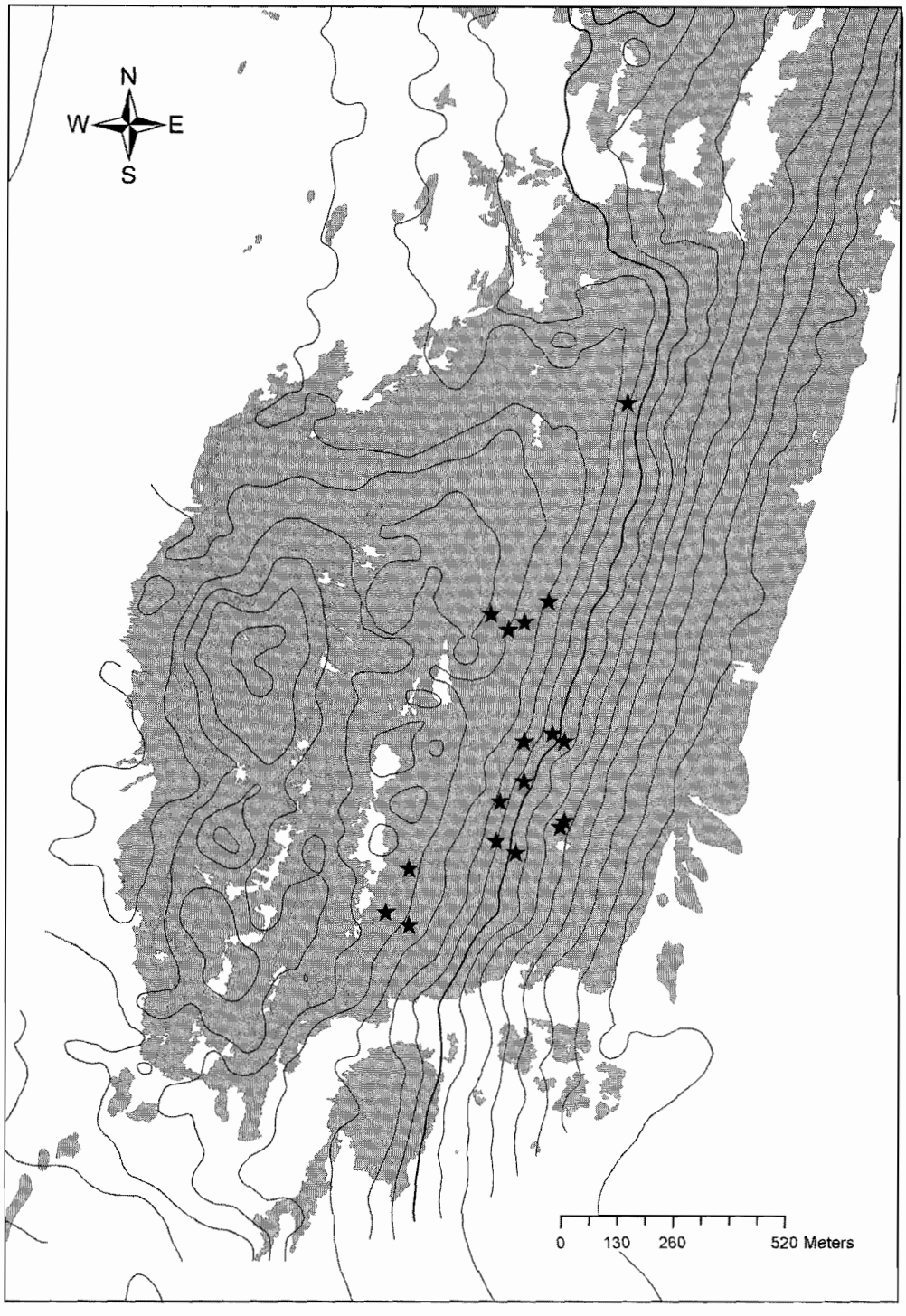

Fig. 1. Location of *Acanthaster planci* aggregations (black stars) on the fore-reef of Two-mile Reef at Sodwana Bay, South Africa, from 1994 to 1999 (seafloor map courtesy of Peter Ramsay, Marine Geosolutions). Isobaths are shown at 2 m intervals with the -26 m isobath depicted in bold. The areas denoted ii and iv indicate distinct sections of the fore-reef that were affected by the *Acanthaster* aggregation. The numbering corresponds to the areas indicated in Fig. 2

Table 1. Projected temporal progression and the absolute number and densities of *Acanthaster planci* observed between September 1994 and 2002 on the fore-reef of TMR at Sodwana Bay, South Africa (after Schleyer, 1998). The September 1994 count in brackets was an estimate.

Date	Count	Area (m^2)	Density (.100 m^{-2})	Projection
May '92				Settlement (back-calculation from size and age relationship).
Dec '92				Commencement of coral feeding phase (coral feeding phase 0-6 months; Moran, 1986).
April '93				*A. planci* aggregation observed on TMR by dive operators.
Sept '94	(200+)	na	na	
Feb '95	34	780	4.4	
March '95	27	200	13.5	
Sept '95	30	300	10	
Nov '95	17	100	17	
Jul '96	26	314	8.3	
Nov '96	93	150	62	
June '98	69	750	9.2	
Sept '98	13	175	7.4	
Nov '98	19	250	7.6	
Jan '99	30	100	30	Outbreak ends with the dispersion and/or mortality of the starfish.
2000	0	0	0	
2001	0	0	0	
2002	0	0	0	
Mean	**36**	**327.1**		**Mean excludes data for 2000 -2002**
SD	**24.3**	**260.1**		

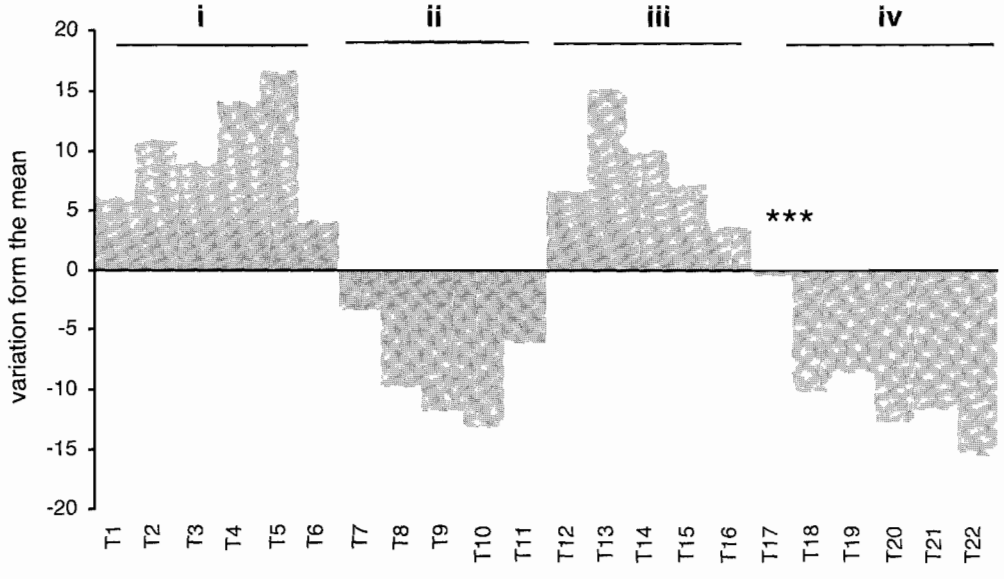

Fig. 2. Variation around the mean cover of hard coral in 22 video transects (T1-T22) recorded from north to south along the fore-reef of Two-mile Reef at Sodwana Bay, South Africa. The location of the *Acanthaster planci* aggregation at the time of the benthic survey is indicated by asterisks (i.e. on the inner edge of reef section iv). The spatial location of the transects denoted by i - iv is shown in Fig. 1

Table 2. Biotic composition of the fore-reef community on TMR at Sodwana Bay, South Africa, expressed as percentage cover and preferred prey of *Acanthaster planci*.

Variable/Category	Average % Cover (n=2)	Range	Preferred prey species
Total coral cover	45.0	42.4-47.6	
Hard coral cover	18.8	16.7-20.9	**Most common prey**
			Alveopora spongiosa
			Alveopora allingi
			Favites peresi
			Favites spp.
			Favia spp.
			Hydnophora exesa
			Montipora spp.
			Acanthastrea echinata
			Oulophyllia crispa
			Common prey
			Echinopora gemmacea
			Symphyllia valenciennesi
			Astreopora myriophthalma
			Least common prey
			Porites spp.
			Coscinaria monile
			Acropora spp.
			Gyrosmilia interrupta
			Goniopora spp.
			Pocillopora verrucosa
Soft coral cover	26.2	25.7-26.7	**Common prey**
			Sarcophyton glaucum
			Least common prey
			Sinularia sp.
			Lobophytum sp.
			Dendronephthya sp.
Macro-algal cover	7.2	4.9-9.5	
Dead coral and algae	39.6	34.3-44.9	

aggregation period. Furthermore, *A. planci* were most often observed at and over the reef-edge during the winter and it is possible that the overhangs and crevices served as a refuge from predation during their winter lethargy. The *A. planci* population seldom ventured beyond the area of the fore-reef. Elsewhere, it appears that this species exhibits a fairly large degree of habitat plasticity and inhabits deeper sections of reefs (Lucas 1982), sheltered lagoons and deeper water on windward slopes of reefs (Zann *et al.* 1990), and surge-swept reef faces (Chess *et al.* 1997), though most authors tend to suggest that it restricts itself to the selected habitat after settlement. However, changes in *A. planci* distribution from the front- to back-reef areas on reefs of the GBR have been reported (Kenchington 1976), as well as a decline in their powers of adhesion with age (Goreau *et al.* 1972). South African reefs are subjected to strong currents and swell-driven surge (Schleyer 2000) and the deep reef-edge of TMR would provide the best refuge from these conditions.

Known predators of *A. planci* that occur on the fore-reef of TMR were the gastropod *Charonia tritonis* and the teleost, *Balistoides viridescens* (Titan triggerfish), but active predation was not observed. However, scarring and injuries on individual starfish were apparent and possibly caused by sub-lethal predation. Scientists also removed between 40 and 50 starfish for genetic studies and gonad monitoring at regular intervals during the spot outbreak.

A. planci population dynamics

The size frequency distribution of the *A. planci* on TMR indicated that individuals within the population increased in size during the ten year study period (Fig. 3). Furthermore, the absence of multiple modes, and incremental diffusion of the primary peak suggested the near absence of recruitment from upstream in the system. No starfish was observed with a body diameter smaller than 40 cm after 1998. The mean body diameter of the *A. planci* ranged between 50 and 55 cm over the study period.

Inferences drawn from the *A. planci* morphometric measurements on TMR were treated with caution as the sample size was small and the growth rate of the starfish is acknowledged to be variable and plastic (Moran 1986; Stump 1996). The gradual increase in mean body diameter over time suggested a lack of recruitment and that the aggregation represented settlement of a single starfish cohort on the South African reefs. It is thus possible that the 1990s *A. planci* aggregation on TMR was a novel, isolated or random event caused by a pulse of recruitment.

Gonad samples from individual starfish were periodically collected during the aggregation period but gonad development was not quantified. However, observations on the reproductive state of the starfish suggest that spawning did occur in the TMR population, just prior to apparent "dispersal" (Schleyer 1998).

The reasons for this spot outbreak remain unknown and the ability of the reefs to recover from such an aggregation will depend on their frequency. Annual monitoring should become a

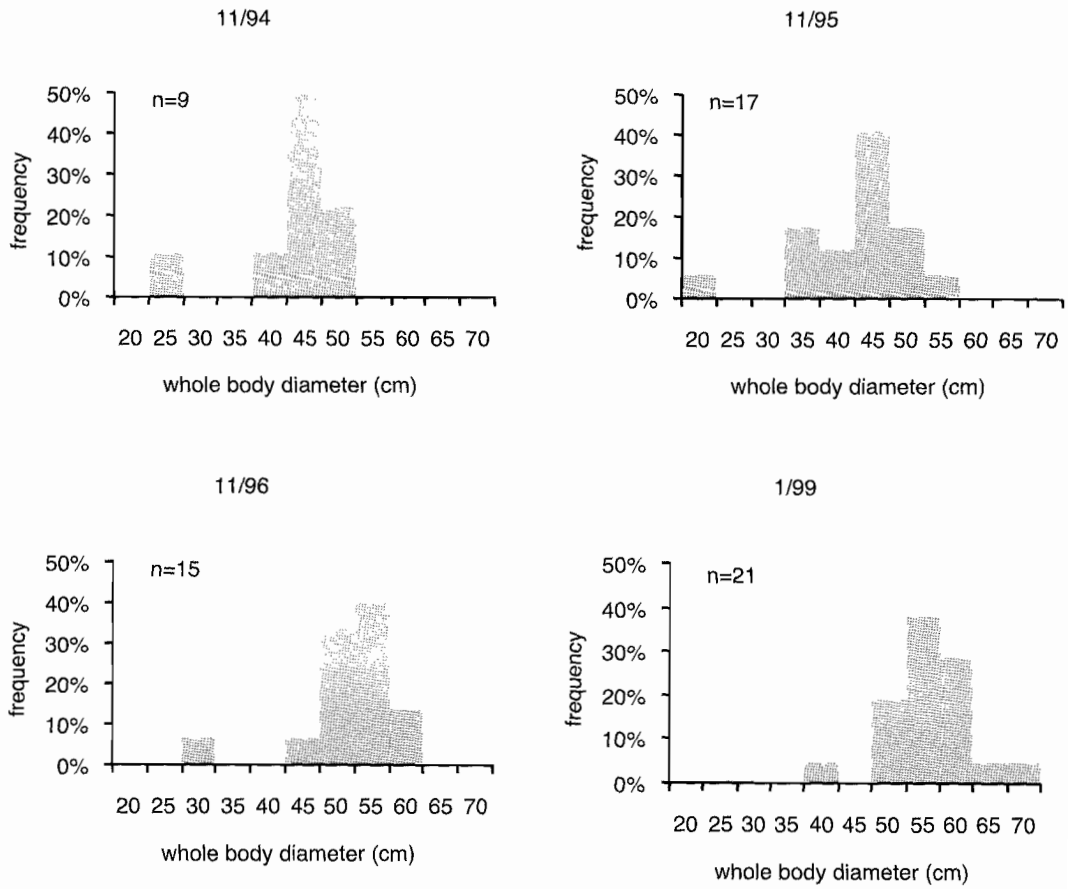

Fig. 3. Size-frequency distribution of whole body diameter of *Acanthaster planci* found on the fore-reef of Two-mile Reef at Sodwana Bay, between November 1994-1996 and January 1999

standard procedure to ensure the early detection of *A. planci* aggregations. Incidental observations by recreational divers are largely limited to the shallow reef locations at Sodwana Bay and thus early detection programmes need to be implemented to detect COTS outbreaks on undived reefs.

Acknowledgments—This work formed part of a wider programme of research financed by Total Southern Africa, the World Wide Fund for Nature, South Africa (WWF-SA), the National Research Foundation of South Africa and the South African Association for Marine Biological Research. We are grateful for assistance in its execution by officers of KwaZulu-Natal Wildlife, a 4 x 4 vehicle provided by the Mazda Wildlife Fund, a research vessel sponsored by BP (Southern Africa) and the support of staff of the Oceanographic Research Institute in the field.

REFERENCES

Aronson, R.B. and Swanson, D.W. (1997) Video surveys of coral reefs: uni- and multivariate applications. In: Lessios, H.A. and Macintyre, I.G. (eds), Proceedings of the 8th International Coral Reef Symposium, Panama (II), June 24-29, 1996. Smithsonian Tropical Research Institute, Balboa. pp. 1441-1446.

Benayahu, Y. (1993) Corals of the South-west Indian Ocean. I. Alcyonacea from Sodwana Bay, South Africa. South African Association for Marine Biological Research. Investigational Report (67), Durban, 16pp.

Buddemeier, R.W. and Kinzie III R.A. (1998) Reef science: asking all the wrong questions in all the wrong places? *Reef Encounter* **23:** 29-34.

Carleton, J.H. and Done, T.J. (1995) Quantitative video sampling of coral reef benthos: large scale application. *Coral Reefs* **14:** 35-46.

Celliers, L. (2001) Effects of a crown-of-thorns starfish outbreak relative to other disturbances on marginal, high-latitude coral communities at Sodwana Bay, South Africa. Ph.D Thesis, University of Natal, Durban, South Africa. 181pp.

Celliers, L. and Schleyer, M.H. (2002) Coral bleaching on high-latitude marginal reefs at Sodwana Bay, South Africa. *Mar. Pollut. Bull.* **44:** 1380-1387.

Chess, J.R., Hobson, E.S. and Howard, D.F. (1997) Interactions between *Acanthaster planci* (Echinodermata, Asteroidea) and Scleractinian corals at Kona, Hawai'i. *Pac. Sci.* **51:** 121-133.

Endean, R. and Cameron, A.M. (1990) *Acanthaster planci* population outbreaks. In: Z. Dubinsky (ed). Ecosystems of the World (25): Coral Reefs. Elsevier, Amsterdam. Pp. 419-435.

English, S., Wilkinson, C. and Baker, V. (1994) Survey manual for tropical marine resources. ASEAN - Australia Marine Science Project: Living Coastal Resources. Australian Institute of Marine Science, Townsville, 368pp.

Goreau, T.F., Lang, J.C., Graham, E.A. and Goreau, P.D. (1972) Structure and ecology of the Saipan reefs in relation to predation by *Acanthaster planci* (Linnaeus). *Bull. Mar. Sci.* **22:** 113-145.

Heydorn, A. (1972) Tongaland's coral reefs- an endangered heritage. *African Wildlife* 26: 20-23.

Kenchington, R. (1976) *Acanthaster planci* on the Great Barrier Reef: detailed surveys of four transects between 19→ and 20→ *S. Biol. Conserv.* **9:** 165-179.

Kleypas, J.A., McManus J.W. and Menez, L.A.B. (1999) Environmental limits to coral reef development: Where do we draw the line? *Am. Zool.* **39:** 146-159.

Lucas, J.S. (1982) Quantitative studies of feeding and nutrition during larval development of the coral asteroid *Acanthaster planci* (L.). J. *Exp. Mar. Biol. Ecol.* **65:** 173-193.

Moran, P.J. (1986) The Acanthaster phenomenon. Oceanogr. *Mar. Biol. Ann.* Rev. **24:** 379-480.

Moran, P.J. and De'ath, G. (1992) 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:** 509-515.

Ramsay, P.J. (1996) Quaternary marine geology of the Sodwana Bay continental shelf, Northern KwaZulu-Natal. Bull. *Geol. Surv. S.A.* **117:** 1-85.

Ramsay, P.J. and Mason, T.R. (1990) Development of a type zoning model for Zululand coral reefs, Sodwana Bay, South Africa. *J. Coast. Res.* **6:** 829-852.

Riegl, B., Schleyer, M.H., Cook, P.J. and Branch, G.M. (1995) Structure of Africa's southernmost coral communities. *Bull. Mar. Sci.* **56:** 676-691.

Rodrigues, M.J., Motta, H., Gonçalves, M.A.M, Carvalho, M. and Schleyer, M.H. (1999) Reef monitoring in Mozambique: The monitoring programme and 1999 report. MICOA-ORI-IIP, Maputo, 64pp.

Schleyer, M.H. (1998) Crown-of-thorns starfish in the Western Indian Ocean. *Reef Encounter* **23:** 25-27.

Schleyer, M.H. (2000) South African coral communities. In: McClanahan, T., Sheppard, C. and Obura, D. (eds.), Coral reefs of the Indian Ocean: Their ecology and conservation. Oxford University Press, New York Pp. 83-105.

Schleyer, M.H. and Celliers, L. (2000) The status of South African coral reefs. In: D. Souter, D. Obura and O. Linden (eds), Coral reef degradation in the Indian Ocean: status report 2000. CORDIO, Stockholm. Pp. 49-50.

Seymour, R.M. and Bradbury, R.H. (1999) Lengthening reef recovery times from crown-of-thorns outbreaks signal systemic degradation of the Great Barrier Reef. *Mar. Ecol. Prog. Ser.* **176:** 1-10.

Stump, R.J.W. (1996) An investigation to describe the population dynamics of *Acanthaster planci* (L.) around Lizard Island, Cairns Section. CRC Reef Research Centre Technical Report (10). Great Barrier Reef Marine Park Authority, Townsville, 56pp.

Zann, L., Brodie, J. and Veikila, V. (1990) History and dynamics of the crown-of-thorns starfish *Acanthaster planci* (L.) in the Suva area, Fiji. *Coral Reefs* **9:** 135-144.