Chapter 3 CROWN-OF-THORNS STARFISH

Green Island reef has been subjected to two major periods of infestation by the crown-of-thorns starfish, A. planci - in 1962-67 and 1979-81. The 1962 outbreak was the first to be reported on the Great Barrier Reef. and preceded an extensive series of infestations of reefs throughout the Great Barrier Reef region which continued until 1977. Similarly, the 1979 outbreak was the first recorded for two years and marked the beginning of another series of reef infestations (Moran, 1986).

Talbot and Talbot (1971) and Kenchington (1977) suggested the primary A. planci outbreaks had occurred on reefs to the north of Green Island in the mid-1950s, as outbreaks generally progressed in a southerly direction during the 1960s and 1970s. However, Moran (1986) could find no direct evidence to support this and Fisk *et al.* (1988) noted that reefs in the Green Island area had been proposed as the location of primary outbreaks of A. planci on the Great Barrier Reef. More recently, hydrodynamic models have predicted that A. planci larvae at Green Island reef are most likely derived from reefs to the north, where coral cover was reduced before starfish were present at Green Island reef (Fisk *et al.*, 1988). This is considered by Fisk *et al.* (1988) to support the idea that Green Island is a site of primary observation rather than primary outbreak.

Oral history projects relating to human experiences of crown-of-thorns starfish on the Great Barrier Reef were conducted by Dalton and Reynolds (1984) and Ganter (1987). The former acknowledged that dates given for various events would vary in accuracy, and this should be kept in mind when considering information from these publications.

A comprehensive review of the course of events during the Green Island infestations is given by Raymond (1986). Fortunately, it appears the accuracy of his information improves following his introduction of Green Island as a 3km long, 2km wide cay which stands only a metre above high tide!

EARLY SIGHTINGS

Raymond (1986) reported that a crown-of-thorns starfish was first filmed on Green Island by biologist and film-maker Noel Monkman in 1930. In 1935 another film enthusiast, Bruce Cummings, saw and filmed A. planci at Green Island but not at Michaelmas Cay or Low Isles (Dalton and Reynolds, 1984). Despite their frequent filming around Green Island, he and his wife saw only about six more over the ensuing three years (Raymond, 1986). All were reportedly small - six or seven inches in diameter (Dalton and Reynolds, 1984).

Dalton and Reynolds (1984) interviewed a diver, Scott, who frequented Green Island reef in the period 1942 - 1960 and saw no A. planci until 1960. Vlasoff and Grigg - builders of the underwater observatory - were interviewed by Dalton and Reynolds (1984) and Ganter (1987) respectively. Grigg commented that the Cairns Harbour Board first noticed crown-of-thorns starfish at Green Island in 1959 and that he had collected some in November of that year, noting that they were gradually increasing in number (Ganter, 1987). Vlasoff recalled starfish 'in numbers' on the reef in 1960, while Scott related that removal of the starfish by hand had commenced in 1960 when Grigg realised they were eating the coral (Dalton and Reynolds, 1984).

Dr John Barnes, a practicing doctor and renowned marine biologist, was reported by Raymond (1986) to have seen his first A. planci on the reef flat to the south-east of Green Island in 1960. The white, circular patches of dead coral nearby were regarded as 'long-term resting places' (Barnes, 1966). While no more specimens of the starfish were sighted during inspections of the reef in 1961, Barnes (1966) reported many more dead patches of coral on the reef flat to the south-east and south of the cay [B1, B2: Fig.3.1].

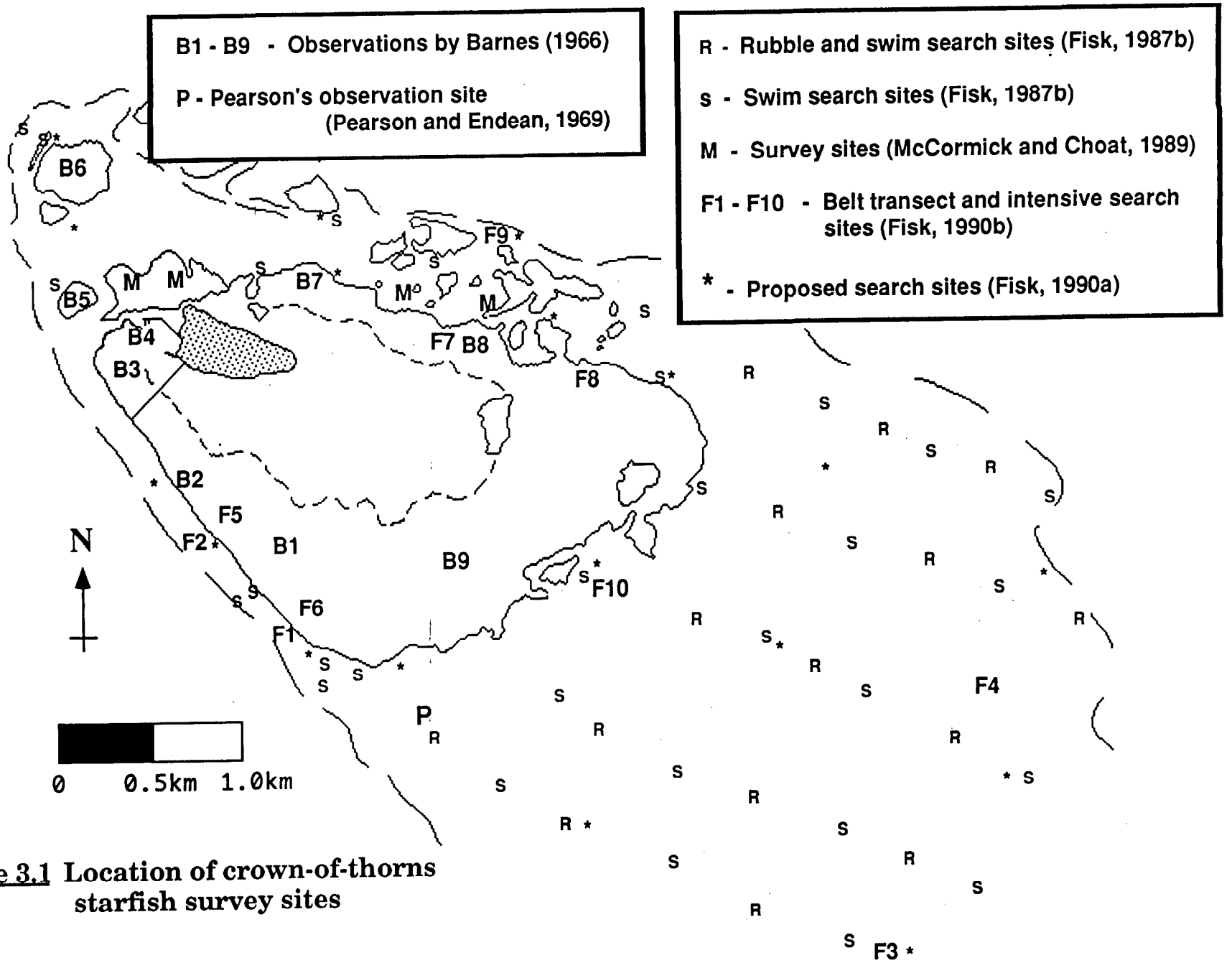

Figure 3.1 Location of crown-of-thorns starfish survey sites

1962 - 1967 INFESTATION

The outbreak

In early 1962 more A. planci sightings were reported to Barnes, including numbers around the underwater observatory by Vlasoff and Grigg (Raymond, 1986). Grigg subsequently collected five specimens in less than an hour and found a large number to the south of the observatory apparently moving northwards in a distinct front [B2: Fig.3.1] (Barnes, 1966). By 1963, the starfish had reached the observatory [B4: Fig.3.1] and Grigg was able to study them at night, discovering that coral damage was actually due to their feeding on the coral polyps (Raymond, 1986). The A. planci infestation at Green Island rated a passing mention in Barnes and Endean (1964).

Control measures, 1964-65

During 1964 the starfish continued to advance in a clockwise direction around the reef, spreading rapidly over the north-western corner [B5, B6: Fig.3.1] where their widespread destruction of the coral prompted the first concerted effort to remove them (Barnes, 1966). This was largely ineffective and coral destruction continued to increase until, by the end of 1964, the area was denuded (Raymond, 1986).

In 1965, a diver employed by Hayles Ltd was stationed to the north-east of the cay [B7: Fig.3.1] to remove the starfish in one small area. Despite his removal of 27,000 A. planci over a 15-month period, at rates of up to 373 a day (Barnes, 1966), considerable damage did still occur and not even the 4ha coral-viewing site could be saved (Moran, 1986).
Birkeland (1982) reported a total of 44,000 starfish were killed by control measures. An interviewee of Dalton and Reynolds (1984) reported the removal of 'about 150,000' starfish during the first period of infestation.

Surveys, 1965-66

A team of fisheries biologists from the Queensland Department of Primary Industries, led by N. Haysom, surveyed portions of Green Island reef in 1965 (Kenchington, 1978). The results of this survey are not available in the published literature.

The first scientific study of A. planci on the Great Barrier Reef was by Barnes (1966), who gave a detailed description of starfish movements around the reef [Fig.3.1]. At this time, they were still highly active in the region due east of the cay [B8: Fig.3.1], but the south-eastern corner of the reef flat showed little evidence of A. planci activity (Barnes, 1966).

Pearson's study, 1966-69

A more extensive study of A. planci on the Great Barrier Reef - conducted by R. Pearson of the Queensland Department of Primary Industries - was based at Green Island from May 1966 to March 1967, after which it was based in Cairns, continuing until March 1968. Studies included visual surveys of starfish numbers, observations of feeding rates, starvation experiments, determinations of fecundity, plankton hauls for larvae and surveys of coral regeneration. Results from these studies are presented in detail by Pearson and Endean (1969), while unpublished size frequency data was used by Kenchington (1977) to derive growth curves for A. planci. Clare (1971) refers to a steel-framed dredge which, in November 1968, was to be used between reefs 'to pick up any crown-of-thorns starfish ... migrating from reef to reef', but the results of its usage are not given.

In a $100m^2$ area on the south-eastern reef slope (marked in September 1966) [P: Fig.3.1], the starfish numbers increased from 219 to 350 within fifteen days and live coral cover decreased from 47% to 15% in two months (Pearson and Endean, 1969).

Visual surveys of A. planci abundance were made by observers swimming for a known length of time over an area of reef. Where large numbers of starfish were encountered only the readily apparent ones were counted, while more detailed searches for concealed starfish were made in areas where they were less abundant. Numbers of A. planci counted during swims of varying duration were standardised to numbers per 20-minute period to give a measure of relative abundance (Pearson and Endean, 1969).

Specific locations of the Green Island reef visual surveys are not given by Pearson and Endean (1969), although counts were generally made in water depths of less than 10m along the 'reef margin'. In May 1966 abundances of up to 351 per 20-minute swim were recorded, increasing to up to 1150 per 20-minute swim by September, after which numbers began to decline (Pearson and Endean, 1969). By January 1967 maximum abundance was 28 per 20-minute swim (Pearson and Endean, 1969) with a total of 36 starfish recorded from 3 sites surveyed (Fisk *et al.*, 1988). In March 1968 no more than two were found per swim (Pearson and Endean, 1969) with a total of five starfish recorded from 4 sites surveyed (Fisk *et al.*, 1988). No starfish were recorded during a survey of 8 sites in November 1968 (Fisk *et al.*, 1988). In August 1969 only one was found in each of two 30-minute and one 20-minute swims (Pearson and Endean, 1969).

Following the two year study, Endean (1969) recommended implementation of hand-harvesting of A. planci and importation and large-scale breeding of the giant triton shell (Charonia tritonis), which he identified as a major predator of the starfish. However, Pearson subsequently disagreed with several of Endean's interpretations of the results and recommended examination of the report by population ecologists (Report of the Committee, 1971). When interviewed by Dalton and Reynolds (1984) Vlasoff commented that triton shells were a deep water species, while tourists were restricted to the reef top and would not have removed sufficiently large numbers of the shells to have precipitated the starfish infestation.

BETWEEN INFESTATIONS

Endean and Stablum's survey, 1970

Endean and Stablum (1973a) surveyed sectors of Green Island reef for A. planci in May and November 1970. Green Island reef was one of a series of reefs surveyed, with several survey methods being employed during the series - snorkelling, scuba diving, use of a glass-bottomed box from a boat and manta towing. The methods employed at Green Island are not specified. During the survey series, visual estimates were generally made over 20-minute periods, with more detailed searches only made within the vicinity of 'freshly killed' hard corals - duration and thoroughness of the Green Island surveys are also unspecified.

An estimated 35,000m^2 of Green Island reef was surveyed, covering areas of reef flat to the west of the cay [B4: Fig.3.1] and on the north-western side of the reef [B5: Fig.3.1], seaward slopes on the south-western [B2, B3: Fig.3.1] and southern sides [B1: Fig.3.1], and 'submerged reef' on the south-eastern side [B9: Fig.3.1]. No specimens of adult or juvenile A. planci were found during the survey.

Pearson's surveys, 1970 - 1976

As reported in Fisk *et al.* (1988), Pearson conducted 20-minute swim surveys at sites around the perimeter of Green Island reef in June 1970 (3 starfish from 6 sites), August 1972 (4 starfish; 8 sites) and August, 1976 (48 starfish; 13 sites). Precise locations of the survey sites are not given by Fisk *et al.* (1988).

1979 - 1982 INFESTATION

The outbreak

In August 1979 Queensland Fisheries Service staff, acting on reports from fishermen and scuba divers, observed a large population of small starfish (about 14cm in diameter) at 10m depth at the 'deeper eastern end' of the reef (Kenchington and Pearson, 1981). A belt transect survey by Pearson in August 1979 yielded 456 starfish from 29 sites around the reef perimeter and two sites within the eastern shoal area (Fisk *et al.*, 1988). Further reports by skindivers and fishermen indicated the population appeared to be spreading up the reef slope and advancing around both sides of the cay towards the western end of the reef (Raymond, 1986). The main advancing front of the A. planci aggregation followed much the same path as in the first outbreak, while a second smaller front advanced more slowly from the eastern end of the reef and along the northern reef face. Both aggregations converged on the north-west patch reefs before dying or disappearing (Kenchington and Pearson, 1982; Fisk *et al.*, 1988).

Surveys, 1979-80

Following an initial survey in December 1979, Endean (1982) estimated that 60% of the hard corals had been killed and that the A. planci population comprised 350,000 individuals. While Endean's estimate of coral mortality was derived from transect surveys, the method employed in estimating starfish abundance is not specified by Cameron and Endean (1981) or Endean (1982). Cameron and Endean (1981) further report that 'Government scientists' concurrently estimated 400,000 starfish to be present, which was 'subsequently' raised to 2 million. I have been unable to locate the surveys which may have given rise to these estimates.

During 1980, Pearson (1980) estimated, using a belt transect technique, that there were 1,642,000 (± 871,351) starfish on the reef. Individual surveys were conducted in March (420 starfish from 16 reef perimeter sites and 2 shoal sites) and September (2142 starfish; 33 perimeter and shoal sites) (Fisk *et al.*, 1988). In September, Pearson also observed many adult starfish up to several hundred metres from the south-western reef edge. These were moving in a north-west direction over the sandy floor at 20m depth. Further observations in October 1980 revealed starfish in depths of 50m up to 1.5km from the reef perimeter (Fisk *et al.*, 1988).

Analysis by Fisk *et al.* (1988) of starfish diameters recorded during this outbreak revealed an assemblage in the eastern shoal area to have a greater number of small starfish than a spatially separated assemblage in the northern reef area. This was considered to be indicative of greater recruitment of starfish to the shoal area, supported by Pearson's observations of movements of starfish from this area along the southern reef slope to the western end of the reef (Fisk *et al.*, 1988).

Control measures, 1980

In mid-1980, the Queensland Fisheries Service tested a series of control measures at Green Island, including hand collecting (removal rate of 38/hour), compressed air injection (21/hour) and injection of chemicals such as copper sulphate (132/hour), formalin and ammonia (Blakey, 1980; Hicks and Blackford, 1981). Of the chemicals tested, 10ml of copper sulphate per starfish was found to be the most effective (Hicks and Blackford, 1981). Despite the collection of 1800 starfish and the injection of 6700 more, there was no discernible effect on the A. planci population in the area (Raymond, 1986).

Shortly afterwards, two divers working in a 2ha coral viewing area at the western end of the cay with copper sulphate injection guns killed 25,850 starfish over 35 days at a rate of 115 per hour (Kenchington and Pearson, 1981). However, the starfish still managed to invade and denude the area, completing the destruction of hard corals to an even greater extent than did the 1962/67 infestation (Raymond, 1986). In total, over 29,000 starfish were killed during the second outbreak (Zann and Weaver, 1988).

POST-INFESTATION SURVEYS

Nash and Zell, 1980

The number of A. planci on Green Island reef declined during 1980, and a manta tow survey by Nash and Zell (1981) in the period between March and May revealed high dead coral cover but relatively few starfish. They surveyed the entire reef margin, some of the reef flat and much of the back-reef lagoon, although specific locations are not given. Observers were towed for 20-minute periods at speeds of around 1.5 knots, thus covering up to 1km of reef per tow. It would appear from this methodology that only the readily apparent individuals would have been counted. Of the twenty-four 500m-unit tows conducted, 10 revealed no A. planci, 6 had one or two starfish, 4 had three to ten individuals and 4 revealed between eleven and forty starfish (Nash and Zell, 1981). The total number of starfish found and their distribution around the reef is not presented.

Cannon and Goeden, 1980

Benthic hauls were undertaken by Cannon and Goeden (1983) in October 1980 to assess the abundance of A. planci in the inter-reefal areas surrounding Green Island reef. Hauls of 5 or 10 minutes duration were taken using a single rigged 5.4m try net. The sampling stations encircled Green Island reef and did not encroach into the south-eastern bommie field. An A. planci specimen was recovered at only one station- approximately 2km south-west of the south-western reef edge at a depth of 40m.

Nash *et al.*, 1981

Specimens of A. planci were collected from Green Island reef in July 1981 by Nash *et al.* (1988). Starch gel electrophoresis was used to genetically compare the Green Island population with other populations of A. planci on the Great Barrier Reef. Distinct differences between the Green Island population and the others sampled were attributed to selection, with the selective pressures probably based on low food availability. It was observed that many of the starfish collected were feeding on a species of the soft coral Sinularia, and one was observed with its stomach everted over the silty bottom at the base of the reef (Nash *et al.*, 1988).

Ayling, 1983

In the period January to March 1983, Ayling (1983) surveyed Green Island reef for A. planci. Five 50m x 10m belt transects were positioned 'randomly' and neither the precise locations nor the degree of search effort utilised are given. No crown-of-thorns starfish were recorded in this survey.

Harriott, 1984

A manta tow survey of the reef perimeter by Harriott in March 1984 located no starfish (Fisk *et al.*, 1988). Precise details of the survey technique (tow speeds, duration of tows etc.) are not given by Fisk *et al.* (1988).

A.I.M.S., 1986

In January 1986, Green Island reef was surveyed by the Australian Institute of Marine Science (Bradbury *et al.*, 1987). Manta tows were utilised, with observers towed for two minute periods at speeds of about 1.5 knots. A total of 38 tows were used to survey the reef margin, and no A. planci were observed (Bradbury *et al.*, 1987; Moran *et al.*, 1988).

Walbran *et al.*, 1986

Walbran *et al.* (1989) sampled the surface sediments at 46 sites on and around Green Island reef in January 1986 [Fig.2.2]. A jawed grab sampler was utilised to retrieve 3-4kg samples which were examined for A. planci skeletal elements. There was no obvious pattern of element distribution, although abundance was low in the reef flat samples. Radiocarbon dating using carbon-14 accelerator mass spectrometry confirmed the elements to be Modern (within the last 200 years) to >Modern (post-1954) in age.

Subsurface sediment cores were obtained at six sites [Fig.2.2] using a pontoon-supported vibracorer. Core results indicated a more uniform geographic distribution of elements than that displayed in the surface sediment, which was ascribed to the reworking and dispersal of elements prior to their internment in the sediment body. They also noted substantial biological reworking of the sediment pile, predominantly by callianassid shrimp. This physical and biological reworking precluded recognition of individual outbreaks in core stratigraphy. The down-core distribution of A. planci elements was considered to be consistent with repeated A. planci outbreak cycles over a period of at least 3000 years. An apparent increase in elemental abundance below 200cm core depth suggested a decrease in the prevalence of A. planci at Green Island reef over the last 1000-2000 years (Walbran *et al.*,1989).

Fisk, 1986

The abundance and distribution of A. planci on Green Island reef was estimated by Fisk (1987b) in July/August 1986. Swim surveys of 5 minutes duration were undertaken at 46 sites on the reef slope and within the bommie field to the south-east of the reef flat [Fig.3.1]. Patches of recently dead coral were searched for starfish, unlike the manta tow surveys of other researchers in which only readily visible starfish were recorded.

The initial survey (one swim at each site) revealed 47 A. planci, while a second survey (two swims at each of a subset of 12 sites within the bommie field) revealed 14. An additional 6 starfish were observed during the course of other activities. The highest number of A. planci observed during a 5-minute swim was 12, the next highest 6 - each on only one occasion. Four or fewer starfish were found during each of the remaining 68 timed swims, with no starfish found in 43 of these.

The distribution of A. planci across the reef slope and bommie field was considered to be apparently random, with the possible exception of the seaward margin of the reef where very few starfish were detected. The size distribution of the juvenile population detected was consistent with that of an 18-month old starfish population, suggesting a single year class probably recruited from the 1984/85 summer. Smaller numbers of younger and older starfish were also found.

Fisk *et al.* (1988) reported a total of 30 starfish found in September 1986 during 5-minute swim surveys of 45 sites around the reef perimeter and within the shoal area. When feeding scars were seen, additional time was taken to search the nearby area for starfish, the number so found being added to the number of non-cryptic starfish sighted.

Detailed rubble searches were also undertaken in September 1986 at 15 of the bommie field sites, within four 0.5m x 0.5m quadrats at each site. Rubble was removed to a depth of approximately 0.5m, with each piece scrutinised for small (>1cm) starfish. In this manner, almost $2m^3$ of rubble was searched and only one starfish - 2cm in diameter and most probably about 9 months old - was found (Fisk, 1987b). This survey appears to be the same survey referred to by Fisk *et al.* (1988) as an October/November survey of 20 sites searching for >0.5cm starfish.

Black and Gay, 1987

Dispersal of A. planci larvae on and around Green Island reef was modelled by K. Black of the Victorian Institute of Marine Sciences utilising the hydrodynamic model detailed in Black and Gay (1987). Data from the numerical dispersion study are unpublished.

A.I.M.S., 1987

Australian Institute of Marine Science personnel surveyed Green Island reef in February 1987 (Bass *et al.*, 1988). Manta tows were utilised, with observers towed for two minute periods at speeds of about 1.5 knots. A total of 51 tows were used to survey the reef margin, with deviations through the patch reefs to the north-west of the cay and at the southern edge of the eastern reef tip. No A. planci were observed.

The reef was resurveyed in June 1987 utilising the same technique, but with the scope of observations expanded to include feeding scars (presumed to be due to A. planci feeding). A total of 62 tows were used to survey the reef perimeter, with the exception of the eastern tip, and no A. planci or feeding scars were observed (Bass *et al.*, 1989a).

Fisk and Harriott, 1987-88

Fisk (1988) and Fisk *et al.* (1988) give data from 5-minute surveys conducted by Fisk and Harriott in May 1987 (15 starfish from 45 sites), November 1987 (9 starfish; 46 sites) and April 1988 (8 starfish; 43 sites). Sites around the reef perimeter and within the eastern shoal area were surveyed utilising the same search effort as the September 1986 survey of Fisk and Harriott.

Searches for 0-1year old starfish were conducted in October/November of 1987 and 1988, using the survey technique described for the October/November 1986 survey of Fisk and Harriott (Fisk *et al.*, 1988). No starfish in this age class were found in 1987 (Fisk, 1988), and results of the 1988 survey are not given by Fisk *et al.* (1988).

Size class data from the 1986-88 surveys revealed the low density population present to be predominantly small starfish, with a decrease in abundance and average size over time (Fisk *et al.*, 1988). The decline in abundance may have been indicative that there was insufficient coral on Green Island reef to support larger starfish once their diet had changed from calcareous algae (Fisk *et al.*, 1988).

McCormick and Choat, 1988-89

During surveys of reef fish abundance within and outside the Green Island reef seagrass beds [Fig.3.1] in May 1988 and April 1989, observations of crown-of-thorns starfish were recorded by McCormick and Choat (1989). No A. planci were recorded within sixty 10x4m strip transects searched in detail on each occasion, and only one starfish was seen during each of the surveys.

A.I.M.S., 1989

Green Island reef was surveyed by the Australian Institute of Marine Science in February 1989 (Bass *et al.*, 1989b). A manta tow technique was utilised, with observers towed for two minute periods at speeds of about 1.5kn, recording abundance of A. planci and of feeding scars . A total of 48 tows were used to survey a clockwise path through the seagrass beds and across the sanded reef flat at a distance of about 150m from the cay until adjacent to the eastern tip of the cay; then around the reef perimeter and back across the reef flat to the south-west of the cay. A feeding scar observation (category <10 scars) was made during the first two-minute tow, apparently in the vicinity of the seagrass beds. No assumptions are made in this report as to the origins of feeding scars (cf. Bass *et al.*, 1989a, in which they are assumed to be 'A. planci feeding scars'), and no A. planci were observed (Bass *et al.*, 1989b).

Fisk, 1989

Two techniques were used by Fisk (1990b) to sample juvenile crown-of-thorns starfish during a survey in November 1989. A total of 10 survey stations were established [F1 - F10: Fig.3.1] in the eastern bommie fields, the south and south-west flanks of the reef edge, the reef flat and the back reef.

Intensive searches of dead coral substrata with a high component of encrusting coralline algae were conducted to locate 0+yr individuals. The searches covered two substratum types where such individuals had previously been located - rubble and rubble/porous substrata under or adjacent to live coral and within 0.25m of plate coral colonies. Within each station, four replicate 0.5m square areas at each of two sites were searched. Only one 0+yr individual was located, at station F2 [Fig.3.1].

Belt transect surveys were utilised to locate 1+yr individuals. At each site, a 20m x 4m belt transect was searched for feeding scars on live coral or visible crown-of-thorns starfish. An area within a radius of 0.25m from each feeding scar was searched down to bedrock. Only one 1+yr individual was located, at station F1 [Fig.3.1]. One individual of 18cm diameter was found outside the belt transects, feeding on a colony of Acropora grandis (Fisk, 1990b).

A.I.M.S., 1990

Green Island reef was surveyed in January 1990 as part of the continuing series of broadscale surveys of crown-of-thorns starfish on the Great Barrier Reef conducted by the Australian Institute of Marine Science. Data is currently in preparation for publication (Moran, pers. comm.).