2 RECRUITMENT AND DISPERSAL OF SCLERACTINIAN CORALS AT GREEN, MICHAELMAS AND UPOLU REEFS

2.1 INTRODUCTION

The Great Barrier Reef is comprised of a series of more than 2900 individual reefs, covering a distance of 2300 km from north to south, with variable but relatively narrow width across the continental shelf (Hopley and Davies 1986). In recent years one aspect of the ecology of the Great Barrier Reef that has particularly interested biologists is the contribution of dispersal processes to the recruitment patterns of reef organisms (e.g. Williams et al. 1984; Leis and Goldman 1984, 1987; Bull 1986). In particular, the degree of dispersal of the larval stages of both fish and corals has received detailed attention, and there is much work in progress that attempts to elucidate the process.

Green Island, near Cairns on the north-central region of the Great Barrier Reef, was badly affected by the crown of thorns starfish, first in the 1960s and again in 1979/80. Following the second outbreak, the surviving cover of hard coral was estimated to be less than 10% by independent observers (Cameron and Endean 1981; Nash and Zell 1981). Even in 1985, about 5 years after the passing of the starfish, line transect surveys at sites around the reef slope showed only 3 of 15 sites with coral cover greater than 10%, and at many sites the cover was still less than 5% (section 1).

The situation at Green Island provides the opportunity for a natural experiment to test the source of coral recruitment to the reef, by comparing the rate of recruitment at Green Island Reef with that at nearby reefs. Since there are few adult corals at Green Island, we hypothesise that the rate of coral recruitment would be less than at nearby flourishing reefs if recruitment was predominantly local (i.e. if reefs were self-seeding).

The aims of this section of the study were three-fold: to examine the natural variation in hard coral recruitment by comparing a number of reefs and reef sites simultaneously; to determine if the recovery of the hard coral community at Green Island Reef following severe predation by the crown of thorns starfish was likely to be limited by a reduction in the reproductive output of the reef; and to look at the dispersal patterns of coral recruits which might give clues to dispersal paths and the degree of interconnectedness of these reef systems.

2.2 METHODS

Racks of settlement plates were placed at depths of 3 to 5m at low tide on the forereef and backreef areas of Green, Upolu and Michaelmas Reefs (figure 6). There were racks at two sites in each forereef and backreef, separated by a distance of 20 to 40m. Each rack contained 8 plates cut from *Platygyra* colonies, 4 with relatively smooth cut surfaces, and 4 with one surface from the outer part of the colony. Plates were bolted in pairs above and below the rack forming a narrow space between the plates (figure 7). This space is referred to as the 'gap' habitat.

Figure 6. The location of reefs used in the larval recruitment study.

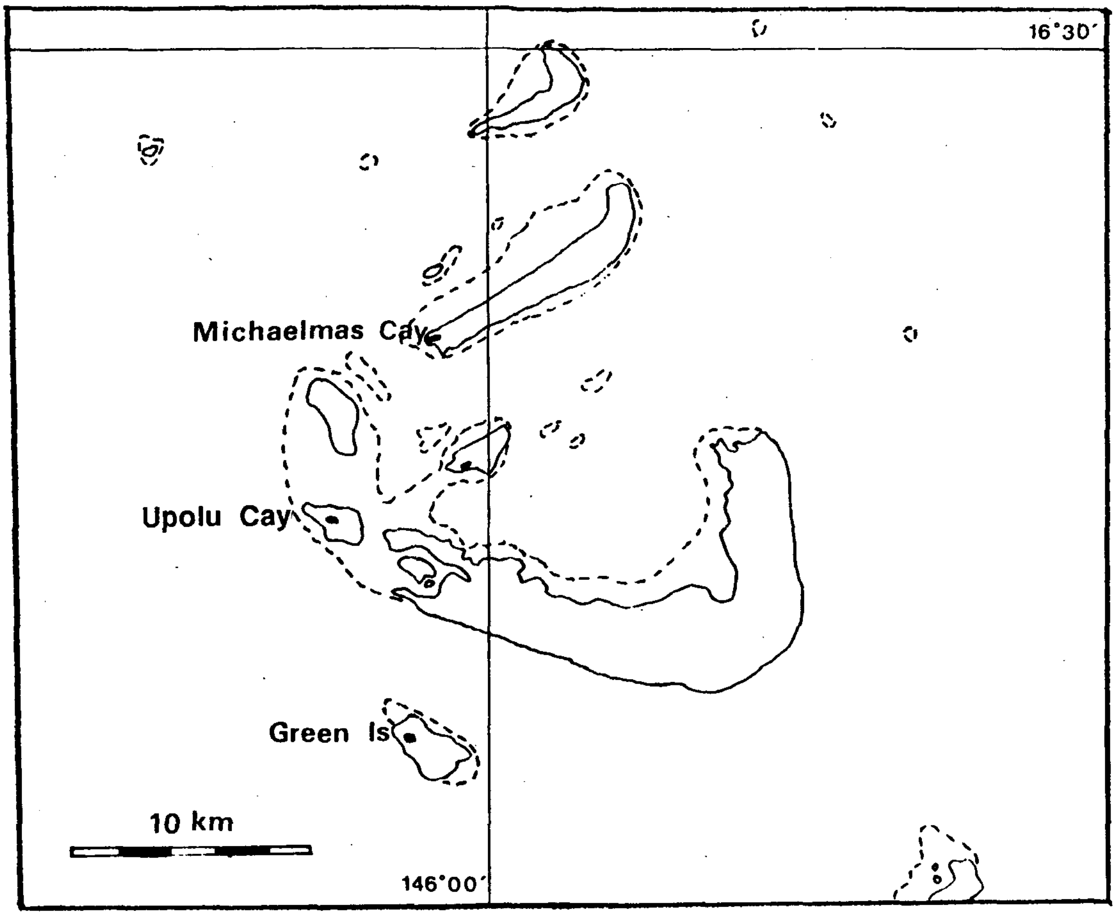
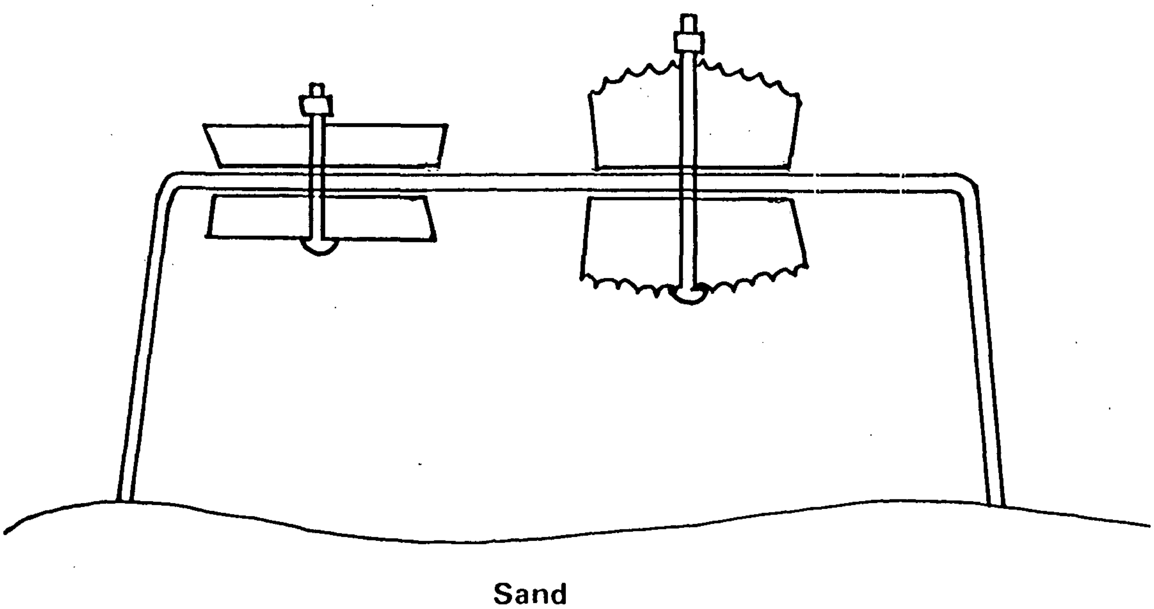


Figure 7. The attachment of settlement plates showing the 'gap' habitat.



Plates were collected and replaced at approximately 6-monthly intervals, in October 1985, March and September 1986. After collection, plates were bleached in a chlorine solution, dried and examined under a dissecting microscope. The number of spat on the top and bottom of each plate was counted. Spat were identified to family level where possible.

2.3 RESULTS

Over 2500 spat were found on all the plates. Of these, only one was found on the uppermost surface of the plates. 52% of spat were found on the lowermost surface of a pair of plates bolted together, and 48% were found in the narrow gap between the two plates. This is consistent with the results reported by Harriott and Fisk (1987b) on settlement preferences of coral spat for different plate types.

The number and identification of spat recruiting over the 18-month period are shown in figure 8. There is a summer/winter variation in the number of spat recruiting at all reefs, although the distinction is less clear for Upolu Reef.

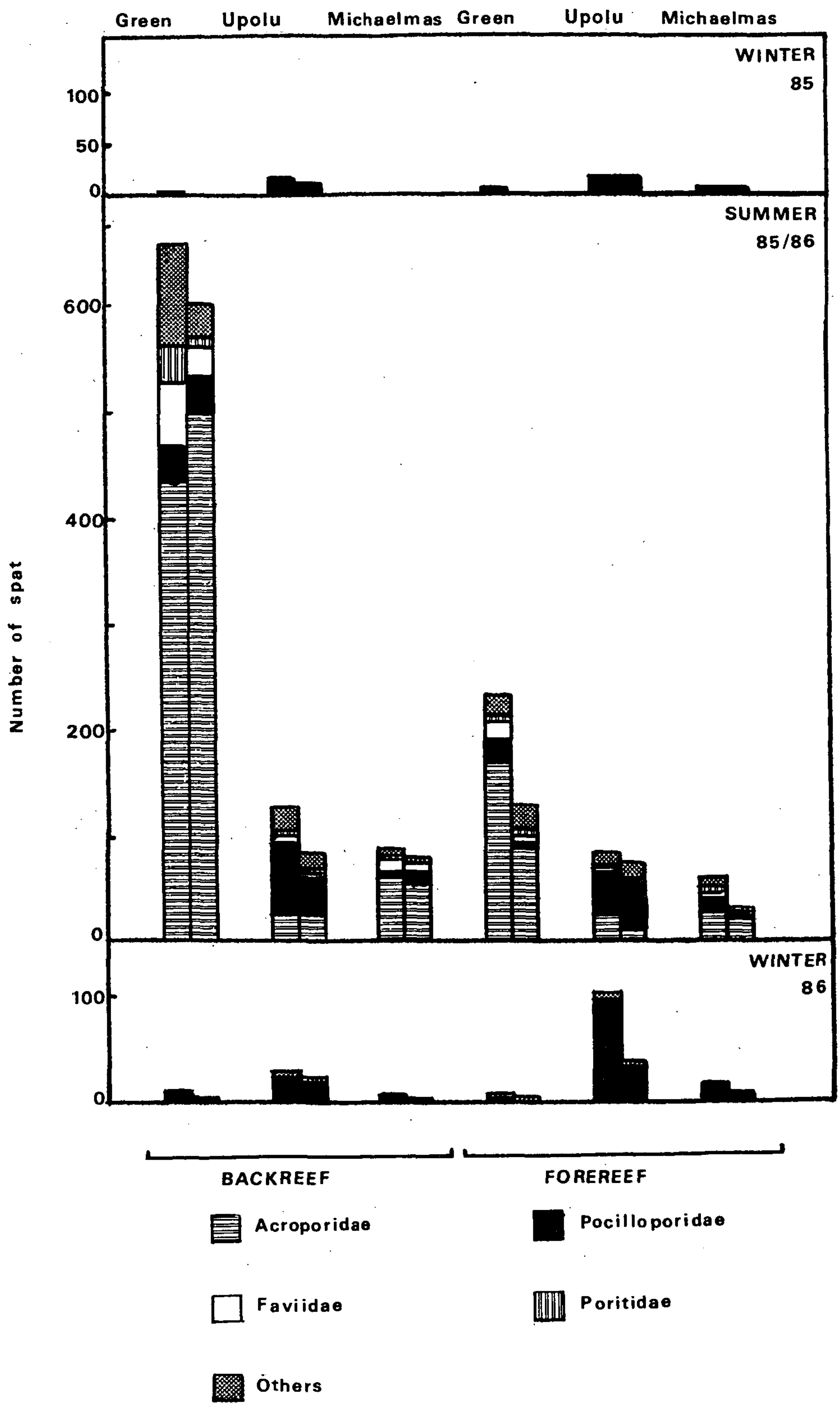
Spat numbers settling on plates over the summer period were analysed by an analysis of variance of log-transformed abundance data which indicated that there was significant variation in spat numbers both amongst the three reefs, and between forereef and backreef sites at each reef (table 1). For all reefs, there was higher recruitment at backreef than forereef sites, and a similar pattern was found at nearby Middle Cay Reef during the same period (Harriott and Fisk 1987b). Green Island had the greatest number of recruits, followed by Upolu Reef then Michaelmas Reef.

Table 2. Results of ANOVA for differences in log-transformed spat abundance with reef (Green, Upolu, Michaelmas) and reef zone (forereef, backreef).

Factor	d.f.	F-ratio	P(F)
Reef	2	39.83	3.4×10^{-4}
Reef Zone	1	20.97	3.8×10^{-3}
Interaction	2	3.33	0.11
Error	6		

Spat that settled in winter were almost exclusively of the family Pocilloporidae (figure 8). On the summer plates, Pocilloporidae were the most abundant taxa only on the plates from Upolu Reef. On Green and Michaelmas Reefs, spat from the family Acroporidae dominated on summer plates.

Figure 8. Summary of spat settlement on plates at Green, Upolu, and Michaelmas Reefs, for an 18-month period.



2.4 DISCUSSION

2.4.1 Recruitment patterns

Spat preference for the lower and 'gap' habitat for all reefs and sites is consistent with the results reported by Harriott and Fisk (1987b). Uppermost surfaces were least favoured, probably because of their propensity for collection of sediment and their susceptibility to grazing, especially by fish (Harriott 1985).

The concentration of spat recruitment in summer at most reefs has been reported previously (Harriott 1985; Wallace and Bull 1982; Wallace 1983, 1985a, 1985b, 1985c) and can be attributed to the phenomenon of the majority of coral species on the Great Barrier Reef spawning in a short period in late spring and early summer (Harrison et al. 1984; Willis et al. 1985; Babcock et al. 1986). This results in the availability of large numbers and a variety of planulae in the water during summer, while only some Pocilloporidae and a few planulating *Acropora* species are known to spawn consistently in winter (Harriott 1983b; Kojis 1986).

There is evidence that planulae of pocilloporid corals are able to settle rapidly and may in fact settle close to their reef of origin. Many pocilloporids brood larvae, which are sometimes asexually produced (Stoddart 1984), and in other cases are not (Ayre and Resing 1986). The larvae of *Pocillopora damicornis*, the best studied of the Pocilloporidae, are capable of settlement 12 to 24 hours after release (Harrigan 1972; Harriott 1983b; Richmond 1982), in contrast to the larvae of non-brooding species which require a minimum of about 4 days before settlement can occur (Babcock 1985).

The cover of pocilloporid corals at the forereef of Upolu Reef was approximately twice that found on Green or Michaelmas forereefs (unpublished line transect data), and pocilloporid spat were approximately twice as abundant at Upolu, compared with the other two reefs. This suggests that local recruitment may be a major factor in the reported high density of pocilloporid recruits at Upolu Reef.

The data on summer recruitment can be used to test the hypothesis that if reefs are predominantly self-seeding, then the depauperate nature of the adult coral population at Green Island would result in lower recruitment rates than for less-damaged reefs. The results contradict this prediction, and the fact that recruitment rates at all sites at Green Island were higher than at any of the sites on the other two reefs (which are less damaged, unpublished data) is strong evidence that the recruits came largely from outside Green Island. This result is consistent with the predictions from oceanographic data and known larval life periods given in Williams et al. (1984) that, over a larval period of approximately one week, larvae are likely to be moved long distances from the parent reef.

2.4.2 Dispersal pathways

A larval dispersal path that would yield the specific recruitment patterns on the three reefs reported here can be predicted from the oceanographic conditions during the period following the peak spawning period for corals on this part of the Great Barrier Reef. During early summer, the currents are predominantly wind-driven apart from the influence of the East Australian Current moving to the south-east (longshore) in periods of calm wind (Wolanski and Pickard 1985; Wolanski and Bennett 1983; Church 1983).

The mass spawning of corals in 1985 occurred on the evenings of 2 and 3 December (R. Babcock, pers. comm.). The most recent data available indicate that many corals are competent to settle as little as four days after spawning (Babcock 1985). Oliver and Willis (1987) report that mass spawning of corals can result in the formation of slicks containing very large densities of living coral larvae compared to the water around them.

Table 3. Wind speed and direction at Fitzroy Island for the 2 weeks following the time of the mass spawning of corals in 1985 (Bureau of Meteorology data). Speed is in knots.

Date	0600		0900		1500	
	Dirn.	Speed	Dirn.	Speed	Dirn.	Speed
2/12	NE	2	NNW	2	NNE	4
3/12	NNW	4	NW	4	NNW	6
4/12	ENE	8	ENE	5	NW	3
5/12	SE	12	SE	15	NNW	4
6/12	E	8	E	8	E	12
7/12	ESE	12	E	12	E	12
8/12	SE	11	SE	9	SE	10
9/12	SE	6	SSE	4	NE	13
10/12	WNW	1	SE	2	ESE	3
11/12	NW	5	NW	5	NW	8
12/12	NNW	3	NW	4	NW	8
13/12	NW	10	NW	6	E	3
14/12	W	3	NW	5	NE	5
15/12	NE	6	NNW	8	NNW	12

Wind records for Fitzroy Island, near Green Island, during the early part of December 1985 (table 3) show a period of northerly winds from 2 to 4 December, southerly or easterly winds from 5 to 7 December, and a period from 7 to 9 December when winds were from the south-east. These data suggest that larvae from corals which spawned on the evenings of 2 and 3 December would have drifted south-eastward for 2 or 3 days then moved to the north-west from 7 to 9 December. Under these circumstances, it is likely that larvae of corals that spawned on Michaelmas, Arlington or Upolu Reefs could have settled on Green Island Reef. There is a break in the reefs to the north of Michaelmas Reef that could account for the failure of a net southerly drift of larvae to recruit at Michaelmas Reef. The formation of

relatively small but dense patches of larvae within slicks (Oliver and Willis 1987) and the relatively large area of water compared to reef adds an element of chance to the probability of large numbers of larvae 'hitting' a reef.

Williams et al. (1984), Wolanski and Jupp (1984), and Wolanski et al. (1986) describe the pattern of eddies in the lee of reef systems, and discuss their possible role in retaining particles, particularly reproductive products close to the reef. Williams et al. (1984) conclude that the systems are unlikely to retain particles for more than a few days and would therefore have a limited role in determining recruitment patterns. It is possible, however, that eddies play a major role in retaining reproductive products briefly as they move past a reef, once they have been in the water mass for several days and are competent to settle. In the circumstances described here, an eddy formed by the current from the south 4 to 7 days post-spawning might have trapped larvae in the leeward reefs long enough to account for the higher numbers of recruits in the backreefs of all the reefs studied.

If the factors discussed here have had a major role in determining recruitment patterns, we should be able to predict recruitment patterns in this reef set from oceanographic conditions during the summer spawnings. For example, the relative abundance of spat between reefs should be different if the strength and direction of winds in the week following spawning varies greatly from that reported for 1985. An increased number of widely spaced settlement plate sets have been deployed to test this hypothesis, and we plan to study this reef set for several years to document long term trends in recruitment patterns.

There are several management implications for a finding of wide dispersal of larval products. Firstly, there have been predictions that recovery times following crown of thorns starfish predation on reefs as badly damaged as Green Island will be slow because of a lack of larval recruits when the adult corals on the same reef are mostly dead (Endean 1976; Pearson 1981). This would clearly not be the case, and the predictions of plentiful larval recruits presented here are born out by the observation of very large numbers of small corals in the field at Green Island 5 years after the starfish damage (sections 1 and 3).

Secondly, if the pattern of heavier than average larval recruitment at Green Island holds true for many years, perhaps because of the conditions prevalent during summer, then we could question whether a high density recruitment of A. planci larvae might not also occur and be a factor in the propensity for Green Island to suffer outbreaks of the starfish.

Finally, evidence of this type adds to the body of literature on the interconnectedness of reef systems indicating that individual reefs must be managed as part of a larger system. Damage to reefs 'upstream' may impact on 'downstream' reefs, particularly if one of the reefs is the usual source of recruits for the other.