3 POPULATION DYNAMICS OF JUVENILE CORALS AT GREEN ISLAND

3.1 INTRODUCTION

When the majority of the hard corals on the reef at Green Island were killed by Acanthaster planci, the coral community was freed from any competition for space with other corals, and patches of dead coral substrate were created which were potential recruitment sites for new corals.

The early phase of the recovery process for corals is little studied because the colonies are not clearly visible for several years (Wallace 1983). The relationship between initial settlement onto the bare surface, subsequent recruitment, and the abundance of larger colonies is significant in our understanding of the dynamics of the recovering reef community. Here, we investigate the juvenile coral populations on two types of dead coral surface approximately five years post-A. planci, and subsequent recruitment to those same sites.

Preliminary results for the first three samples that cover a 10-month period are presented here. The study is on-going, and the results of the longer term study will be presented separately.

3.2 METHODS

Two easily recognised and readily available substrates were chosen for our permanent quadrats. These were dead standing plate Acropora (A. hyacynthus plates), and smoother clean limestone substrates (e.g. dead Porites colonies). We sampled five of each substrate at each of two depths (3m and 6m) in both a forereef and a backreef site. The settlement plates referred to in section 2 were located in these same areas.

At the time of the initial mapping in November 1985, coral cover was very low in the sample quadrats, although some juvenile corals were present in all quadrats. We used a 1m x 1m quadrat subdivided by string into 25 equal smaller squares to aid accurate relocation of individual colonies. The quadrat location was defined by two steel stakes which were usually marked in two corners of a quadrat. Compass bearings and hand drawn maps aided relocation of each set of quadrats.

The dead Acropora plates varied in size (mean=0.57m^2, range=0.23 to 1.0m^2) and outlines of the plate shape were recorded on the map of the quadrat. The area of the plate was measured from the maps using a planimeter. The solid substrates were a constant 1m^2. Recruitment and abundance figures were then calculated per m^2 for the plates.

Juveniles were defined in this study as those with a mean diameter less than or equal to 20cm. Colonies were identified to generic level. At the first census, most colonies had an encrusting morphology with height less than 1cm, so colonies were measured along the longest horizontal axis and along the horizontal axis

perpendicular to this. At the time of the second census, many colonies had changed in morphology to the adult type colony shape and a height measurement was also taken.

Colonies were mapped and measured in November 1985, the quadrats were censused for presence/absence of colonies in May 1986, and the colonies were re-mapped and measured in September 1986.

Two of the marked dead Acropora plates on the forereef disappeared between the first two census periods, almost certainly due to the effects of Cyclone Winifred (Harriott and Fisk 1987a). There were therefore reduced samples for the study of recruitment during the year and a subsample of four of the five quadrats per site was used in the analyses. Mortality and recruitment rates were calculated in two ways: by including the plates lost during the cyclone and by excluding them from an analysis. Where a reduced sample set was used, the four quadrats were chosen randomly for the recruitment analyses, and the quadrats with the four highest initial colony numbers used for the mortality analyses. Each colony was given a unique number for tracing through time and all data were included in a database management program.

3.3 RESULTS

3.3.1 Fission and fusion rates

Over the study period 13 colonies were added to the total number of colonies under examination via the splitting or fission of colonies present at the commencement of the study. In addition, 8 colonies merged or fused to other colonies, thereby reducing the number of colonies under examination. Colonies which underwent fission or fusion were not included in estimates of recruitment or mortality, respectively.

3.3.2 Abundance of juveniles

Corals from the families Acroporidae and Faviidae were the most abundant juveniles for all substrates, depths, and sites pooled (table 4).

A 3-way ANOVA of juvenile abundance per m^2 showed a significant effect ($p<0.01$) of site (forereef versus backreef) on juvenile density, and a significant interaction between the factors depth and substrate type (table 5).

Juvenile density was higher in the backreef than the forereef. The interaction between the factors depth and substrate is illustrated in figure 9. At the shallow sites, densities were similar on plates and solid substrates, while at 6m, juveniles were far more abundant on the solid substrates than on the dead plates.

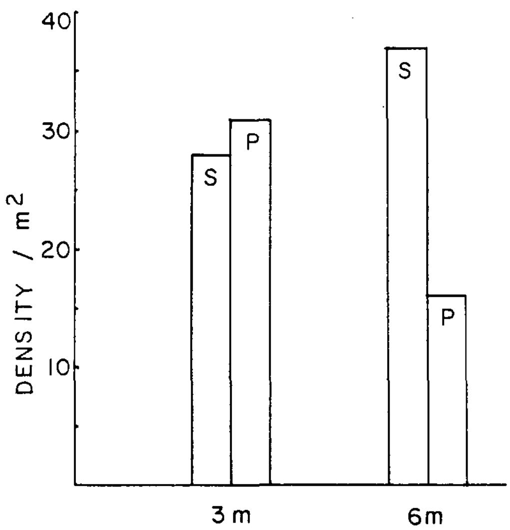
Table 4. The relative abundance of the major families and genera of juveniles pooled for all substrates, depths, and sites. Only those genera with 20 or more records are listed here (=86% of all records).

Families	No.	% of Records	Genera	No.	% of Records
Acroporidae	552	43	*Acropora*	438	35
Faviidae	366	28	*Porites*	195	15
Poritidae	200	16	*Favia*	142	11
Pocilloporidae	56	4	*Montipora*	109	9
Mussidae	52	4	*Leptastrea*	74	6
			Favites	59	5
Total	1226	95	*Stylophora*	38	3
			Cyphastrea	25	2
			Lobophyllia	22	2
			Total	1102	86

Table 5. Results of a 3-way ANOVA of initial density of juveniles per m^2 in November 1985, with respect to the factors: substrate type (dead plates and solid substrates), depth (3m and 6m), and site (forereef and backreef). *=significant.

Factors	d.f.	Mean Squares	F-test Ratio	P(F)
Site	1	1974.02	11.04	0.002 *
Depth	1	207.03	1.16	0.29
Substrate	1	198.01	1.11	0.30
Site x Depth	1	148.24	0.83	0.37
Site x Substrate	1	70.24	0.39	0.54
Depth x Substrate	1	1600.23	8.95	0.005 *
Site x Depth x Substrate	1	87.01	0.49	0.49
Error	32	5722.00		

Figure 9. The initial abundances of juvenile corals at Green Island Reef, expressed as an interaction of the factors depth and substrate type. S=solid substrates, P=dead *Acropora* plates.



3.3.3 Recruitment 1985-86

Table 6 shows the results of a 3-way ANOVA with 4 replicates for each of the two substrate types, two depths and two sites. Only the factor 'site' had a significant effect on recruitment, with higher recruitment on the backreef than the forereef site.

Table 6. Results of a 3-way ANOVA of recruitment rates of corals with respect to the factors: substrate type (dead standing plates, solid substrates), depth (3m and 6m) and site (forereef, backreef). *=significant.

Factors	d.f.	Mean Square	F-test Ratio	P(F)
Site	1	318.8	34.1	5×10^{-6}*
Depth	1	5.3	0.6	0.46
Substrate	1	16.5	1.8	0.20
Site x Depth	1	9.0	1.0	0.34
Site x Substrate	1	22.0	2.4	0.13
Depth x Substrate	1	0.8	0.1	0.78
Site x Depth x Substrate	1	19.5	2.1	0.16
Error	24	9.3		

Recruitment rates of the families are given in table 7. The recruitment rates of the different families closely reflect their previous abundance in the juvenile coral community, with acroporids being the fastest recruiters, as well as the most abundant juvenile corals.

Table 7. Abundance of juvenile coral recruits by family.

Family	% of initial abundance	% of subsequent recruits	% on smooth limestone	% on dead plates
Acroporidae	43	42	41	45
Faviidae	28	30	26	40
Poritidae	16	12	14	7
Mussidae	4	7	9	3
Pocilloporidae	4	2	-	-

3.3.4 Mortality

Table 8 gives the results of 3-way ANOVAs on the effects of depth, site and substrate type on mortality rates. When mortality due to loss of the whole substrate (i.e. dead plate) was excluded, there was no significant effect for any factor (table 8A). However, when mortality due to plate loss was included (using all five quadrats in each data set), there was a significant difference in mortality due to substrate type (table 8B).

Table 8. Results of a 3-way ANOVA of mortality rates of juvenile corals with respect to the factors: substrate type (dead plates and solid substrates), depth (3m and 6m) and site (forereef and backreef). Percentage data was arcsin transformed. * = significant.

A. Mortality due to plate loss not included.

Factors	d.f.	Mean Sq.	F-test Ratio	P(F)
Site	1	96.6	0.35	0.56
Depth	1	3.3	0.01	0.91
Substrate	1	780.2	2.83	0.11
Site x Depth	1	67.2	0.24	0.63
Site x Substrate	1	41.8	0.15	0.70
Site x Depth x Substrate	1	888.3	3.26	0.08
Error	24	275.4		

B. Mortality due to plate loss included.

Site	1	12.4	0.03	0.86
Depth	1	2.6	0.007	0.93
Substrate	1	2284.7	5.85	0.02*
Site x Depth	1	97.0	0.25	0.62
Site x Substrate	1	523.4	1.34	0.26
Site x Depth x Substrate	1	867.7	2.22	0.15
Error	32	390.8		

The difference between the data sets indicates that there is not higher mortality of juveniles of dead plates, but that plates are more susceptible to catastrophic damage such as that caused by Cyclone Winifred.

There were no clear differences in the mortality rates of the major families i.e. Acroporidae (26%), Faviidae (25%) and Poritidae (26%).

3.3.5 Net changes

Net changes in the number of colonies for each of the factors (sites, depths, substrates) for the 10-month period: November 1985 to September 1986, are summarised in table 9.

Solid substrates showed a net increase in all sites and depths, while dead Acropora plates showed a net decline in numbers in shallow sites and a net increase in deeper sites, for both forereef and backreef sites.

Table 9. Net changes in number of colonies for the 10-month period: November 1985 - September 1986. Mortality due to plate loss included. P=plates, S=solid.

Sites:	Forereef				Backreef				Total
Depths:	3m		6m		3m		6m		Fore- and
Substrates:	P	S	P	S	P	S	P	S	Backreef
Initial Nos:	131	106	26	142	75	185	67	230	962
+ Recruits:	15	25	11	26	23	68	21	65	254
- No. Dead:	42	18	8	21	41	30	14	63	237
=	104	113	29	147	57	223	74	232	979
Net change =	-27	+7	+3	+5	-18	+38	+7	+2	+17

3.3.6 Growth rates

The preliminary results for growth rates of juvenile corals showed no apparent pattern with respect to depth or substrate type. However, there appears to be a clear difference between genera in growth rate, and corals of the same genus almost invariably grew faster in the forereef than the backreef (table 10). Further analysis of growth patterns will await the continuation of this section of the project over a longer time period. A significant number of corals of all types exhibited no growth or negative growth over the 10-month period.

Table 10. The mean increase in diameter (cm) over 10 months, of the major juvenile coral genera at the forereef and backreef sites.

Genus	Forereef	Backreef	All corals
Acropora	2.8	1.4	2.11
n=	122	110	232
Montipora	2.3	1.1	1.68
n=	30	33	63
Porites	0.8	0.3	0.41
n=	30	77	107
Favia	0.8	0.5	0.62
n=	23	46	69
Favites	0.8	0.1	0.34
n=	14	20	34
Leptastrea	0.7	0.3	0.53
n=	16	14	30
Cyphastrea	-0.4	0.4	0.01
n=	7	7	14
Goniastrea	1.1	0.4	0.63
n=	4	8	12
Platygyra	1.8	0.7	1.50
n=	7	3	10
Stylophora	1.2	1.2	1.2
n=	3	18	21

3.4 DISCUSSION

From this study, we have shown that juvenile corals were more abundant and recruited more rapidly on a backreef site compared to a forereef site. This result is consistent with results from our study of coral spat recruitment, where higher recruitment rates were found in the backreef than the forereef (Harriott and Fisk 1987b, sec. 2.3).

Juvenile corals of the families Acroporidae, Faviidae, and Poritidae recruited to Green Island Reef during the study period in the same relative abundance as the established juveniles, indicating that a consistent recruitment pattern over the last few years would alone have given rise to the current taxonomic status of the coral population, without the need to invoke differential post-recruitment mortality. In fact, the combination of recruitment and mortality as expressed in the net turnover measurements acted to maintain the observed structure of the juvenile community. Wallace (1985c) also concluded that larval recruitment largely determined species composition at her study reef where recovery was in progress after heavy *A. planci* predation.

In addition, juvenile corals were recorded in approximately the same relative taxonomic composition, at the family level, as the coral spat on settlement plates (section 2). This supports the hypothesis that a pool of recruits of similar taxonomic composition has been added to Green Island Reef for several spawning seasons at least.

Juvenile pocilloporid corals have been relatively scarce at the study sites, both as established juveniles and juvenile recruits. The family Pocilloporidae is the only abundant winter spat at Green Island, so perhaps post-settlement mortality may therefore be occurring which is more or less specific to the pocilloporids.

Initial results indicate that juvenile coral mortality rates did not differ significantly between depths or sites examined here, nor did they differ greatly between the dominant families. Destruction of the dead plates was the only factor that had a large impact on the juvenile mortality.

Growth rate, measured as change in mean diameter, was consistently greater in the forereef site than the backreef site. Acropora and Montipora increased in diameter at three to eight times the rate of the faviid and poritid corals measured. Stylophora grew at approximately half the rate of Acropora and Montipora.

The net increase in colony numbers in three of the four study sites and depth combinations indicates that Green Island Reef is in an early successional stage where the number of colonies increases over a number of years before space becomes limited and competition eventually reduces the number of colonies (Pearson 1981). Other studies on communities at later successional stages (Harriott 1983a; Hughes and Jackson 1985) have shown relatively constant colony numbers and constant diversity despite high turnover rates. High turnover of colonies was observed in our study (mortality rates: 13%-52% per year), but net increases in colony numbers also occurred.

The process which appears to have the major influence on the early successional stages in the development of the coral community appears to be recruitment of the broadcast spawning species. Acropora spp. are the most dominant and successful group of recruits, with greatest abundances, recruitment rates and growth rates. The recovering coral community at Green Island is Acropora dominated, as has been described for other post-A. planci reefs (Pearson 1981, sec.1).

For corals such as Pocillopora damicornis, successful recruitment as juveniles was limited. However as it was also one of the corals most resistant to predation by A. planci, and relatively large remnant patches have survived at Green Island (section 1) it is unlikely to suffer local extinction at Green Island. On the other hand, if a preferred coral prey species was dependent for dispersal on a brooding reproductive cycle (where propagules tend to settle close to parents), or vegetative reproduction by fragmentation (Wallace 1985c), it is conceivable that the species could be entirely removed from a reef system for long periods by repeated intensive A. planci outbreaks.

Incomplete predation by A. planci of colonies of important reef-building corals can result in substantial remnant populations (Done, 1985). These remnants may provide resistance against species composition change on a whole reef scale, and result in the persistence of many genotypes. The contribution of remnants to juvenile coral community composition was not assessed at Green Island because so many years had passed since the last A. planci outbreak.

The recruitment and juvenile studies from this project suggest that the contribution of remnants is not significant in comparison to the contribution of larval recruitment in the recovery and re-establishment of the coral community.

The juvenile coral population mapped in this study will be recensused in future years. These data should allow analysis of small scale changes in the community structure as the colonies become larger, and factors such as interspecific competition and overgrowth will have an increasing role to play. The long term stability or otherwise of the juvenile recruitment patterns reported here can then be tested.