RESULTS

Environmental conditions over the study period

Cyclones and rain depressions

In early 1986, two cyclones impinged on the north Queensland coast. Cyclone Winifred, which crossed the coast between Cairns and Townsville on February 1, 1986, was the first severe cyclone in 14 years to have a major impact on the east Australian coast (Crane 1986). Effects along the Cape Tribulation coast were apparently small (40-50 kn winds were recorded at Low Isles). A rain depression Vernon on the 22-23 January 1986 was mentioned in the meteorological logbook at Low Isles. Cyclone Namu formed to the north of Cooktown in late April 1986 but broke up to the south of Cooktown by 27 April. The effect of this small cyclone was quite severe on some of the reefs in the study area (Ayling and Ayling 1987; this study). No cyclones were recorded in 1987.

Bleaching

The summer of 1986/87 was characterised by calm conditions and a late summer wet season which meant low cloud cover over much of the most intense summer period. Extensive bleaching of scleractinian and some alcyonarian corals was reported along Cape Tribulation reefs and was thought to have commenced some time between 15 January 1987 and 26 February 1987 (Ayling and Ayling 1987). Some bleaching down to 5m depth was still evident in May 1987 but was mainly restricted to partial bleaching in some pocilloporids, *Montipora* spp. and some alcyonarians (Fisk 1987).

Sedimentary regime

Bonham (1985) identified three high impact areas due to the new road construction - north of Cape Tribulation, Donovan Point and Cowie Point. Bonham also pointed out that substantial amounts of sediment from the road had reached the marine environment. At low tide this turbid water is carried onto the living coral zone of the reefs and wave action helps deposition there (Bonham 1985). Fresh/brackish water floats from creeks are also transported in longshore currents driven by prevailing winds (Bonham 1985).

There is also extremely high turbidity due to re-suspension of fine bottom sediments which are in situ along the coast. The net northerly flow of water and suspended sediments occurs most of the year from February to October due to moderate south-easterly winds (10-20kn, (Pickard 1983)). Net southerly flow is expected for the other three months of the year when northerly winds are common. Continuous re-suspension of sediments means that fine turf algae will trap large amounts of sediment and this will reduce substrata available for coral settlement.

Belperio (1983) concluded that fine terrigenous silt and mud are contained within the inner shelf waters (0-20m depth) and that there is continuous deposition and re-suspension as they move north. Hoyal (1986) also found an increase in fine sedimentation from the south to the north, though he could not conclude that there was a significant increase in fine sediment in the nearshore environment due to road construction. He did, however, find red coloured sediment in sediment traps which were inshore close to road disturbance areas but was not in traps in any other places. This could be interpreted as indicating that sediment from road activities reached the coral zones adjacent to some road areas.

Coral spat recruitment

Coral spat at Cape Tribulation showed a noticeable preference for exposed (outer and inner) vertical or near vertical surfaces compared to spat on mid-shelf reefs (Harriott and Fisk 1988) for similar depths. We interpret this as a need to maximise light and minimise sedimentation compared to mid-shelf reefs where light is apparently not as critical in the shallow depth range and most spat settle in cryptic positions.

Spat recruitment patterns show a distinctive summer dominance in abundance, with small numbers in winter. Winter 1986 and 1987 results are shown in table 2. The settlement surfaces differed between the two periods. However, the general trend remains, with low numbers of corals, predominantly of the family Pociloporidae, settling in winter and mostly in the southern reefs.

Table 2. Winter spat results for 1986 and 1987.

Cut Platygyra plates were used in 1986 and ceramic tiles were used in 1987. Reef 3/10 (1986) was replaced by the adjacent reef 3/9 in 1987. - = no data. All spat are Pociloporidae except those in brackets. The commas separate spat numbers from each rack (2 racks per reef).

	SOUTH		CENTRAL		NORTH	
Reef	1/1	1/2	2/6	2/17	3/10,9	3/11
Year						
1986	2,1	0,2(1)	0,0	-,-	0,0	0,1
1987	25,10	2(1),10	0,0	0,-	0,0	0,(17)

The northern reef 3/11 in 1987 had a relatively large number of unidentified very young spat. These may have been recruits of a mass spawning species that spawned earlier in summer than usual in this period. This was the case for some species at Magnetic Island that year (R. Babcock, pers. comm.).

All further spat results presented here refer to the summer periods of 1985/86, 1986/87, and 1987/88. The number of days the plates were left in the water varied due to deployment and collection date differences, i.e. 148 days, 228 days, 164 days respectively. Total spat numbers are shown in figure 2, and data for each family are given in Appendix 1. Reef 2/17 did not always have all settlement plates intact or both racks present after any summer period, which at least partially accounts for the lower total spat numbers for this reef. The 1985/86 summer totals are from cut Platygyra plates which represented much lower total surface areas per rack than the ceramic tiles used in the following two summers.

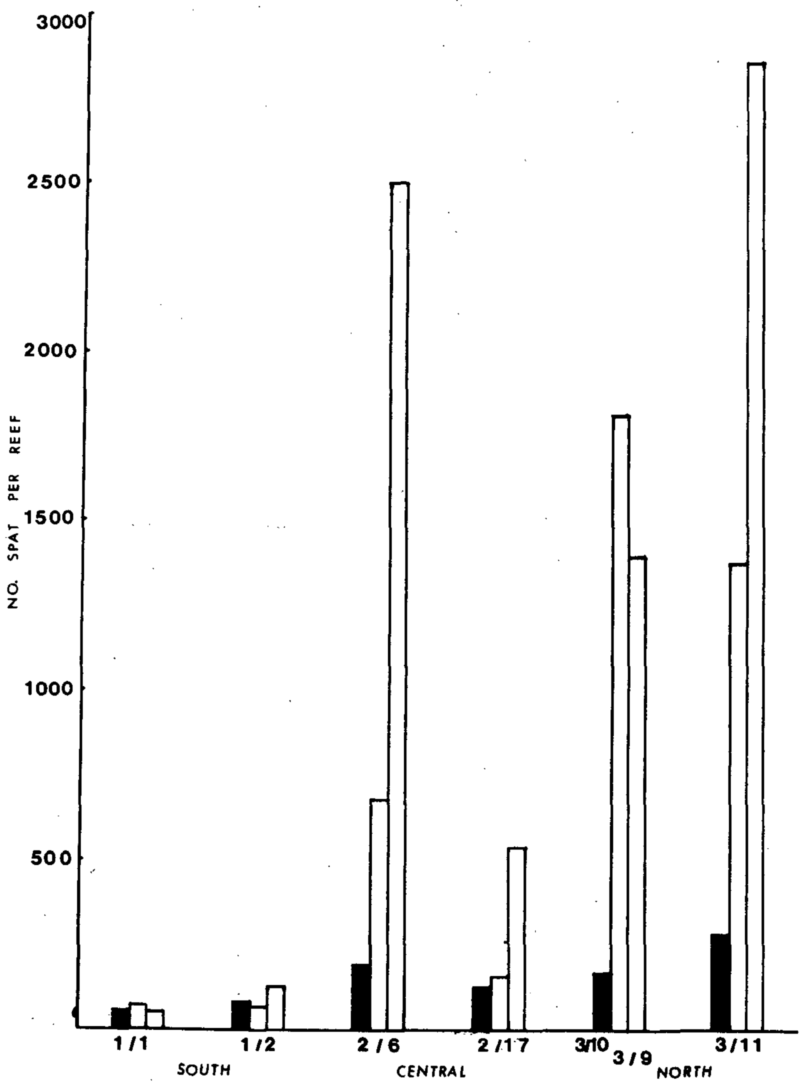

Figure 2. The abundance of spat on settlement plates for the summer periods : 1985/86 (dark, plates of cut Platygyra); 1986/87 (middle plot, plates of ceramic tiles). The number of spat refer to the total number recorded on each reef using a standardised sub-sample of settlement surfaces per rack from 2 racks on each reef. Reef 2/17 usually did not have all tiles remaining on racks in 1986/87 and 1987/88, accounting in part for the lower total abundances at this reef.

Analysis of spat data was approached by treating each summer period separately because the factor years is not an independent variable due to replacement racks being re-deployed in exactly the same position. The data for 1985/86 and 1987/88 were analysed using a 1-way ANOVA block design analysis to test for differences between zones. Because of missing racks, this analysis could not be used on the 1986/87 data. The 1986/87 and 1987/88 data were analysed by reefs using 1-way ANOVA with Tukeys test to distinguish reefs that significantly varied (at 0.05 level) from each other. The relative proportions of each family within a reef set of plates was used to test if coral larvae were from a single well mixed larval patch from which all reefs could receive recruits.

Summer 1985/86

The number of spat per rack ranged from 30 to 450 (mean = 151, SD = 108, no. racks = 12). There was no significant difference in the number of spat per rack between reefs but the number of poritid spat was relatively consistent between the 3 zones (1-way nested ANOVA, F = 2.61, P(f) = 0.13, df = 2,9). The number of poritid spat was relatively consistent between reefs but the number of acroporid spat varied greatly (Appendix 1). However, the proportion of all spat represented by the pocilloporid, acroporid, and poritid families did not vary significantly between zones (1-way nested ANOVA, F = 2.95, P(F) = 0.1; F = 3.07, P(f) = 0.1; F = 4.41, P(F) = 0.06, respectively).

Summer 1986/87

The number of spat per rack (totals from 1 pair each of horizontal and vertical tiles) ranged from 21 - 1111 (mean = 378, SD = 369, no.racks = 11) (Appendix 1). There was a significant difference in the total number of spat per rack between reefs (1-way ANOVA, F = 15.35, P(F) = 0.005; df = 5,5; 1 rack from reef 2/17 lost). Further analyses using Tukeys tests showed that the differences were due to zonal differences. That is reefs 1/1, 1/2 (South zone) had significantly smaller numbers of spat than reefs 3/9 and 3/11 (North zone). Also, reef 3/9 had significantly higher spat numbers than reefs 2/6 and 2/17 (Central zone).

The proportions of some of the major spat families (acroporids and poritids) varied significantly between reefs (P(F) = 0.004,0.0000, respectively) (Appendix 1). Pocilloporids and faviids did not vary significantly (ANOVA, P(F) = 0.06, 0.0773, respectively) but this may be due to relatively low numbers of these 2 families represented on the tiles. The significant difference in the proportion of acroporids was due to the high numbers of acroporid spat on the northern reefs (3/9 and 3/11). The proportion of poritidae differed because of large (1/1) to very large (1/2) relative numbers in the southern zone reefs and a larger proportion on one rack at reef 2/17 (central), compared to lower numbers at reefs 2/6 (central) and 3/9, 3/11 (north).

ANOVA (1-way) of differences in the proportion of live spat on plates at the time of collection revealed a significant difference between reefs (F = 8.54, P(F) = 0.0172, df = 5,5) due to significantly higher numbers of live spat at reef 1/2 compared to reefs 2/6, 3/9, and 3/11. There is a trend towards a higher proportion of live spat in the southern zone compared to the central and northern zones.

Summer 1987/88

The number of spat per rack (using 2 vertical, 2 horizontal pairs) ranged from 21 to 1664 (mean = 622, SD = 602, no.racks = 12; Appendix 1). Because rack number 1 from reef 2/17 had no remaining horizontal plates, spat per reef were compared using one pair of vertical plates per rack.

Results of the nested ANOVA to test for differences between zones showed no differences for total number of spat per zone, as well as for the proportion of faviids, acroporids, poritids, or live spat. The proportion of pocilloporids did differ with the southern zone having the highest relative proportions.

When the reefs within each zone were analysed separately, there was a significant difference in the total number of spat per reef (1-way ANOVA, F = 12.07, P(F) = 0.004, df = 5,6). Tukey's test showed significantly higher numbers on racks at reef 3/11 and 2/6 compared to reefs 1/1, 1/2. Reef 3/11 was also significantly different from 2/17.

The relative proportion of acroporids and pocilloporids differed significantly between reefs (F = 7.96, P(F) = 0.013; F = 92.68, P(F) = 0.0000, respect.) with higher proportions of acroporids in central (reef 2/6) and northern reefs (reef 3/11) compared to reef 1/1 (south). Also, there were significantly higher proportions of pocilloporids on the southern reefs (1/1, 1/2) compared to all other reefs. The poritids and faviids did not differ significantly between reefs in their relative proportions (F = 2.59, P(F) = 0.139; F = 0.862, P(F) = 0.555, respect.). The actual numbers of each spat family did vary between reefs but not necessarily in the same way as their relative proportions.

There was no significant difference in the proportion of live spat on the plates from any reef (ANOVA, F = 4.12, P(F) = 0.0571, df = 5,6).

Juvenile coral dynamics

In November 1985, 29 genera were recorded from the 36 permanent quadrats and in subsequent years an additional 9 genera were recorded in a total of 42 quadrats (Appendix 2).

Acropora spp. and *Montipora* spp. dominated all sites (in the no.colonies/quadrat) while most other genera were patchy over the study reefs. Representation of genera within a reef ranged from 21-58% of the total number of genera recorded over all the quadrats. The southern two reefs had 39% of all recorded genera present, while the central and northern zones had 76% and 66%, respectively.

Abundance, recruitment, and survival rates for the major juvenile families were calculated for the two-year period of the study from 1985 to 1987 (table 3). Additional data are given for the most abundant family, Acroporidae (table 4).

Survival rates

There was a significant difference in the survival rates of all corals between reefs over the two-year period (ANOVA, $F = 6.37$, $P(F) = 0.01$, $df = 4,9$). Tukey's tests showed a difference in survival between reef 1/1 and the other 4 reefs (data for reef 3/9 did not span the two-year period and were not included in this analysis).

Recruitment

Recruitment of corals (at visible size) measured here included both migration of colony fragments from outside the quadrats and larval recruitment. Daughter colonies produced through fission of a single large colony also contribute to an increase in the number of colonies but this occurred infrequently and is not included in the recruitment estimates.

Overall, recruitment rates into permanent quadrats were not significantly different between any of the reefs over both year periods (1985-86: $F = 1.92$, $P(F) = 0.192$, $df = 4,9$; 1986-87: $F = 1.61$, $P(F) = 0.21$, $df = 5,18$). However, in 1986-87 the acroporids showed a significant difference in recruitment rates ($F = 3.89$, $P(F) = 0.014$, $df = 5,18$), which was due to a higher recruitment at reef 1/1 (south) compared to reefs 2/6 and 2/17 (central) (Table 4).

Size frequency plots of juveniles (figure 3) show that relatively large numbers of colonies of both *Acropora* and *Montipora*, particularly in the size class of 6-10 cm mean diameter, were contributing to the high recruitment rate in the southern zone reefs. The size ranges of recruits suggest that recruitment is mainly via migration of larger colonies into the quadrats, rather than from recruitment of larvae.

Table 3. Survival and recruitment of juvenile colonies.

For the two-year period from 1985-87 and grouped into major families and pooled minor families (others). The minor families include representatives from Dendrophylliidae, Oculinidae, Fungiidae, Caryophylliidae, Merulinidae, Pectiniidae, Agariciidae. Only 1 reef in the northern zone was followed for the two years and 2 quadrats in this reef were followed compared to 3 quadrats at all other reefs. Data presented as % survival and (initial no.).

	SOUTH		CENTRAL		NORTH
Reef	1/1	1/2	2/6	2/17	3/11
Survival Rates:					
F.Acroporidae	11%(106)	29%(136)	31%(33)	47%(15)	30%(20)
F.Pocilloporidae	0 (8)	30%(10)	0 (2)	0 (3)	0 (1)
F.Poritidae	0 (0)	33%(9)	30%(23)	50%(2)	27%(11)
F.Faviidae	20%(5)	29%(7)	76%(21)	73%(11)	40%(5)
Others	0 (14)	11%(18)	56%(25)	73%(15)	27%(11)
Pooled	10%(133)	27%(180)	45%(106)	59%(46)	29%(48)
Recruitment:					
1986	29	36	29	6	58
1987	60	48	21	7	41

Table 4. Abundance, recruitment, and relative survival of Acroporids.

	SOUTH		CENTRAL		NORTH
Reef	1/1	1/2	2/6	2/17	3/11
Initial Nos. (1985)	106	136	33	15	20
% of all Survivors at each reef	92%	80%	25%	26%	43%
% of all Initial corals	79%	76%	35%	33%	42%
Recruitment					
1986	26	27	16	0	25
1967	52	31	9	1	17

Table 5. Relative contribution of spat settlement and colony migration to the recruitment rates (mean recruits/m^2). Recruitment into permanently marked quadrats for the two-year period 1985-87. Figures refer to the combined totals of each family grouped into zones. Size refers to mean diameter in cm; recruits in the <2.5cm size class are assumed to be from spat settlement, and recruits in the >2.5cm size class are assumed to have resulted from colony migration.

	SOUTH		CENTRAL		NORTH	
	<2.5	>2.5	<2.5	>2.5	<2.5	>2.5
No.Perm.Quads.	14		14		10	
Acroporids	0.77	5.6	0.28	1.0	0.34	4.4
Pocilloporids	0.03	0.43	0.0	0.07	0.07	0.2
Poritids	0.03	0.36	0.15	0.3	0.14	0.1
Faviids	0.0	0.07	0.22	0.21	0.14	0.1
Other	0.16	0.5	0.32	0.64	0.31	1.1
Totals	2.2	6.9	1.36	2.2	2.9	5.9

To gauge the relative contribution of spat settlement and colony migration to the recruitment rates, the size class differences between colonies <2.5cm (assumed spat settlement) and colonies >2.5cm (assumed colony migration) are compared (table 4). In all cases, except for the poritids and faviids in the northern zone reefs, the recruitment by migration was greater than spat recruitment.

Mortality rates

Mortality rates of all corals combined showed no significant difference between individual reefs in the 1985-86 year ($F = 3.04$, $P(F) = 0.077$, $df = 4,9$). There was a significant difference between reefs in the following year period 1986-87 ($F = 3.04$, $P(F) = 0.037$, $df = 5,18$). This difference was due to significantly higher mortality rates at reef 1/1 (south) than at 1/2 (south) and 2/17 (central) (Tukey's Test).

Size class distributions

The size frequency distributions of corals within the 3 zones (combined total from 2 reefs in each zone) and for the 3 census periods between 1985-1987 (inclusive) are given in Appendix 3. Numbers are low for all major families except the acroporids, and the 'other families' group includes diverse genera which were usually abundant in one particular reef but rare or absent on most other reefs.

Kolmogorov-Smirnoff tests were conducted on grouped data using proportions of colonies in size frequency groupings, to test if there were significant differences between reefs and years in the size structure of the juveniles (Appendix 4). There was no significant difference in size frequencies between any of the zones in any year period over the study period (Appendix 5). However, two zones showed significant differences (at the 0.05 level) in size frequency distributions between two consecutive years. That is, the southern zone reefs differed between 1986 and 1987, and the northern zone reefs showed a significant difference between 1985 and 1986. These differences could be reasonably interpreted as the result of cyclones in the 1985-86 period at least.

Relationship between spat and juvenile abundances

Table 5 gives the proportion of each of the major families recorded on settlement plates for the two-year period from October 1985 to October 1987, and a corresponding estimate of the proportion of each family assumed to be the result of spat recruitment (<2.5cm mean dia.) in permanent quadrats over the same time period. For example, the acroporids showed higher relative proportions in the quadrats compared to plates in the southern zone, but lower relative proportions in quadrats compared to plates in the central and northern zones.

Table 6. Proportions of each hard coral family settling on settlement plates compared to the proportion of each family of visible recruits (<2.5cm mean dia., and overall proportion of juveniles) in permanent quadrats. Data is for the two-year period 1985-87 (incl.). N = no. spat or visible recruits. Ppn. = proportion of total in a particular zone.

	SOUTH			CENTRAL			NORTH		
	Plates	Quadrats <2.5	Overall	Plates	Quadrats <2.5	Overall	Plates	Quadrats <2.5	Overall
Acroporidae:									
Ppn	0.54	0.77	0.8	0.72	0.28	0.22	0.68	0.34	0.54
N	254	24	218	1056	6	36	2797	10	121
Pocilloporidae:									
Ppn	0.19	0.03	0.06	0.001	0	0	0.01	0.07	0.03
N	90	1	16	2	0	0	34	2	6
Poritidae:									
Ppn	0.16	0.03	0.05	0.03	0.15	0.12	0.05	0.14	0.07
N	77	1	15	49	3	19	196	4	15
Faviidae:									
Ppn	0.02	0	0.03	0.002	0.22	0.24	0.01	0.14	0.08
N	8	0	9	3	4	39	37	4	19
Others:									
Ppn	0.01	0.16	0.07	0.24	0.32	0.42	0.26	0.31	0.28
N	45	5	18	349	6	67	1066	9	64
Total									
N	474	31	276	1459	19	161	4130	29	225