

SURVEY METHODS AND HABITAT NOTES

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Survey Methods

Stations were selected by exploratory snorkelling to ensure that they covered the range of underwater topography present and a representative range of habitats (Table 3). Fifteen stations were then intensively sampled to a depth of 20 m, fourteen using SCUBA (Figure 1). Rough transect profiles were made at each station and notes made from visual observations on bottom type, dominant fauna and estimates of live coral coverage (Table 4). Voucher specimens were collected and are lodged in the Western Australian Museum.

Habitat Notes

The habitats at each sampling station are outlined in Table 4. In general subtidal habitats are very similar around the island; hard bottom substrates of limestone covered by dead and living corals predominated with very limited areas of soft (sandy) bottom substrate. Because of the narrowness of the subtidal terrace (a maximum of about 150 m) and steep drop-off to deep water, the total area of littoral reef habitat around the island is not great.

The most salient observation on the subtidal

habitat of the present survey was the high proportion of dead coral around the entire island and at all depths sampled. This extensive coral die-off had not occurred in 1978 when G. Allen and R. Steene conducted their survey on the fishes, but was evident on their 1986 visit. This poses the following two questions; when did the die-off occur and what caused it?

Information of the timing of the die-off was obtained by interviewing people who had dived at Christmas Island between 1978 and 1986 and examining available underwater photographs. It is apparent that the coral mortality occurred between September 1982 and March 1984 and was gradual and insidious. (Unfortunately no suitable photographs taken in 1983 have been obtained so the date of the die-off cannot be fixed more precisely). There is no evidence to suggest occurrence of a conspicuous, sudden catastrophic physical environmental event or that an *Acanthaster* outbreak occurred. 1982/83 was one of the strongest El Niño events on record (Cane, 1983) while Brown (1987), in a review of worldwide die-off of corals, shows that coral die-off was probably associated in a number of widespread instances. On the basis of mean weekly surface water temperatures (at four points half a degree to the north, south, east and west of Christmas Island and one point adjacent to it) derived from NOAA satellite images it is apparent that mean surface water temperature in the region of Christmas Island was between approximately 0.5°C and 1.0°C cooler than average for a prolonged period (June to December) in 1982 and then slightly above average from January to March 1983. This is indicative of large-scale hydrological changes that would be expected in the eastern Indian Ocean associated with El Niño (Cane, 1983). While the absolute temperature drop seems unlikely to have been sufficient to be lethal to corals, stress in some way associated with the El Niño seems the most likely cause of the die-off. It is noteworthy that Blake & Blake (1983) record extensive coral die-off in the lagoon of the Cocos (Keeling) Islands in March 1983 which they attribute to El Niño associated stress.

Present observations suggest that coral die-off must have been almost total to a depth of about 10 m. Many dead colonies, which were still standing, were recognisable to genus and species, *Porites* and

Table 3 Localities of snorkel reconnaissance dives.

Locality	Locality
A	Steep Point
B	Wright Point
C	Greta Beach
D	Between C and John D. Point
E	Dolly Beach
F	Dorothy Beach
G	South Point
H	W. of N.W. Point
I	Martin Point
J	Off Dales
K	Winifred Beach
L	N. of Egeria Point
M	Jones Point
N	E. of Middle Point
	W. of Vincent Point
P	Vincent Point
Q	E. of Vincent Point
R	Midway between Vincent Point and Lost Lake Cave
S	Rhoda Beaches
T	Daniel Roux Cave
U	325 m NE of Jones Point
V	400 m NE of U

Merulina ampliata colonies being the dominant survivors. The non-scleractinian coral *Heliopora coerulea* was very common, both living and dead. *Pocillopora verucosa*, *P. damicornis*, *Galaxea fascicularis* and *Acropora* spp. were the most conspicuous and widespread recolonising species evident in 1987. Most colonies were small, with a maximum diameter not exceeding 10 cm. The higher rate of survivorship by deeper water corals (>15 m) is inconsistent with a rampant *Acanthaster* outbreak, which on the Great Barrier Reef includes corals at this depth (Done, pers. comm.).

REFERENCES

Blake, W. and Blake, J. (1983). *An account of events in the lagoon of Cocos Keeling atolls in March 1983*. Unpublished Report to the Australian National Parks and Wildlife Service: 1-30.

Brown, B.E. (1987). Worldwide death of corals – natural cyclical events or man-made pollution. *Marine Pollution Bulletin* 18: 9-13.

Cane, M.A. (1983). Oceanographic events during El Niño. *Science* 222: 1189-1194.

Table 4 Habitats at stations sampled around Christmas Island.

Station	Locality	Habitats
1 Flying Fish Cove	.1	Steep coral sand/rubble beach.
	.2	Limestone platform with dead coral slabs; brown algal turf and encrusting corallines; live coral <1%.
	.3	Steep dropoff to sand/rubble bottom: live coral <1%.
	.4	High relief large dead or partially dead colonies of <i>Leptoria</i> , <i>Merulina</i> , <i>Porites</i> and <i>Diploastrea</i> with some regenerating faviids; live cover 5-10%.
	.5	Low to moderate relief; similar to 1.4 above but extensive <i>Acropora</i> rubble mounds with numerous small colonies of colonising <i>Galaxea</i> . Live cover 5-20%.
	.6	Slope of variable inclination – steep or vertical at western side of Cove with live and dead <i>Acropora</i> (10-30% live cover increasing with depth), moderate to gentle slope at centre of cove becoming scree slope of coral rubble, mainly plate and staghorn <i>Acropora</i> ; 5-10% live cover. <i>General- .3-.5: Echinothrix diadema, Diadema savignyi</i> very abundant.
2 Cave E. of NW Point	.1	Intertidal wall of cave with encrusting (faces N.E.) corallines and vermetids. Subtidally the purple hydrozoan coral <i>Distichopora violacea</i> conspicuous. Cave floor wave-swept, coralline encrusted.
	.2	Dead <i>Acropora</i> rubble, some live <i>Montipora</i> plates and few small <i>Pocillopora</i> colonies; live coral cover 10% (up to 80% in <i>Montipora</i> areas).
	.3	Diverse coral fauna, <i>Montipora</i> , <i>Pocillopora</i> and <i>Lobophyllia</i> dominant; gorgonians and antipatherians conspicuous on side of smooth walled gully; live cover 10%-30% increasing with depth.
3 Ethel Beach	.1	Shallow sand and rubble covering limestone pavement.
	.2	Limestone platform with scattered slabs and slightly raised rim; encrusting corallines, <i>Porites</i> microatolls, isolated <i>Goniastrea retiformis</i> , <i>Favites</i> spp. and zoanthids <i>Palythoa</i> spp.; live coral cover <5%.
	.3	High relief gutters and caves; short algal turf and small colonies of faviids, <i>Pocillopora</i> , <i>Hydnophora</i> , <i>Acropora</i> , <i>Goniopora</i> , <i>Echinopora</i> and <i>Heliopora</i> ; live cover <1%.
	.4	Coral spp. as in .3 but extensive staghorn <i>Acropora</i> rubble mounds with up to 100% cover of <i>Galaxea</i> . Dead <i>Montipora</i> plates; live cover <10%.
	.5	Sand and rubble forming scree gullies down slope in places.
	.6	Slope with diverse corals, mainly dead plates (<i>Montipora</i>); live cover 30% increasing with dept
4 Between Lily Beach and Steep Point		Series of terraced rock pools up to 1.5 m impounding water at different heights(3-6 m above sea level) resulting indifferent physical regimes. Highest pools with high water temperatures and little or no water exchange except in storms, bare of algal or coral growth and blennies abundant. Lowest pools with constant splash inflow with corals (<i>Acropora</i> spp., <i>Pocillopora damicornis</i> , <i>Goniastrea</i> spp., <i>Symphyllia</i> spp. and <i>Porites</i>) and typical reef faunas. Pools have raised rims due to vermetid tubes concreted by corallines. Brown alga <i>Turbinaria ornata</i> and zoanthids abundant. Also echinoderms, especially limpet-like <i>Colobocentrotus atratus</i> in high energy pools

Table 4 (cont.)

Station	Locality	Habitats
5 Waterfall	.1	Rubble and boulder beach.
	.2	Wave-swept limestone pavement with short (grazed) algal turf and few small <i>Pocillopora</i> colonies; strong fresh-water inflow but very prolific fish life; live coral cover <1%.
	.3	High relief gullies (2–3 m) and ridges with tops covered in brown algal turf; live coral cover <1%. Some Alcyonacea and zoanthids on ridges.
	.4	Sloping terrace with large mounds of staghorn <i>Acropora</i> rubble and recolonising <i>Galaxea</i> ; many overturned large dead tabular <i>Acropora</i> colonies; some small <i>Montipora</i> ; live coral cover 5–10%.
	.5	Slope with many dead corals as in .4 but extensive areas of Alcyonacea, increasing with depth; live coral cover 5–10%.
	.6	Steep slope characterised by foliose corals (eg. <i>Echinophyllia</i> , <i>Pachyseris</i> , <i>Leptoseris</i>). Large dead plates of tabular <i>Acropora</i> ; live coral cover up to 70% increasing with depth.
6 Off Golf Course	.1	Wave-swept limestone pavement dissected by gutters.
	.2	Large wave-washed boulders.
	.3	Moderate relief sloping terrace with scattered dead bommies and outcrops.
	.4	Steep slope with good live coral cover below 20 m.
		Remarks: No estimates on live coral coverage.
7 N. of S.E. Point (between Tait Point and Andrews Point)	.1	Wave swept pavement dissected by deep gutters filled with sand and rubble; live coral cover <1%.
	.2	Pavement with 35% cover by Alcyonacea and occasional small <i>Pocillopora</i> colonies.
	.3	Rubble and limestone slabs; 5% cover of Alcyonacea and hard corals.
	.4	High relief of large dead coral colonies largely covered by Alcyonacea (85% cover).
	.5	Low relief similar to .4.
8 Greta Beach	.1	Greta Beach, coral sand/rubble.
	.2	Limestone platform with brown algal turf.
	.3	Sand bottom.
	.4	Large dead and some partially live <i>Porites</i> bommies with extensive cover (25%) of Alcyonacea; small pockets of sand between bommies.
	.5 and .6	30% live cover increasing to 60% with depth, mainly Alcyonacea.
		.7 Rubble and sand.
9 Winifred Beach	.1	Coral sand/rubble.
	.2	Wave-scrubbed pavement with fine green algal turf; dissected by deep (3 m) gutters.
	.3	Sand and rubble with scattered slabs and boulders.
	.4	High relief dead <i>Acropora palifera</i> formations with some small colonies alive and regrowth of encrusting corals; live cover 10%.
	.5	Mainly dead but some large living <i>Porites</i> bommies with laterally projecting shelves; <i>Montipora</i> , <i>Pavona</i> , <i>Hydnophora</i> , faviids and small <i>Acropora</i> spp. common; diverse Alcyonacea; live coral cover 20%.
	.6	Similar to .5 but with extensive mounds of staghorn <i>Acropora</i> rubble with scattered new <i>Galaxea</i> colonies.
	.7	Sand and rubble.
10 Merial Beach	.1	Coral rubble.
	.2	Wave-scrubbed pavement with fine green/ brown algal turf; cut by deep gutters with rubble bottoms.
	.3	Small scattered corals (<i>Pocillopora</i>); live cover <5%.
	.4	Boulders covered in green algal turf.
	.5	Huge boulders with sand bottom between.
	.6	Large <i>Porites</i> bommies, mainly dead but some living; some scattered Alcyonacea, few other hard corals; live coral cover <10%.
	.7	Sand and limestone slabs.

Table 4 (cont.)

Station	Locality	Habitats
11 West White Beach	.1	Coral sand/rubble.
	.2	Wave-scrubbed pavement with fine brown algal turf.
	.3	High relief limestone cut by deep longitudinal gullies covered by brown algal turf increasing shoreward and scattered small (5–10 cm) recolonising <i>Acropora</i> and <i>Pocillopora</i> colonies; live coral cover <5%. Approx. 4m ² covered by giant anemones also extensive areas covered by soft coral <i>Sarcophyton</i> .
	.4	Staghorn <i>Acropora</i> rubble mounds with recolonising <i>Galaxea</i> (5% cover).
	.5	Moderate relief; many dead and some living small <i>Porites</i> colonies. Extensive recolonisation by diverse corals (20% live cover).
	.6	Steep dropoff with diverse coral fauna dominated by dead and some live plate corals; foliose corals eg. <i>Leptoseris</i> and <i>Pachyseris</i> at depth; live coral cover 30%.
12 Egeria Point	.1	Shallow groove and spur formations cut into wave-washed pavement; brown algal turf and encrusting corallines.
	.2	Large limestone boulders off cliff.
	.3	Sand, rubble and small limestone slabs between ridges and pinnacles of coral rock with small scattered colonies of <i>Acropora</i> , <i>Pocillopora</i> , <i>Pavona</i> , <i>Montipora</i> and several faviids; also several alcyonaceans; live coral cover 5–10%.
	.4	Vertical face with ledges and overhangs with sand and <i>Halimeda</i> ; diverse corals on wall, mainly <i>Montipora</i> plates; also gorgonians, antipatherians and some alcyonaceans; live coral cover 20–40%.
13 100 m E. of N.W. Point	.1	Terraced rock pools a few cm to approx. 1.2 m deep with raised algal rims; faviids, <i>Porites</i> , <i>Heliopora</i> , <i>Pavona</i> , <i>Montipora</i> , zoanthids and red, green and brown (<i>Turbinaria ornata</i>) algae.
	.2	Brown algal turf on dead coral outcrops interspersed with sand; scattered small <i>Pocillopora</i> and <i>Acropora</i> and <i>Galaxea</i> on staghorn <i>Acropora</i> rubble mounds; live coral cover 5%.
	.3	High relief dead <i>Heliopora</i> (massive), <i>Montipora</i> plates and <i>Porites</i> ; many live fungiids, small <i>Porites</i> colonies and <i>Pocillopora</i> ; live coral cover 20%. <i>Remarks:</i> Obviously a particularly diverse and spectacular area prior to coral die-off.
14 North East Point	.1	Smooth pavement with gutters and occasional boulders.
	.2	Sand and rubble.
	.3–.5	Low relief; live coral cover increasing from 30% to 60% at 30 m.
15 Dolly Beach	.1	Coral sand/rubble.
	.2	Not seen.
	.3	Moderate relief dead corals and moderate live cover (20%), mainly <i>Pocillopora</i> and faviids.
	.4	As in .3 but extensive staghorn <i>Acropora</i> rubble mounds with recolonising <i>Galaxea</i> .
	.5	Scattered high <i>Platygyra</i> bommies, mostly dead but regenerating in patches; several species of alcyonaceans, <i>Galaxea</i> and <i>Montipora</i> ; live coral cover up to 60%.
	.6	Mainly dead <i>Montipora</i> plates, also <i>Galaxea</i> , <i>Goniopora</i> , alcyonaceans and gorgonians; live coral cover 30%.