Distribution of Corals After *Acanthaster planci* (L.) Infestation at Tanguisson Point, Guam[1]

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Abstract

Distributional analysis of the reef corals was undertaken at Tanguisson Point in the early part of 1970, one year after the starfish infestation, and includes relative abundance of coral species and percentage of substrate occupied by living corals by reef zones and the distribution of corallum size and growth forms for the entire reef. By using coral distributional studies conducted prior to the starfish infestation period on an adjacent reef at Tumon Bay, a baseline value was established for the above parameters. Using this baseline data it was found that the total number of species at Tanguission Point had decreased from 146 to 96, and the number of genera from 36 to 33. In the major zones of starfish infestation the per cent of reef surface covered by living corals dropped from 49 to 21 in the reef front zone, from 59 to less than 1 in the submarine terrace zone, and from 50 to less than 1 in the seaward slope zone. There was a relative decrease in all corallum size ranges except the 0–5 cm range and a relative decrease in all the coral growth forms differentiated, except the encrusting types. There is some coral recovery taking place as evidenced by the presence of small, newly established corals from planula settlement and the presence of small surviving patches of previous living corals.

INTRODUCTION

In September, 1968, the University of Guam, Marine Laboratory, was awarded a grant from the Environmental Protection Agency (Grant No. 18050–EUK) to study the marine environment at the proposed site of the Tanguisson Point electrical power generating plant. The primary objective of the grant was to obtain baseline data, before the plant became operational, for use in determining the effects of the heated outfall water upon the fringing reef ecosystem.

During the summer of 1968, the fringing reef along Tumon Bay and Tanguisson Point was heavily infested with the coral-eating crown-of-thorns starfish, *Acanthaster planci* (L.). Preliminary investigation showed that most of the corals had been killed by this animal along the offshore reef slopes, except for a narrow band along the reef margin and inner reef front zones. Objectives of this study are: (1) To determine distribution of reef corals at Tanguisson Point in order to

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provide baseline data for assessment of possible changes induced by plant operations and evaluation of reef recovery in regions previously devastated by *A. planci* (Randall, in press). (2) To compare the present coral distribution data to that which occurred prior to the *A. planci* infestation. In the case of objective 2, coral distribution data prior to *A. planci* infestation are not available for the section of fringing reef adjacent to the power plant site, but comparable data are available for a section of contiguous fringing reef located at Tumon Bay (Randall, 1973). The Tumon Bay coral distribution data are, therefore, used as a control to aid in the estimation of what the Tanguisson reef was like in an undisturbed condition.

METHODS

TRANSECTS

Three permanent transects (A, B, and C), were established at Tanguisson Point. Fig. 1 shows the location of these transects on the reef in respect to the Tumon Bay transects. Stations were established at 10 m intervals along the transects from the upper intertidal zone to a depth of 30 m on the seaward slope zone. These

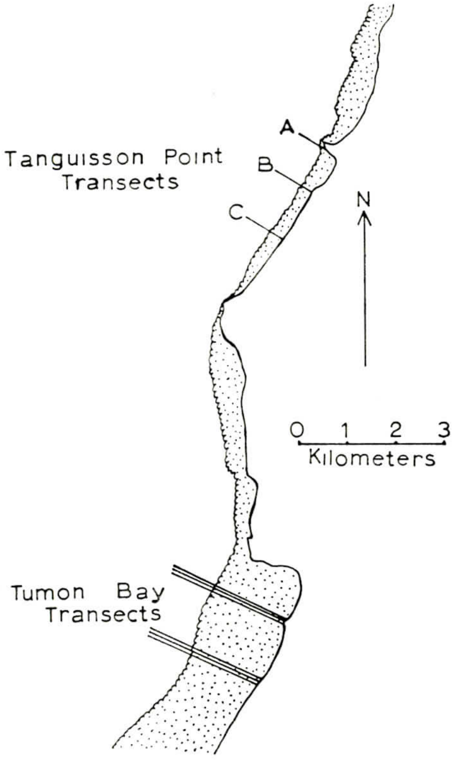

Fig. 1. Northwest coast of Guam showing the location of the Tanguisson Point and Tumon Bay transects. Stippled area denotes fringing reef flat.

station locations were permanently marked by placing three to five links of ship anchor chain (4.7 kgm per link) at each. Stations were identified by attaching numbered fiberglass cards to the anchor chain links. At each station a reference point was established at the point where the numbered card was attached to the anchor links. Two wire grid quadrats, each one meter square, were positioned at the station reference points. After positioning of the quadrat grids the following data were recorded from each: (1) transect station number; (2) quadrat number; and (3) specific name, size, and growth form of each living coral found within the confines of the grid.

SIZE DETERMINATION AND GROWTH FORM

The diameter of individual coral colonies was measured with a meter stick with movable trammel points. If circular, the colony diameter measurement was made at the widest point across the corallum. If the colony shape was not circular, its outline was sketched and several measurements were recorded. The various coral growth forms differentiated follow those described by Wells (1956). A columnar form was added which differentiates an intermediate mode of development between the massive and ramose forms. A subdivision of ramose forms into corymbose, cespitose, and arborescent modes of branching was made.

RESULTS AND DISCUSSION

COMPARISON OF CORAL REEFS AT TUMON BAY AND TANGUISSON POINT

The Tumon Bay and Tanguisson Point fringing reefs have been under surveillance by the author since 1966. Comparisons of physical reef characteristics and coral distribution indicate that the reef margin, reef front, submarine terrace, and seaward slope zones at Tumon Bay and Tanguisson Point were similar (except for slightly less topographic relief at the latter) in reef development before starfish predation took place. A zonal description of the Tumon Bay fringing reef is given in Randall (1973) and need not be repeated for the Tanguisson Point region. The only zones not comparable at the two locations are the subzones of the reef flat, which were not infested with starfish during the population explosion stage. Based on the above assumptions, a comparison can be made of the coral communities between the two study locations.

Table 1 lists the frequency distribution of coral species observed on the transects by reef zones. This table shows that 86 species representing 30 genera occurred on the three transects. Combining the number of species shown on Table 1 that did not occur on the transects, but occurred in the general region between transects A and C, the total number of species is raised to 96 representing 33 genera for the Tanguisson Point area (Table 2). Table 2 shows that the total number of living coral genera surviving the *A. planci* predation is nearly the same as that found before predation. The only genera not found at Tanguisson Point, after the starfish preda-

Table 1. Relative frequency of occurrence and zonal distribution of corals at Tanguisson Point. Relative frequency of occurrence expressed as a percentage of the total number of colonies found in a transect zone or combination of zones. Data from Transects A, B, and C are combined. The species are listed in order of decreasing frequency when all zones are combined.

Name of Coral	Reef Margin		Reef front		Submarine terrace		Seaward slope		All Zones combined	
	No.	Rel. %	No.	Rel. %	No.	Rel. %	No.	Rel. %	No.	Rel. %
Galaxea hexagonalis Milne Edwards & Haime	—	—	94	15.03	13	4.06	1	.62	108	8.29
Goniastrea retiformis (Lamarck)	10	5.52	69	10.92	8	2.50	—	—	87	6.68
Favia stelligera (Dana)	11	6.08	39	6.17	20	6.25	—	—	70	5.38
Montipora verrilli Vaughan	12	6.63	31	4.91	10	3.13	12	7.45	65	4.99
Pavona varians Verrill	—	—	13	2.06	39	12.19	—	—	52	3.99
Favia pallida (Dana)	3	1.66	18	2.85	18	5.63	12	7.45	51	3.92
Porites lutea Milne Edwards & Haime	5	2.76	9	1.42	17	5.31	17	10.56	48	3.69
Pocillopora verrucosa (Ellis & Solander)	12	6.63	21	3.32	8	2.50	1	.62	42	3.23
Acropora nana (Studer)	14	7.73	23	3.64	—	—	—	—	37	2.84
Pocillopora meandrina Dana	15	8.29	15	2.37	—	—	—	—	34	2.61
Acanthastrea echinata (Dana)	—	—	24	3.80	9	2.81	—	—	33	2.53
Leptoria gracilis (Dana)	8	4.42	20	3.16	5	1.56	—	—	33	2.53
Leptastrea purpurea (Dana)	—	—	4	.63	16	5.00	12	7.45	32	2.46
Leptoria phrygia (Ellis & Solander)	5	2.76	16	2.53	9	2.81	—	—	30	2.30
Porites sp. 1	14	7.73	10	1.58	—	—	1	.62	29	2.23
Millepora platyphylla Hemprich and Ehrenberg	14	7.73	9	1.42	—	—	—	—	23	1.77
Pocillopora setchelli Hoffmeister	12	6.63	11	1.74	—	—	—	—	23	1.77
Stylocoeniella armata (Ehrenberg)	—	—	8	1.27	4	1.25	10	6.21	22	1.69
Montipora sp. 1	—	—	6	.95	6	1.88	7	4.35	19	1.46
Galaxea fascicularis (Linnaeus)	—	—	4	.63	6	1.88	8	4.97	18	1.38
Pavona clavus (Dana)	—	—	10	1.58	8	2.50	—	—	18	1.38
Acropora hystrix (Dana)	8	4.42	9	1.42	—	—	—	—	17	1.31
Favites complanata (Ehrenberg)	—	—	6	.95	6	1.88	5	3.11	17	1.31
Goinastrea parvistella (Dana)	—	—	6	.95	11	3.44	—	—	17	1.31
Leptastrea transversa Klunzinger	—	—	—	—	4	1.25	13	8.07	17	1.31
Plesiastrea versipora (Lamarck)	7	3.87	10	1.58	—	—	—	—	17	1.31
Acropora nasuta (Dana)	10	5.52	6	.95	—	—	—	—	16	1.23

Porites (Synaraea) iwayamaensis Eguchi	—	—	—	—	4	1.25	12	7.45	16	1.23
Psammocora nierstraszi van der Horst	3	1.66	10	.58	3	.94	—	—	16	1.23
Millepora exaesa Forskaal	—	—	5	.79	10	3.13	—	—	15	1.15
Leptastrea sp. 1	—	—	1	.16	—	—	13	8.07	14	1.08
Porites lobata Dana	—	—	4	.63	10	3.13	—	—	14	1.08
Stylophora mordax (Dana)	—	—	8	1.27	5	1.56	—	—	13	1.00
Acropora murrayensis Vaughan	8	4.42	4	.63	—	—	—	—	12	.92
Acropora studeri (Brock)	—	—	6	.95	5	1.56	—	—	11	.84
Goniastrea pectinata (Ehrenberg)	—	—	—	—	8	2.50	1	1.86	11	.84
Favia favus Forskaal	—	—	4	.63	6	1.88	—	—	10	.76
Montipora elschneri Vaughan	—	—	8	1.27	2	.63	—	—	10	.76
Acropora surculosa (Dana)	—	—	7	1.11	2	.63	—	—	9	.69
Platygyra rustica (Dana)	—	—	6	.95	3	.94	—	—	9	.69
Acropora humilis (Dana)	—	—	5	.79	—	—	3	1.86	8	.61
Montipora foveolata (Dana)	—	—	4	.63	4	1.25	—	—	8	.61
Montipora sp. 3	—	—	8	1.27	—	—	—	—	8	.61
Platygyra sinensis (Milne Edwards and Haime)	—	—	5	.79	3	.94	—	—	8	.61
Porites australiensis Vaughan	—	—	3	.47	5	1.56	—	—	8	.61
Acropora abrotanoides (Lamarck)	—	—	7	1.11	—	—	—	—	7	.54
Pavona (Polyastra) sp. 3	—	—	4	.63	—	—	3	1.86	6	.46
Cyphastrea chalcidicum (Forskaal)	—	—	4	.63	—	—	2	1.24	6	.46
Lobophyllia costata (Dana)	—	—	4	.63	2	.63	—	—	6	.46
Montipora sp. 2	—	—	—	—	6	1.88	—	—	6	.46
Acropora palmerae Wells	4	2.21	1	.16	—	—	—	—	5	.38
Distichopora violacea (Pallas)	5	2.76	—	—	—	—	—	—	5	.38
Echinopora lamellosa (Esper)	—	—	2	.32	—	—	3	1.86	5	.38
Montipora sp. 4	—	—	5	.79	—	—	—	—	5	.38
Montipora sp. 5	—	—	1	.16	4	1.25	—	—	5	.38
Pocillopora sp. 1	—	—	1	.16	4	1.25	—	—	5	.38
Psammocora (Plesioseris) haimeana Milne Edwards & Haime	—	—	—	—	—	—	5	3.11	5	.38
Astreopora gracilis Bernard	—	—	1	.16	3	.94	—	—	4	.31
Lobophyllia corymbosa (Forskall)	—	—	—	—	—	—	4	2.48	4	.31
Acropora smithi (Brook)	—	—	3	.47	—	—	—	—	3	.23

Table 1. Continued

Name of Coral	Reef Margin		Reef front		Submarine terrace		Seaward slope		All Zones combined	
	No.	Rel. %	No.	Rel. %	No.	Rel. %	No.	Rel. %	No.	Rel. %
Astreopora myriophthalma (Lamarck)	—	—	—	—	3	.94	—	—	3	.23
Cycloseris cyclolites (Lamarck)	—	—	—	—	—	—	3	1.86	3	.23
Echinophyllia aspera (Ellis and Solander)	—	—	—	—	—	—	3	1.86	3	.23
Goniopora columna Dana	—	—	—	—	1	.31	2	1.24	3	.23
Leptoseris hawaiiensis Vaughan	—	—	—	—	—	—	3	1.86	3	.23
Montipora conicula Wells	—	—	3	.47	—	—	—	—	3	.23
Montipora monasteriata (Forskaal)	—	—	3	.47	—	—	—	—	3	.23
Montipora tuberculosa (Lamarck)	—	—	—	—	3	.94	—	—	3	.23
Acropora valida (Dana)	—	—	2	.32	—	—	—	—	2	.15
Cycloseris sp. 1	—	—	—	—	2	.63	—	—	2	.15
Favia rotumana (Gardiner)	—	—	—	—	2	.63	—	—	2	.15
Favites favosa (Ellis and Solander)	—	—	—	—	2	.63	—	—	2	.15
Montipora granulosa Bernard	—	—	2	.32	—	—	—	—	2	.15
Pocillopora eydouxi Milne Edwards & Haime	—	—	2	.32	—	—	—	—	2	.15
Psammocora exesa Dana	—	—	2	.32	—	—	—	—	2	.15
Acropora sp. 1	—	—	1	.16	—	—	—	—	1	.07
Coscinaraea columna (Dana)	1	.53	—	—	—	—	—	—	1	.07
Cyphastrea serailia (Forskaal)	—	—	1	.16	—	—	—	—	1	.07
Favites flexuosa (Dana)	—	—	—	—	—	—	1	.62	1	.07
Heliopora coerulea (Pallas)	—	—	—	—	1	.31	—	—	1	.07
Hydnophora microconos (Lamarck)	—	—	1	.16	—	—	—	—	1	.07
Millepora dichotoma Forskaal	—	—	1	.16	—	—	—	—	1	.07
Montipora hoffmeisteri Wells	—	—	1	.16	—	—	—	—	1	.07
Pavona (*Pseudocolumnastraea*) *pollicata* Wells	—	—	1	.16	—	—	—	—	1	.07
Porites (*Synaraea*) *hawaiiensis* Vaughan	—	—	—	—	—	—	1	.62	1	.07
Porites (*Synaraea*) *horizontalata* Hoffmeister	—	—	—	—	—	—	1	.62	1	.07
Totals	181		632		320		161		1302	
Total species	21		65		45		28		86	
Total genera	12		24		22		19		30	

tion, but that were earlier found at Tumon Bay before the starfish predation were *Euphyllia, Paracyathus,* and *Polycyathus.* Of these three genera, two *Euphyllia* and *Polycyathus,* are more or less restricted to the reef flat, and *Paracyathus* is an ahermatypic coral of little importance in terms of reef building. The high number

Table 2. The following data summarize the number of genera and species for the major divisions of corals at Tumon Bay and Tanguisson Point reefs.

	Tumon Bay		Tanguisson Point	
	Genera	Species	Genera	Species
Hermatypic Scleractinians	31	139	30	91
Ahermatypic Scleractinians	2	2	0	0
Non-Scleractinians	3	5	3	5
TOTAL	36	146	33	96

of genera surviving *A. planci* predation, even though of low density, may be essential in the recovery of devastated reefs if diversity of seed populations is an important prerequisite.

The number of species found on the Tanguisson reefs after *A. planci* predation is 34 per cent less than that at Tumon Bay. The number is reduced to 27 per cent if those species (Randall, in press) that are specific for the reef flat moat, which is well developed only at Tumon Bay, are discounted.

COMPARISONS OF CORAL DISTRIBUTION BY REEF ZONES

The percentage of coral coverage and the number of coral genera and species that were observed or collected from the various reef zones at Tumon Bay and Tanguisson Point are shown in Table 3. Specific and coral coverage differences between Tanguisson Point and Tumon Bay inner and outer reef flat subzones are not due to *A. planci* predation. Differences in physical parameters and lack of a well developed inner reef flat moat, that retains water at low tide, account for the near absence of corals in these two subzones at Tanguisson Point. Some *A. planci* predation occurred in the reef margin zone at Tanguisson, but not to the extent

Table 3. Total number of genera and species, and average per cent of coral cover by reef zones.

	Tumon Bay			Tanguisson Point		
Reef Zone	Genera	Species	% Cover	Genera	Species	% Cover
Inner Reef Flat	18	48	5.4	0	0	0
Outer Reef Flat	16	37	14.9	2	2	0.1
Reef Margin	14	26	26.4	12	21	22.6
Reef Front	32	98	49.1	24	70	20.9
Submarine Terrace	28	73	59.1	24	47	0.9
Seaward Slope	26	57	50.1	21	32	0.5

that coral distribution was greatly changed there.

A. planci predation has caused some damage in the reef front zone. A 29 per cent reduction in the number of species and a 25 per cent reduction in the number of genera has occurred in this zone. Similarly, the amount of living coral coverage has been reduced 58 per cent. Coral damage to the reef front zone is not uniformly distributed across it. The inner (shoreward) half of the reef front zone at Tanguisson Point has a near pre-starfish number of genera and species and percentage of reef surface covered by living corals, while on the outer (seaward) half these parameters have been greatly reduced.

The number of species found living on the submarine terrace and seaward slope at Tanguisson Point is much lower than at Tumon Bay because of the extensive starfish damage. On the submarine terrace the number of species has been reduced about 36 per cent whereas the number of genera has been reduced by only 14 per cent. Even greater changes occurred on the seaward slope where reductions of 44 per cent in the number of species and 19 per cent in the number of genera took place. The total reef surface occupied by living corals on the submarine terrace and seaward slope averages less than one per cent of surface coverage at Tanguisson, whereas at Tumon Bay the mean per cent of coverage at each zone was 59.5 and 50.1, respectively. It was in these two zones that *A. planci* predation was most intense. It was astounding to see such large areas of previously living coral killed in less than a year's time by *A. planci.*

COMPARISON OF CORAL SIZE DISTRIBUTION

There has been a shift in corallum size in all reef zones where corals were killed by *Acanthaster*. This shift was less intensive on the reef margin and inner part of the reef front zones where starfish predation was light. At Tanguisson Point 87 per cent of the coralla found in the submarine terrace and seaward slope zones were less than 10 cm in diameter, whereas at Tumon Bay 52 per cent were in this size range for the same zones. Reduction in coralla size in regions of starfish

Table 4. Size distribution of corals at Tumon Bay and Tanguisson Point.

Diameter range	Tumon Bay		Tanguisson Point	
in cm	No. of corals	Rel. Freq.	No. of corals	Rel. Freq.
0– 5	825	25	801	62
6–10	863	27	323	25
11–15	503	15	95	7
16–20	298	9	28	2
21–25	210	6	18	1
26–30	216	6	15	1
31–35	104	3	2	< 1
36–40	51	2	6	< 1
41–45	40	< 1	7	< 1
46–up	193	6	7	< 1
TOTAL	3302		1302	

predation is due to the small size of newly established coralla and the small size of regenerating parts of older, larger coralla that survived the initial *A. planci* predation. Table 4 shows the relative changes in corallum size for all reef zones combined.

COMPARISON OF CORAL GROWTH FORM DISTRIBUTION

Table 5 shows that the greatest changes took place in an increase of encrusting growth forms and a decrease in the corymbose and cespitose forms. Increases in encrusting forms is to be expected, as newly settled corals usually develop first as small encrusting patches before assuming their adult form. Also many small patches have survived *A. planci* predation on larger massive coralla. Those patches appear initially as small encrusting areas as they overgrow the dead regions of the parent corallum. Corymbose growth forms are largely represented by various species of *Acropora* which are preferred food of *A. planci* and therefore were heavily preyed upon in the outer part of the reef front, submarine terrace, and seaward slope zones and selectively preyed upon in the reef margin and inner part of the reef front zones. Although selective predation of cespitose growth forms of *Acropora* took place in the reef margin and inner reef front zones, these forms have remained relatively abundant (Table 5) because of the presence of numerous *Pocillopora* colonies which survived *A. planci* predation in the same zones.

Table 5. Growth form distribution of corals at Tumon Bay and Tanguisson Point.

	Tumon Bay		Tanguisson Point	
Growth Form	No. of corals	Rel. Freq.	No. of corals	Rel. Freq.
Massive	564	17	202	16
Encrusting	457	14	788	61
Foliaceous	17	1	5	< 1
Flabellate	59	2	13	1
Corymbose	673	20	42	3
Cespitose	872	26	232	18
Arborescent	587	18	9	< 1
Phaceloid	2	< 1	7	< 1
Columnar	68	2	2	< 1
Solitary	3	< 1	2	< 1
TOTAL	3302		1302	

RESETTLEMENT AND REGENERATION

At Tanguisson Point, starfish predation was intensive on the submarine terrace and seaward slope, and the resulting predation has left, in most places, less than 1 per cent of the reef surface covered with living coral growth. Resettlement and regeneration has not taken place in these two zones to the extent that it has in the wave agitated parts of the reef front, possibly because of the following factors:

(1) More intensive predation in these zones has left fewer seed populations of corals to initiate coral resettlement and regeneration. (2) Less optimum coral growth parameters occur at these two zones. (3) Low level *A. planci* predation is in equilibrium with coral regeneration and development in these zones. (4) The standing crop of various seasonal species of algae is greater on seaward reef zones where corals have been killed by *A. planci* than it is on seaward reef zones where luxuriant coral development is found (personal communication with R. T. Tsuda). This may prevent planulae settlement or retard and kill newly developing patches of coral. Coral reef recovery of the Tanguisson Point fringing reef is covered in more detail in Randall (in press).

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