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Survival and growth of coral transplants in Central Philippines*

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Fragments of scleractinian corals, hydrocorals, and octocorals in Sumilon Marine Park and in Bantayan, Dumaguete, Central Philippines were transplanted in denuded portions of shallow coral reefs in these localities in 1979 and 1980. Their survival and growth rates were observed. Yearly survival rates for species ranged from 18 to 100%; overall rates were 40% for the Sumilon transplants and 71% for the Bantayan transplants. Yearly growth rates of the survivors were also variable; the fastest growers increased from 10 to 20 cm in diameter and from 100 to almost 800 cm² in area (strictly the area occupied by the transplants). These growth rates are several times larger than those of corals growing on discarded tires at deeper water (16-23 m). The preliminary data indicate that it is feasible to transplant corals to rehabilitate denuded reefs.

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Most coral reefs in the Philippines are under stress from a number of natural and man-induced causes, and many of them are already showing evidence of degradation (1, 2). To arrest the progressive deterioration of these valuable marine resources we must not only implement the legal measures for their conservation but also search for ways of restoring their high levels of productivity.

One of these ways is coral transplantation. [redacted] In the scleractinian *Galaxea fascicularis*, for example, a single polyp is able to multiply into a number of new polyps (3) Connell (4) mentions his observations in the Great Barrier Reef, Australia and those of others elsewhere that fragments of reef-building scleractinian corals when buried in sand are able to regenerate thriving colonies. Bothwell (5) reports that the asexual method of reproduction occurs regularly in certain species of *Acropora* in the Great Barrier Reef. The asexual mode of reproduction would seem to be of adaptive value in places occasionally subjected to typhoons and other causes of mechanical damage in reefs.

The purpose of this preliminary study is to gather information on the survival and growth rates of transplanted coral fragments that could be used in reef management programs.

Methods

The transplant sites were in shallow water of about 1.5-2.5 m depth at medium tides in Sumilon Marine Park and in Bantayan, Dumaguete. Portions of various sizes were removed from coral colonies and transported in water to the nearby transplant sites. Most transplants were arranged in plots measuring 1 x 1 m or 2 x 2 m and having hard rock substrates. The boundaries of these plots were marked with nylon strings (Fig. 1-4). Some transplants were tied with nylon strings to cross-shaped bamboo sticks situated in a sea-grass community (Fig. 5). Transplants on hard substrates were set in rock depressions, previously excavated with a pointed iron bar, at distances varying from 30 to 36 cm. At-

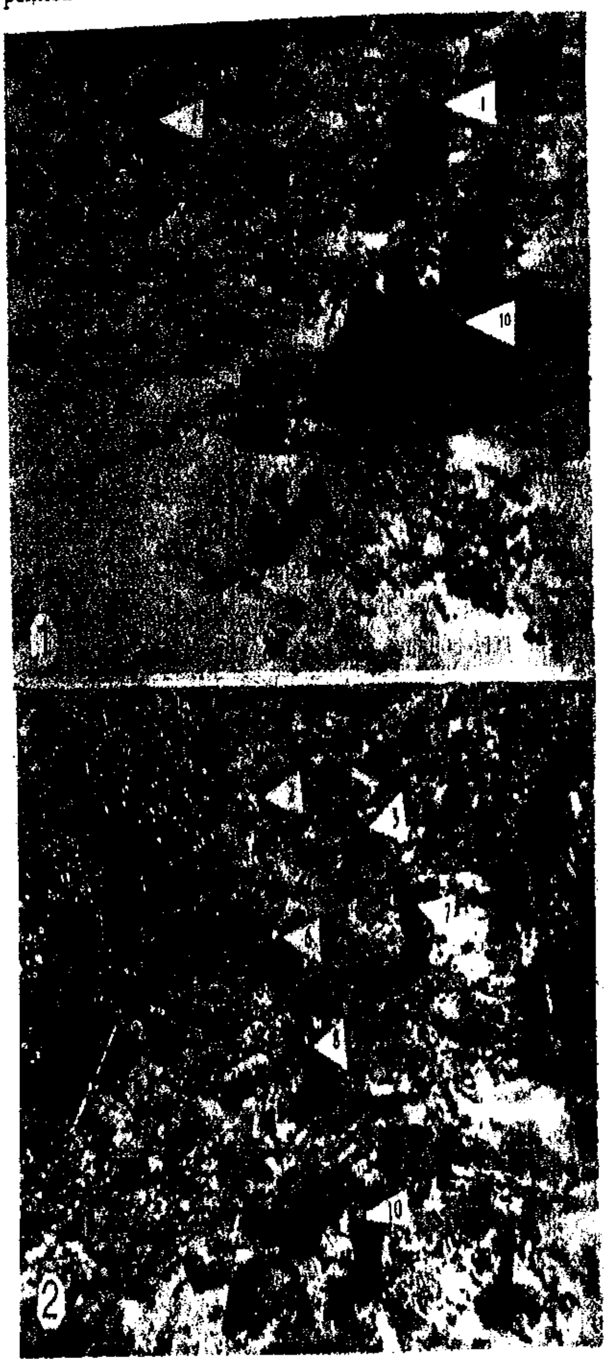

Fig. 1, 2. Transplant Plot St-1 (1) and Plot St-3 (2), Sumilon Island, showing surviving transplants in late November, 1981. In Fig. 1: 1, 3 — *Acropora securis;* 10 — *Heliopora coerulea.* In Fig. 2: 2, 3, 7, 8, 10 — *Porites* sp.; 6 — *Hydnophora microconus* (dying).

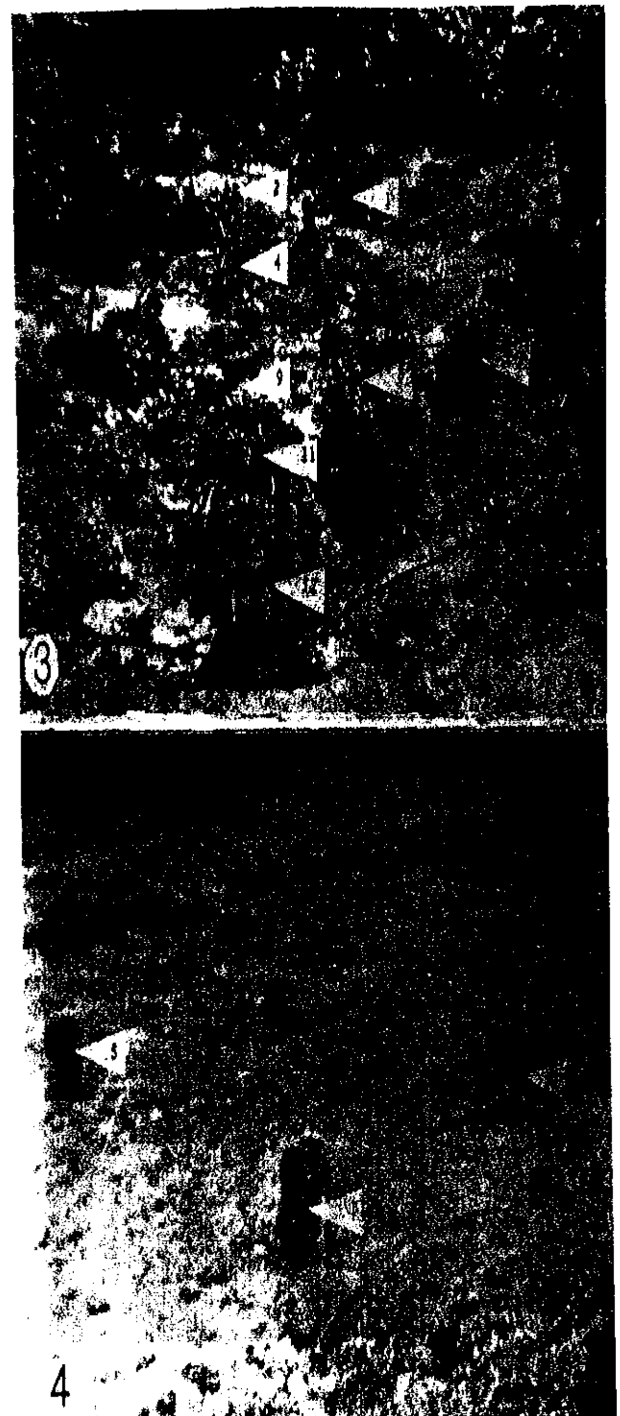

Fig. 3, 4. Transplant Plot St-2 (3) and Plot St-4 (4), Sumilon Island, showing surviving transplants in late November, 1981. In Fig. 3: 1, 2, 4, 11 — *Millepora* sp.; 7, 8 — *Pocillopora danae;* 9, 12 — *Pocillopora verrucosa.* In Fig. 4: 1 — *Acropora securis* (?); 3 — *Acropora brueggemanni;* 5 — *Heliopora coerulea;* note two colonies of *Dendrophyllia micranthus* growing near *A. securis* (?).

tachment was by means of pre-mixed ordinary cement transported from the surface in plastic bags. Generally, the cement hardened after several minutes, fixing the transplants to the substrate. Measurements of the short and long diameters of the transplants (in mm) were taken with a caliper every 2 or 4 months. The accuracy of these measurements is commented upon in Gomez et al. (6). The foregoing transplanting procedure was performed by 2 or 3 scuba diver-assistants during the period of study from 1979 to 1981.

Fig. 5. Coral transplants tied to a T-shaped bamboo stick in Bantayan, Dumaguete City, ca. 6 ft in depth, photographed one year after transplantation in January, 1979.

Results and discussion

A total of 90 coral fragments belonging to 13 genera and about 23 species were transplanted in Sumilon and Bantayan. Their survival and growth rates are summarized in Tables 1, 2 and 3.

Table 1. Survival and growth of coral transplants in Sumilon Island, Cebu. Observations from four 1 x 2 m plots at depth of 4–5 feet, July 1980 to August 1981.

Species	Number of transplants	Annual survival (no.; %)[a]	Average size of survivors at transplantation (mm)[b]	Annual increment: linear growth (mm)	Annual increment: area of coverage (mm²) range	Annual increment: area of coverage (mm²) mean
Acropora securis	4	2; 50	43 x 116 129 x 148	17 x 28 7 x 38	13.7–57.2 14.6–93.9	35.4 54.2
Heliopora coerulea	11	2; 18	42 x 50 48 x 153	5 x 2 0 x 33	1.6–3.5 6.41–43.1	2.5 24.5
Millepora spp. (including *M. platyphylla* and *M. elegans*)	7	4; 57	85 x 110 41 x 174 57 x 153 90 x 144	-21 x 11[c] 21 x 58 39 x 79 49 x 56	-24.6–20.0[c] 17.0–184.9 46.9–238.9 88.1–151.3	— 100.9 142.9 119.7
Pocillopora danae and *P. verrucosa*	7	4; 57	142 x 192 116 x 135 135 x 149 130 x 206	21 x 6 52 x 58 45 x 51 52 x 23	18.4–50.3 116.0–149.4 111.3–139.8 89.4–127.4	34.3 132.7 125.5 108.4
Porites sp.	6	2; 33	34 x 107 106 x 114	50 x 33 4 x 26	46.3–64.0 6.8–58.9	55.1 32.8
Total:	35	14				
Overall survival (%):		40				

[a]Dying transplants were considered dead.
[b]Long and short diameters; measurements generally applicable to spreading species; height in upright forms like *Heliopora* not measured.
[c]Negative because of breakage.

Table 2. Survival and growth of coral transplants in Bantayan, Dumaguete City, Negros Oriental. Observations from four 2 x 2 m plots at depth of 5-8 feet, August 1980 to September 1981.

Species	Number of Transplants	Annual survival (no.; %)[a]	Average size of survivors at transplantation (mm)[b]	Annual increment: linear growth (mm)	Annual increment: Area of coverage (cm²) range	Annual increment: Area of coverage (cm²) mean
Acropora affinis	4	4; 100	66 x 100	122 x 116	243.4–287.9	265.6
			86 x 136	78 x 120	153.1–410.4	281.7
			93 x 105	26 x 51	43.3–104.5	73.9
			86 x 180	165 x 154	436.7–621.7	529.2
Acropora brueggemanni	4	3; 75	50 x 129	83 x 40	93.6–119.3	106.4
			84 x 140	44 x 78	73.3–219.3	146.3
			39 x 112	132 x 72	167.4–217.7	192.5
Acropora formosa	5	5; 100	145 x 241	203 x 152	756.9–786.0	771.4
			133 x 151	170 x 192	582.1–744.9	663.5
			122 x 241	173 x 141	566.6–689.9	628.2
			58 x 92	52 x 141	68.6–359.9	214.2
			86 x 172	148 x 175	372.0–713.3	542.6
Euphyllia fimbriata	3	3; 100	88 x 173	62 x 37	111.3–115.9	113.6
			96 x 122	62 x 53	123.6–123.7	123.6
			57 x 127	36 x 28	42.4–62.0	52.2

(*Table 2, continued*)

Species	Number of Transplants	Annual survival (no.; %)[a]	Average size of survivors at transplantation (mm)[b]	Annual increment: linear growth (mm)	Annual increment: Area of coverage (cm²) range	Annual increment: Area of coverage (cm²) mean
Hydnophora sp.	2	1; 50	100 x 191	11 x 15	18.2–46.8	32.5
Montipora foliosa	5	1; 20	127 x 215	57 x 8	27.5–139.2	83.3
Montipora undata	3	1; 33	84 x 148	3 x 49	4.0–132.8	68.4
Seriatopora caliendrum	3	2; 67	173 x 180	42 x 82	128.0–284.7	206.3
			131 x 175	66 x 43	170.0–132.7	151.3
Symphyllia sp.	3	3; 100	104 x 106	37 x 38	71.2–74.6	72.9
			125 x 157	22 x 19	47.0–49.7	48.3
			83 x 93	31 x 31	48.0–58.8	53.4
Turbinaria foliosa	3	2; 67	52 x 132	33 x 13	28.3–35.5	31.9
			54 x 158	17 x 17	16.7–44.5	30.6
Total:	35	25				
Overall survival (%):		71				

[a] Dying transplants were considered dead.
[b] Long and short diameters.

Table 3. Growth of corals attached to bamboo sticks at depth of about 6 feet in Bantayan, Dumaguete City, Negros Oriental, from January 19, 1979 to May 2, 1981.

Species and no. of transplants	Number of survivors year 1	Number of survivors year 2	Average size of survivors at transplantation[a] (mm)	Annual linear growth increment (mm)[a] year 1	Annual linear growth increment (mm)[a] year 2	Mean annual increment in area (cm^2) year 1	Mean annual increment in area (cm^2) year 2	
Acropora affinis (2)	2	2	139 x 148	28 x 40	103 x 317	67.00	1,039.45	
			116 x 212	2 x 2	3 x 34	4.02	64.51	
A. speciosa (2)	2	1	179 x 200	22 x 20	-117 x -96[b]	51.02	—	(Dead)
			126 x 170	47 x 39	37 x 77	87.78	94.03	
Hydnophora rigida (1)	1	—	76 x 84	51 x 91	—	133.21	—	(No data)
Pavona sp. (1)	1	—	79 x 92	26 x 18	—	33.07	—	(No data)
Pocillopora danae (2)	2	0	120 x 179	- 2 x 9[b]	—	8.61	—	(No data)
			109 x 139	19 x 7	—	19.78	—	(Dead)
P. verrucosa (4)	4	4	132 x 189	25 x 12	- 9 x 30[b]	36.24	40.12	(Partly dead)
			151 x 173	15 x 25	54 x 90	42.71	253.63	
			167 x 179	-27 x -10[b]	76 x 61	-35.66[b]	201.83	
			130 x 179	29 x 14	28 x 52	41.37	127.49	
Seriatopora octoptera (4)	4	1	122 x 123	23 x 27	—	41.13	—	(Dying)
			135 x 197	54 x 45	—	113.40	—	(Lost)
			90 x 104	-10 x -21[b]	—	-17.13[b]	142.69	(Dying)
			95 x 115	10 x 3	—	8.22	29.40	(Partly dead)
Stylophora danae (2)	2	0	118 x 118	10 x 18	—	21.41	—	(Lost)
			124 x 142	6 x 14	—	17.34	—	(Lost)
S. pistillata (2)	2	0	159 x 176	31 x 38	—	78.05	—	(Dying)
			115 x 149	24 x 41	—	60.87	—	(Dead)
Total no. of transplants:	20	8						
Overall survival (%):	100	40						

[a]Long and short diameters. [b]Negative because of breakage.

Survival. Annual survival rates of species or groups of species varied from 18 to 57% (Table 1) for the Sumilon transplants and from 20 to 100% (Table 2) for the Bantayan transplants, with overall annual survival rates of 40% for Sumilon and 71% for Bantayan. The survival rate of all coral species attached to bamboo sticks in Bantayan was 100% in the first year and down to 40% in the second year (Table 3).

Among the species represented by four or more transplants, *Acropora* spp. appeared to have the highest annual survival rate (50-100%), followed by *Pocillopora* spp. and the hydrocoral *Millepora* (57-100%), *Montipora* spp., *Porites* sp., and the octocoral *Heliopora* (18-33%). Because of the small number of samples, our data are at best only indicative.

The factors responsible for the low survival rates of most of the species are not known. Causes of the condition of the dead or dying colonies were not obvious. There was no evidence of grazing by fishes or echinoderms. Interspecific competition, manifested as growth inhibition of faster-growing ramose and foliose species by massive or encrusting ones (7), can be ruled out since the transplants were sufficiently spread out as to avoid close contact, the primary condition favoring direct competition. The shallow depth (1.5-2.5 m) at which the corals were transplanted, however, could have exposed the transplants to disturbance by wave action, especially at the Sumilon site which is open to waves generated by the southwest monsoon from June to October. [redacted]

Growth. The values recorded for diameter and areal increment of a coral may be considered net growth as these were estimated without determining the area removed through natural breakage (which was unknown). Furthermore, "horizontal growth" was estimated, growth in height being ignored. The procedure is applicable generally to branching species but not to certain foliaceous species like *Heliopora* *coerulea*, which grow more along the vertical than along the horizontal axis. Consequently, growth rates of such species are underestimated. Strictly speaking, our method of growth measurement has resulted in the estimation of the areas occupied by the transplants rather than in the volume of their skeletons.

Because of the limited samples, only tentative conclusions may be made of the annual growth rates. [redacted]). The annual linear growth increments of the fastest growing species range from 10 to about 20 cm and are about equal to or twice the growth rate of *Acropora* naturally growing in Sumilon (8), and 2 to 4 times the growth rates of the fast growers on an artificial reef set at 16-23 m depth (6). Similarly, the areal growth increments, which range from about 100 to almost 800 cm^2, are about 2 to 13 times the rates of the fast growers of the artificial reef.

Two factors might explain these fast growth rates. First, the greater sunlight intensity in the transplant sites, which are not more than 2.5 m in depth. [redacted]

Species of *Acropora* registered the highest growth rates among our transplants. It might be mentioned that *Acropora formosa*, which exhibited the highest growth rate (Table 2), has widely spaced branches and thus occupies a relatively large area of the environment. (The measurements of *Acropora affinis* (Table 3), which appears to have increased more than 1,000 cm^2 in one year, may be in error and are ignored here.)

[redacted]

[redacted] The data in the Tables 1-3 are not inconsistent with this conclusion, although the need for more data is obvious.

In conclusion, it would appear that some species of stony corals, octocorals, and hydrocorals can be propagated asexually by transplanting fragments which grow relatively fast and have moderate survival rates. Coral transplantation could be used to rehabilitate reef areas denuded by overharvesting and by destructive fishing methods like dynamite blasting.

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