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Cocos Island (Pacific of Costa Rica) coral reefs after the 1982-83 El Niño disturbance

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Abstract: Cocos Island coral reefs were adversely affected by the 1982-83 El Niño warming event. Surveys made in 1987 indicated dramatic coral mortality at all depths (1-24m). Live coral cover on three studied coral reefs was 2.6, 2.9 and 3.5%. Population densities of the corallivores *Acanthaster planci* and *Arothron meleagris* were relatively high with their feeding activities concentrated on the few surviving colonies. Density of *Diadema mexicanum* was also high, being responsible for the erosion of large reef framework areas. It is predicted that recovery of the original reef-framework thickness is in the order of centuries.

Key words: Eastern Pacific, coral reef, El Niño, Cocos Island, recovery.

Widespread death of reef-building corals occurred in the eastern Pacific, associated with abnormally high sea surface temperatures that persisted for long periods during the 1982-1983 El Niño (Glynn *et al.* 1988, Glynn 1990). There were significant reductions in live coral (50-100 %) on reefs in the Galápagos, Colombia, Panamá and Costa Rica (review in Glynn 1990). The distribution and abundance of several reef-associated invertebrates such as *Diadema mexicanum* Agassiz, *Jenneria pustulata* (Lightfoot), *Trapezia* spp., and *Alpheus lottini* Guerin experienced major changes (Glynn 1985a, b).

Pearson (1981) has suggested that recovery of coral reefs after major natural disturbances can take several decades. Recovery occurs through one or a combination of three mechanisms: (1) regeneration of surviving colonies (Colgan 1987), (2) fragmentation of surviving colonies (Highsmith 1982), and (3) larval settlement (Loya 1976). In Guam, recovery after catastrophic predation by *Acanthaster planci* (Linnaeus) was faster than expected because the structural integrity of the reef framework was not destroyed and cryptic colonies survived (Colgan 1987). There has been some recovery of the coral community after the 1982-1983 El Niño in some areas of the tropical eastern Pacific, but in other areas recovery has been impeded by intensification of corallivore activity (Glynn 1985a, Guzmán & Robertson 1989), red tides (Guzmán *et al.* 1990), low recruitment rates (Glynn *et al.* 1991), and an increase in the destruction of the reef framework by echinoids (Glynn 1988). These disturbances may eventually lead to a replacement of the corals by fleshy and crustose algae and to changes in the reef community structure.

The purpose of this paper is twofold: to describe the coral reef community structure at Cocos Island after the 1982-83 El Niño event, and second, to speculate about possible recovery times of the reefs.

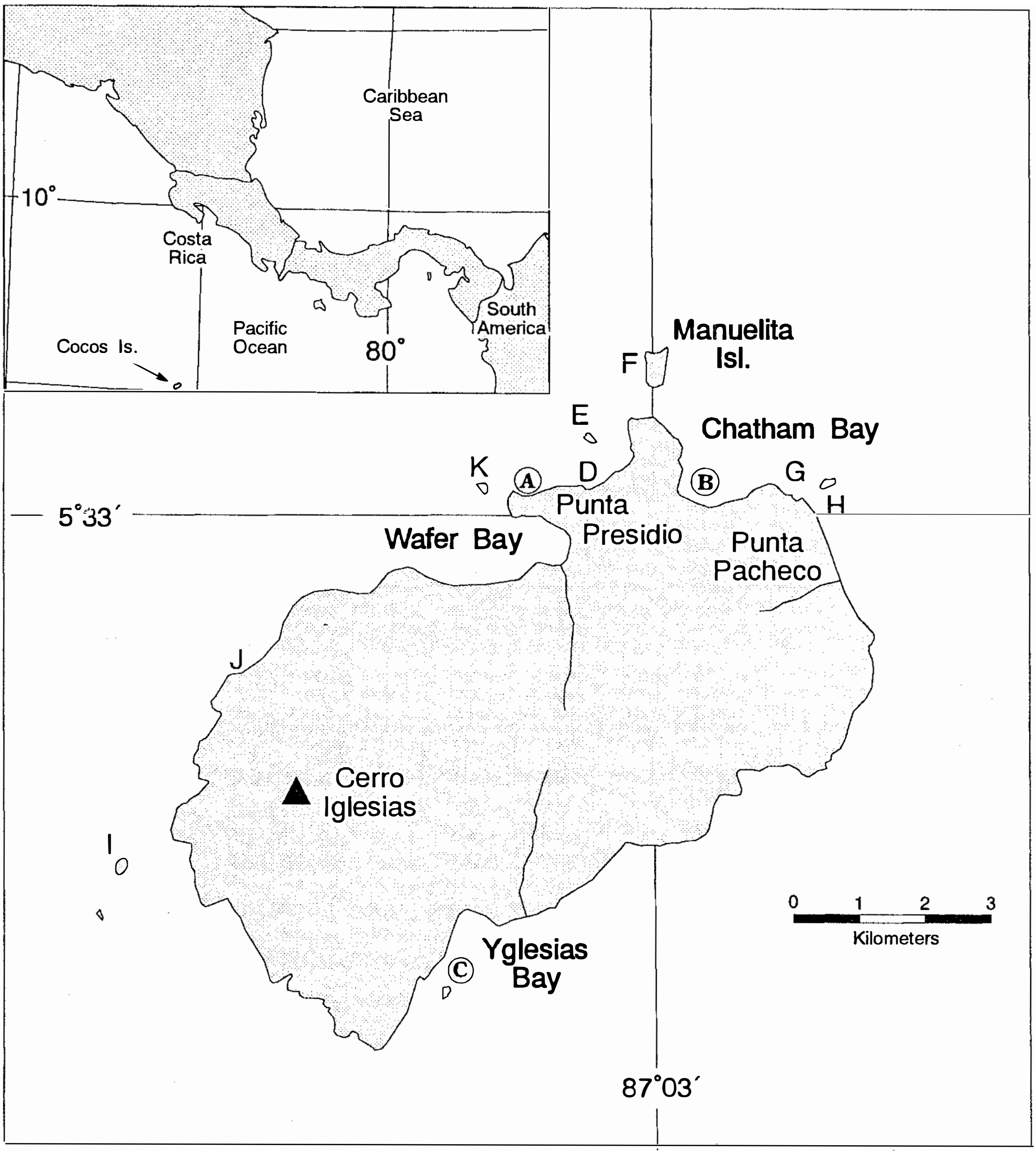

Fig. 1. Cocos Island Reef sites A through C, were visited in 1978; sites A through K in 1986; and sites A, B and G in 1987.

MATERIAL AND METHODS

Study area: Cocos Island (Isla del Coco) is located at 5°32'N and 87°04'W (Fig. 1), approximately 500 km southwest of Costa Rica and 630 km northeast of the Galápagos Islands. Its perimeter is 23.3 km and the area 46.6 km^2. The highest point (575 m) is Cerro Iglesias on the west side (Castillo *et al.* 1988). The island was claimed by Costa Rica in 1832 and declared a National Park in 1978 (Boza 1978). In 1984 the protected area was extended to include the marine environment within 5 km of the island and in 1991 it was again expanded to within 25 km.

Cocos Island is the only subaereally exposed portion of the aseismic Cocos Ridge, and is of volcanic origin associated with the Galápagos hot spot and superimposed by more recent seamount volcanism (Castillo *et al.* 1988).

Sampling: Cocos Island was first visited in July 1978. Three reefs were surveyed at depths between 5 and 25 m (Fig. 1, sites A, B, C). In December 1986, three years after the event, eleven reefs were visited between 1 and 30 m depth (Fig. 1, sites A to K). Unfortunately, only general observations, and underwater photography of the coral species composition and distribution could be made during both expeditions. The information concerning sites I and J was provided by J.K. Reed, who visited those reefs during the same cruise.

In December 1987, four years after the El Niño event, quantitative surveys were performed (during a five days expedition) at three of the reefs visited previously (Fig. 1, sites A, B, G). Those reefs, namely Punta Presidio (A), 10-30 m depth, Bahía Chatham (B), 3-20 m, and Punta Pacheco (G), 1.5-20 m, represent three of the four well developed reefs around the island (the fourth is at site C).

We ran 10m line transects (Loya 1978) at distance intervals of 5 m (reefs A and B) and 8 m (reef G), following depth contours, at three stations haphazardly selected at each of the three reefs. We did 72 transects at Punta Presidio, 80 at Bahía Chatham and 147 at Punta Pacheco (total 2990 m of reefs). The sections with dead coral framework were scrutinized to identify the species, and reconstruct the structure (*i.e.* coral zonation, abundance, colony size and composition) of the former reef. Colony size was measured along the maximum length of living tissue. Diversity was calculated using the Shannon-Weaver index (Margalef 1957) and compared using Hutchenson's formula (Hutchenson 1970).

We estimated the density (ind./ha) of the corallivorous seastar *A. planci* and the pufferfish *A. meleagris* (Bloch and Schneider) at the three reef areas; these two species can influence the community structure of the coral reefs in the eastern Pacific (Glynn 1974, 1985a, b, Guzmán 1988, Guzmán and Robertson 1989). All individuals encountered on an estimated 15 m wide independent belt-transect were recorded. The transects (census), four and five for *A.planci* and *A. meleagris* respectively at Presidio reef (each 180 m long), four at Pacheco (each 235 m) and 4 at Chatham (each 200 m) reefs, were run perpendicular to the shore from the shallow part of the reef to its base.

The sea urchins *Eucidaris thouarsii* (Valenciennes) in Galápagos (Glynn 1988, Colgan 1990) and *D. mexicanum* in Panamá (Glynn 1988) and Caño Island, Costa Rica (Guzmán 1988) are eroding the reef frameworks. To determine *D. mexicanum* density at Cocos Island, 10x1 m long transects were surveyed parallel to the shore, at 5 m intervals, at two stations in each of the three reefs.

Reef thickness was estimated measuring with a metric tape the maximum height of exposed blocks of framework or on larger colonies.

Temperature deviations relative to a 20 year average (1947-1967) were obtained from data based on 4000 to 6000 ship observations per month, with a precision of 0.2 °C and of 1 to 3 nautical miles in position (F. Miller, per. comm.)

RESULTS

A total of 29 coral species, of which 20 are shallow-water dwellers, have been reported for the island (Table 1). The massive coral *Pavona gigantea* Verrill is reported from Cocos Island for the first time. Several species have not been found after the El Niño event.

Before the 1982/83 coral mortality, all the reefs had high live coral coverage (Fig. 2a, per. obser.), and large areas of agariciid corals (*Pavona* spp. and *Gardineroseris planulata* (Dana)) were commonly observed. *A. planci* was abundant and it was never observed feeding upon poritid corals (Fig. 2c). Bakus (1975) reported that the subtidal community was dominated (about 95 % of the live coral cover) by the massive coral *Porites lobata* Dana (erroneously identified as *P. californica*). In 1987 the reefs at Punta Presidio and Punta Pacheco had a continuous reef framework, while the Chatham reef framework was solid from 3 to 7 m in depth and was then formed by large coral patches intermixed with sand and coral rubble down to 20 m.

TABLE 1

Scleractinian corals from Cocos Island, Costa Rica

Suborder ASTROCOENIINA
- Family THAMNASTERIIDAE
  - 1. *Psammocora stellata* Verrill a, d, g
  - 2. *Psammocora superficialis* (Gardiner) b
- Family POCILLOPORIDAE
  - 3. *Pocillopora capitata* Verrill c
  - 4. *Pocillopora damicornis* (Linnaeus) b, d
  - 5. *Pocillopora elegans* Dana b, d
  - 6. *Pocillopora eydouxi* Milne Edwards & Haime d
  - 7. *Pocillopora meandrina* Dana b, d g
  - 8. *Pocillopora verrucosa* Squires b

Suborder FUNGIINA
- Family AGARICIIDAE
  - 9. *Pavona clavus* Dana d, g
  - 10. *Pavona gigantea* Verrill g
  - 11. *Pavona varians* Verrill b, d, g
  - 12. *Gardineroseris planulata* (Dana) a, b, g
  - 13. *Leptoseris papyracea* (Dana) a, c
- Family FUNGIIDAE
  - 14. *Fungia (Cycloseris) curvata* (Verrill) e
  - 15. *Fungia (Cycloseris) distorta* Michelin a, e
- Family PORITIDAE
  - 16. *Porites lobata* Dana' b, c, g

Suborder FAVIINA
- Family FAVIIDAE
  - * 17. *Cladocora debilis* Milne Edwards & Haime a
  - * 18. *Cladocora pacifica* Cairns f
- Family RHIZANGIIDAE
  - 19. *Astrangia dentata* Verrill b
  - 20. *Culicia rubeola* Dana f

Suborder CARYOPHYLLIINA
- Family CARYOPHYLLIIDAE
  - * 21. *Anomocora carinata* Cairns f
  - * 22. *Caryophyllia diomedeae* Marenzeller f
  - * 23. *Desmophyllum cristagalli* Milne Edwards & Haime f
  - * 24. *Polycyathus hondaensis* (Durham & Barnard) a
- Family FLABELLIDAE
  - * 25. *Javania cailleti* (Duchassaing & Michelotti) f

Suborder DENDROPHYLLIINA
- Family DENDROPHYLLIIDAE
  - * 26. *Dendrophyllia californica* Durham f
  - * 27. *Endopachys grayi* Milne Edwards & Haime a, f
  - 28. *Rhizopsammia verrilli* van der Horst b, f
  - 29. *Tubastrea coccinea* Lesson b, c, d, f

Species reported in: a = Durham & Barnard (1952), b = Durham (1962), c = Bakus (1975), d = Cortés & Murillo (1985), e = Hoeksema (1989), f = Cairns (1991), g = this study. Species marked with an asterisk (*) are deep water (>30m).

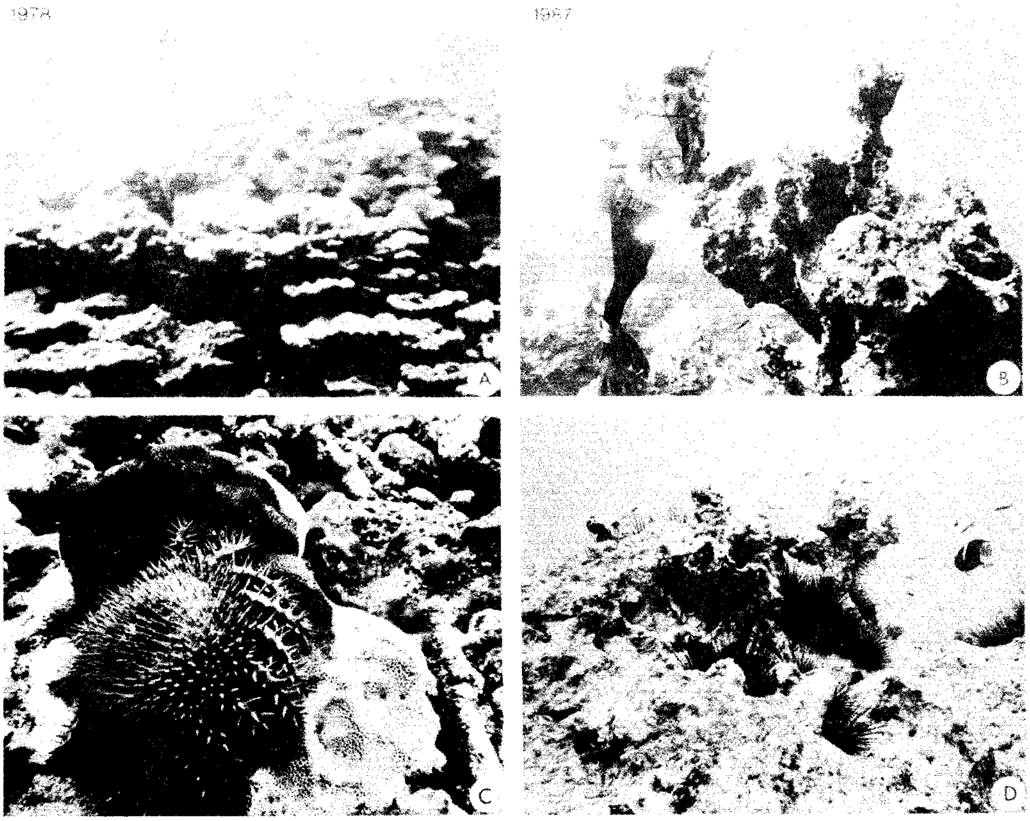

Fig.2. Reefs at Cocos Island: (a) reef slope dominated by *P. lobata* at 10m depth about four years (1978) before the 1982-1983 El Niño warming event; (b) *P. lobata* framework at 6 m depth bioeroded by sea urchins about four years (1987) after the 1982/83 El Niño; (c) the seastar *A. planci* feeding upon the once abundant massive coral species *G . planulata* in 1978 at 12 m depth; and (d) the sea urchin *D. mexicanum* grazing on dead *P. lobata* reef framework at 6 m depth in 1987.

The reef-framework at Punta Presidio was composed of dead *P. lobata* (Fig. 3, Table 2). Live coral cover was low (3.47 ± 0.27 %) and it consisted of eight coral species (Table 2). Even so, it was the highest percentage of live coral observed at Cocos Island. The most common live species was *P. lobata,* which was present at all depths, but it was most abundant between 9-12 m. The average colony size for *P. lobata* was 7.9 cm (n= 53, S.E.= 0.76, range= 1.8-21.6 cm). *Pocillopora meandrina* Dana was rare and colony sizes averaged 13.2 cm (5, 5.73, 7.2-25.2 cm). All other species were represented mainly by new sexual recruits (individuals that settled on dead framework). The *Pavona* species had an average size of 3.1 cm (15, 0.51, 1.8-5.4 cm), and reached a relatively high abundance at 18-21 m (Fig. 3). The colony size averages for *Psammocora* and *Gardineroseris* were 2.7 cm (29, 0.31, 1.8-3.6 cm) and 6 cm (3, 1.29, 3.6-9 cm), respectively.

The result of the surveys from Bahía Chatham are presented in Figure 4 and Table 2. Again most of the substrate was dead *P. lobata,* but sand and rubble represented a higher percentage of the substrate than in the former reef (Table 2), because the dead framework had a patchy distribution. Live coral coverage was higher toward deeper areas and it consisted of four coral species: *P. lobata, Psammocora stellata* Verrill, *Pavona varians* Verrill and *Pocillopora meandrina.* Their colony size averages were 4.1 cm (n= 46, S.E.= 0.81, range= 1.8-19.8 cm), 3.2 cm (31, 0.29, 1.8-72 cm), 4.9 cm (11, 0.95, 1.8-10.8 cm) and 12.9 cm (3, 3.4, 5.4-19.8 cm), respectively. There were no live corals at shallow areas,

TABLE 2

Summary of data from the three reefs studied at Cocos Island, Costa Rica, in December 1987

Reef	Depth range (m)	Number of Transects	Mean percent and standard error								
			Live^{a}	Dead	Sand	*Porites*	*Pocillopora*	*Psammocora*	*Pavona*	*Gardineroseris*	H'^{b}
Presidio	9-24	72	3.47 (0.27)	94.20 (2.41)	2.33 (1.18)	1.32 (0.42)	0.07 (0.05)	0.57 (0.07)	1.15^{c} (0.13)	0.36 (0.08)	0.337 (0.13)
Chatham	2-18	80	2.91 (0.42)	86.70 (3.11)	10.14 (2.75)	1.08 (0.21)	0.03 (0.03)	0.74 (0.33)	1.06 (0.09)	0.00	0.264 (0.03)
Pacheco	1-18	147	2.60 (0.35)	88.69 (2.43)	8.71 (2.41)	2.59 (0.35)	0.04 (0.04)	0.21 (0.12)	0.04 (0.02)	0.00	0.235 (0.05)
Grand mean	1-24	299	2.99 (0.20)	89.86 (1.83)	7.06 (1.96)	1.57 (0.30)	0.05 (0.00)	0.50 (0.12)	0.75 (0.29)	0.12 (0.09)	
Colony Size Grand mean^{d}						5.3(0.91) 194	14.7(1.22) 11	3.1(0.19) 76	4.3(0.44) 31	6.0(1.29) 3	

Also given: colony size grand means per coral species. Data in parenthesis are standard errors. a= Live coral cover percentages between-reefs did not differ significantly (ANOVA, $P>0.05$ for all); b= Diversity did not differ significantly; c= Three pavonid species: *Pavona varians* (0.87%, *P. gigantea* (0.16%) *P. clavus* (0.12%); d= Mean(standard error) and number of measurements.

which may be due to the presence of terrigenous sediments produced by landslides near the reef.

The reef at Punta Pacheco (Fig. 5) was the largest of all and it was composed of dead *P. lobata* framework in the shallow areas and sand and rubble in deeper areas (>15 m). The predominant live coral was *P. lobata* and its abundance increased with depth until 15 m (Fig. 5). Average size of colonies was 3.9 cm (n= 39, S.E.= 0.58, range= 1.8-36 cm). As a whole, Punta Pacheco reef had the lowest percentage of live coral (Table 2) and most of it consisted of new recruits of *Pavona* and *Psammocora*, and old colonies of *Pocillopora*, with an average colony size of 5.0 cm (5, 0.79, 1.8-7.2 cm), 3.6 cm (16, 0.45, 1.8-9 cm) and 18 cm (3, 4.25, 9-27 cm), respectively. *P. varians* was the only pavonid species observed at this reef.

Table 2 is a summary of all data. The differences between reefs in live coral coverage were not significant (1-way ANOVA, $F=2.29$, $P>0.05$). *P. lobata* was always the most abundant coral but at Punta Presidio and Bahía Chatham the pavonids had also high values. Diversity (Shannon-Weaver index) was highest at Punta Presidio and lowest at Punta Pacheco, but the differences were not significant (Hutchenson's t-test, $P>0.05$). In all cases dead coral coverage, consisting mainly of *P. lobata* framework, was high (Table 2). In general, whole live *P. lobata* colonies were not seen at any of the reef sites, but only colonies with patches of live tissue.

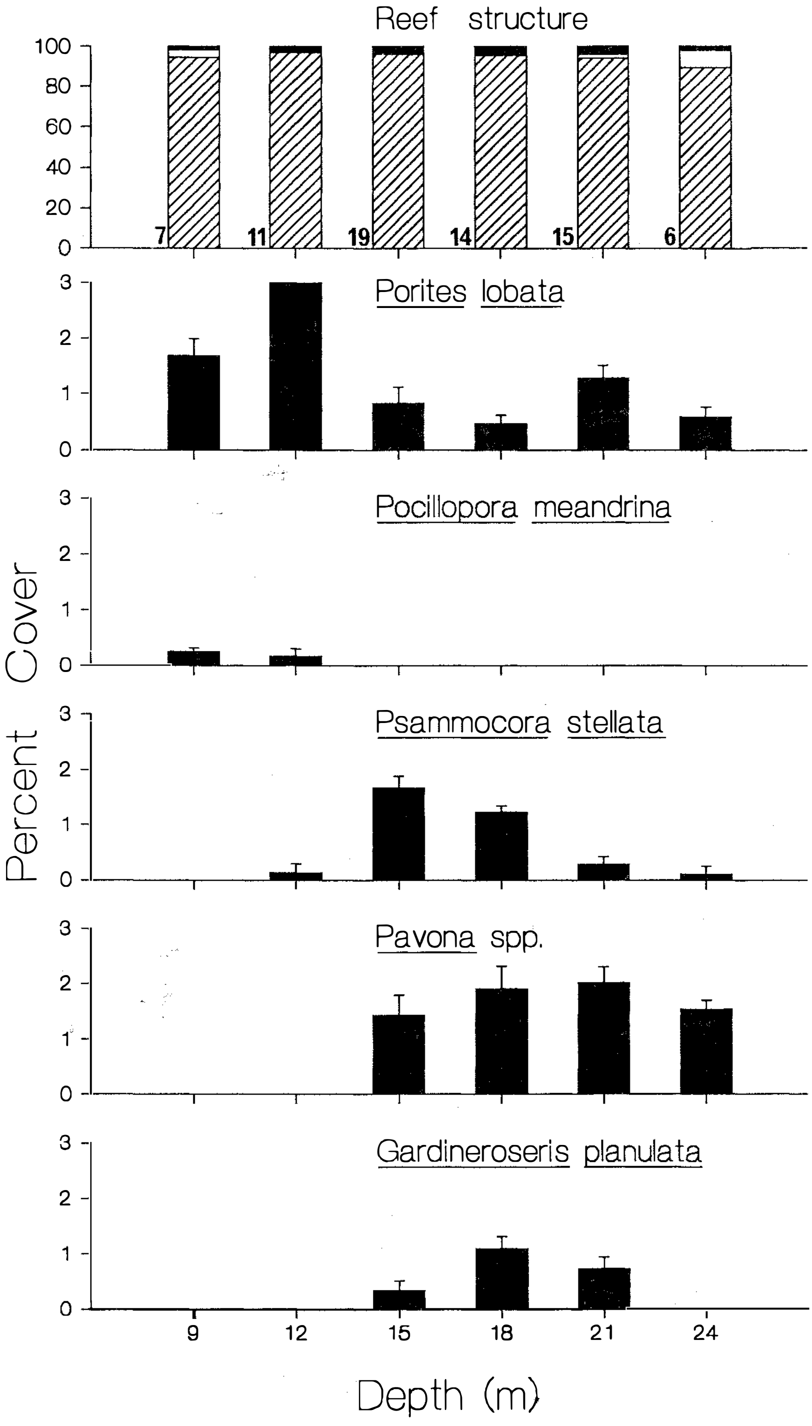

Fig.3. Percent cover of the substrate on December 1987 by depth at Punta Presidio reef (Site A, Fig. 1): Filled area = live coral; hatched area = dead coral *(Porites lobata)*; open area = sand and rubble. Given is the mean percent coverage and standard error bars of live coral by species. Number of transects/depth are given on the left side of each bar on top graph. *Pavona* spp. = *P. varians, P. clavus, P. gigantea.*

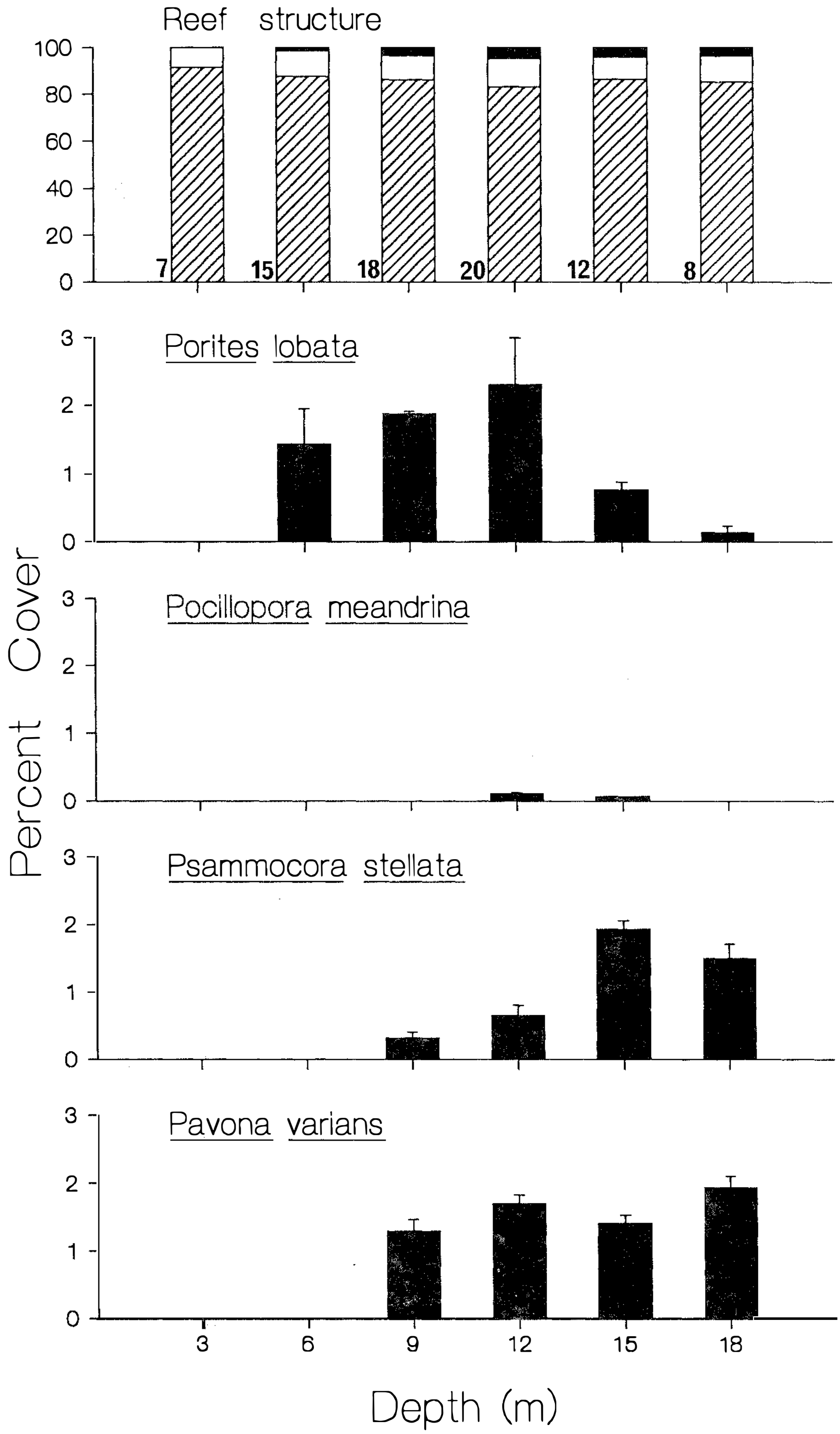

Fig.4. Percent cover of the subtrate on December 1987 at Bahía Chatham reef (Site B, Fig. 1). Captions as in Fig. 3.

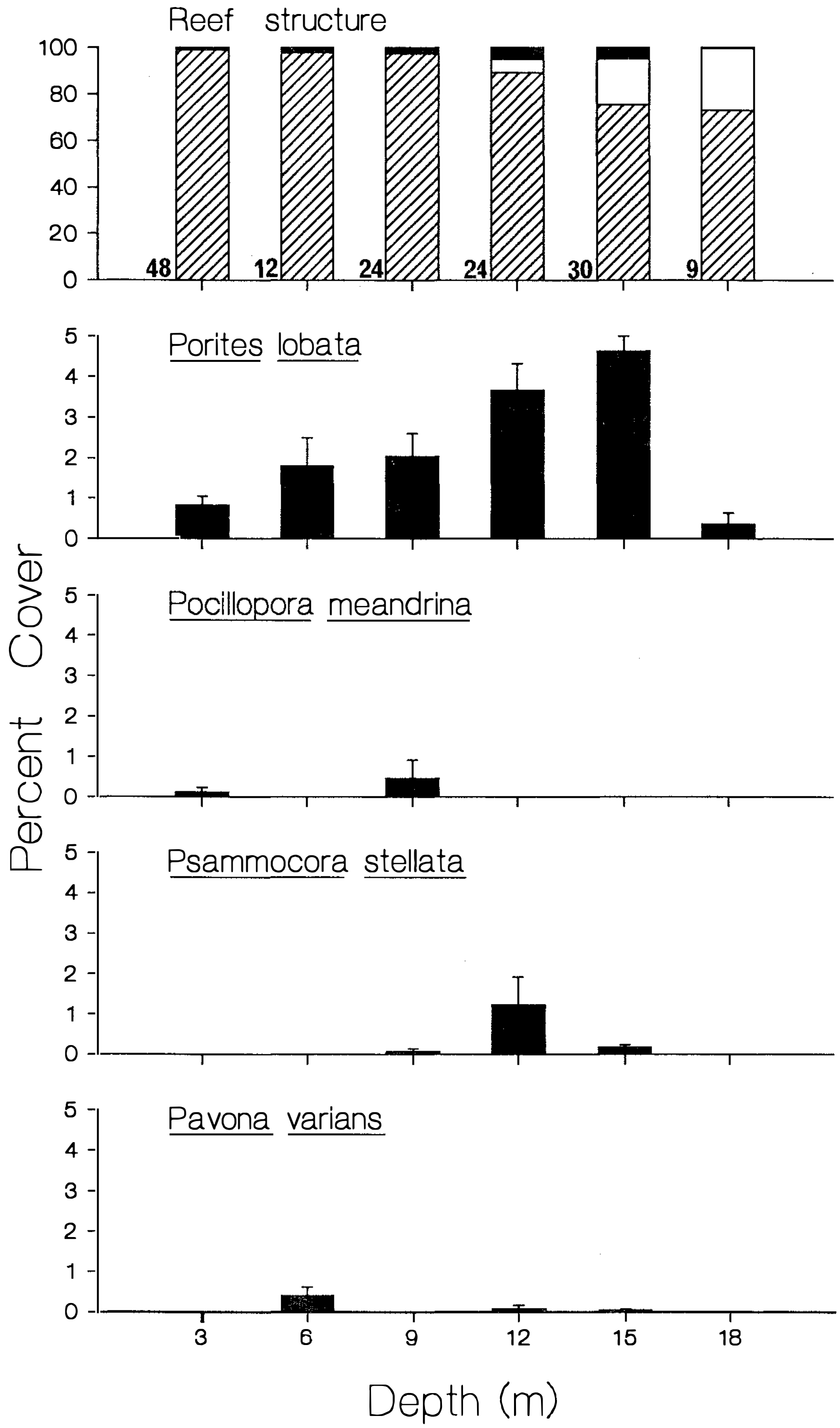

Fig.5. Percent cover of the substrate on December at Punta Pacheco reef (Site G, Fig. 1). Captions as in Fig.3.

TABLE 3

Population density of the corallivores Acanthaster planci *and* Arothron meleagris *at three reefs at Cocos Island, Costa Rica*

Reef	*A. planci*[a] n	*A. planci*[a] ind./ha	*A. meleagris*[b] n	*A. meleagris*[b] ind./ha
Presidio	4	4.6(1.7) (0.0-7.4)	5	9.3(1.1) (7.4-11.1)
Chatham	4	11.7(4.2) (0.0-20.0)	4	7.5(1.6) (3.3-10.0)
Pacheco	4	15.0(1.4) (11.4-17.1)	4	7.9(1.1) (5.7-11.4)
Grand mean	12	10.4(1.9) (0.0-20.0)	13	8.2(0.7) (3.3-11.4)

Mean (S.E.) and (range), n = number of censuses. a = Densities were significantly different between reefs (ANOVA, F = 4.41, $P < 0.05$); b = Densities were not significantly different between reefs (ANOVA, F = 0.49, $P > 0.05$).

The densities of *A. planci* were significantly different between reefs (Table 3), being higher at Punta Pacheco and Chatham, and lowest at Punta Presidio reef (Student-Newman-Keuls, multiple comparison test). The densities of the puffer fish *A. meleagris* were not significantly different (Table 3).

The density of *D. mexicanum* was highest at Bahía Chatham, lowest at Punta Presidio and intermediate at Punta Pacheco (Table 4). The mean density of *Diadema* at Punta Presidio was lower than at the other two reefs (SNK test; P> 0.05).

At Cocos Island, during the 1982/83 El Niño warming event, the mean sea surface temperature (SST) deviation was 1.35 ± 0.23 °C, with deviations of 1.26 °C and 1.52 °C higher than the previous 28 months and the subsequent 26 months respectively (Fig. 6). The high temperature anomalies persisted for 17 months, with a mean of 29.05 ± 0.19 °C during the period and with temperatures over 29 °C (or 2.0-2.5 °C deviation) from December 1982 to August 1983. The long-term average for the island was 27.75 °C (based on monthly records from 1947 to 1967).

TABLE 4

Population density (ind./m^2) of Diadema mexicanum *at three reefs (based on 2500 quadrats) along the depth gradient at Cocos Island, Costa Rica*

	Punta Presidio Reef			Bahía Chatham Reef			Punta Pacheco Reef		
Deptb (m)	Number of transects[a]	Mean(SE)		Number of transects[a]	Mean (SE)		Number of transects[a]	Mean (SE)	
1-3	0	-	-	8	19.4	(1.0)	32	15.2	(0.4)
6	0	-	-	14	23.2	(0.6)	16	25.1	(0.7)
9	12	25.9	(1.1)	12	29.3	(0.8)	8	26.0	(0.9)
12	14	13.4	(0.5)	18	16.1	(0.6)	20	12.7	(0.6)
15	10	10.6	(0.6)	18	8.1	(0.4)	16	8.2	(0.4)
18	16	7.4	(0.5)	10	6.8	(0.6)	6	5.4	(0.4)
21	12	4.8	(0.4)	0	-	-	0	-	-
24	8	4.6	(0.5)	0	-	-	0	-	-
Grand mean[c]	72	11.4	(0.3)[b]	80	16.7	(0.3)[b]	98	15.5	(0.2)[b]

a = Number of m^2 sampled at each depth interval; b = Densities were significantly different between depth intervals (ANOVA, F = 127.4, F = 100.5, F = 84.1, $P < 0.000$, respectively), and density ranges were 0-67 ind./m^2; 0-64 ind./m^2 and 0-55 ind./m^2, respectively; c = Densities were significantly different between reefs (ANOVA, F = 58.5, $P < 0.05$).

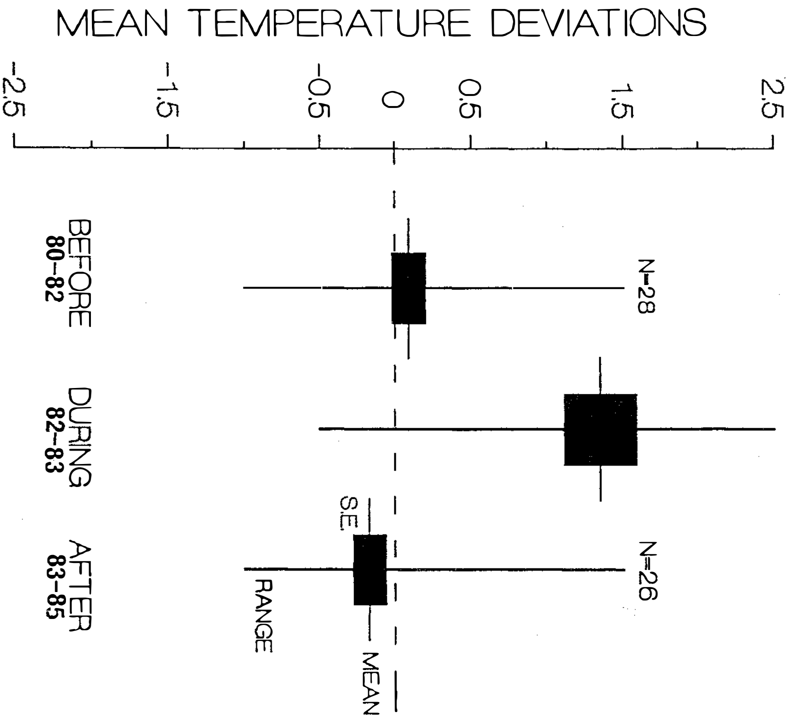

Fig.6. Sea surface temperature deviations from the 20 yr average 1947-67 between 1980 and 1985 at Cocos Island. Before El Niño warming event (January 1980 - April 1982); during (May 1982 - September 1983); and after (October 1983 - December 1985). Horizontal line indicates mean, filled box indicates standard error, vertical line represents range and N signifies months.

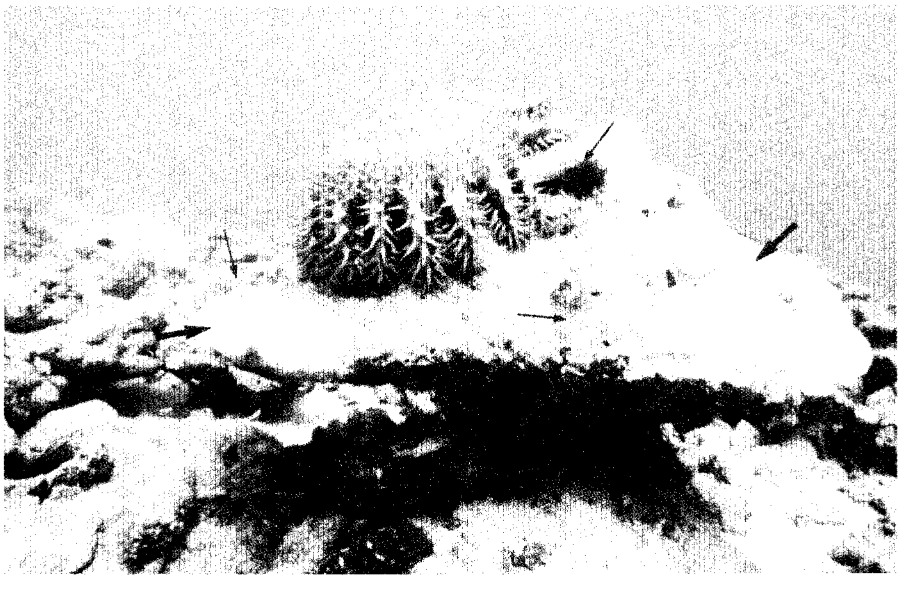

Fig.7. The seastar *A. planci* killing the surviving patches of live tissue of a *P. lobata* coral colony, at 15m depth (1987). The thick arrow indicates recent coral killed and the thin arrow indicates surviving patches.

DISCUSSION

Impact of the 1982/83 El Niño: During the El Niño wanning event, coral bleaching and mortality were observed by the park rangers (F. Cortés, pers. comm.). Glynn *et al.* (1988) found a strong geographic relationship between coral mortality in the eastem Pacific and the intensity of temperature warming that occurred duringthe 1982-83 El Niño event. From the least (continental Costa Rica) to the most affected (Galápagos Islands) reefs, increases were observed in local relative sea surface temperature, length and rate of warming. The mean SST deviation of 2.61 °C recorded for Galápagos was almost twice the value (1.35 °C) for Cocos Island, however, the 90 % dead coral cover found at Cocos is close to the average 97 % coral mortality for Galápagos, the highest reported for the region. The mortality observed in both localities may include secondary El Niño related mortality (e.g. predation). There were 9 months at Cocos Island with temperature deviations of 2.0-2.5 °C. This suggests a close relationship between the severity of coral mortality at both localities and the duration of temperature deviations. In general, eastern Pacific coral mortality was observed over a wide range of depths and affected most of the species irrespective of their dominance as reef-builders (Glynn 1990). Based on the high dead coral cover observed to all coral species at all depths, it can be concluded that at Cocos Island coral mortality was unifonn.

Before the mortality event, Cocos Island reefs were probably some of the best developed in the eastern Pacific (we have visited almost all eastern Pacific reefs). A consolidated reef framework (1.5 m average thickness, range 0.5-3.0 m, measured to the base of the reef) composed of the massive coral *P. lobata* extending down to 30 m depth was one of the major features that distinguish these from other reefs (Fig. 2a). There were several reefs around the island, with individual sizes ranging from 10 to 20 hectares. So far, only one small dead pocilloporid framework (approx. 500 m^2) that resembles others in the region has been found close to Punta Pacheco. Therefore, the great development of coral reefs observed in Cocos Island may suggest that high temperature stress did not affect the reefs before the 1982-83 warming event. Additionally, the reefs at Cocos were dominated in time and space numerically and/or structurally by the long-lived coral *P. lobata,* suggesting that no recent disturbances have occurred (*sensu* Done 1982, Potts *et al.* 1985).

Prospect of recovery

a) *Colonization and Regeneration of Corals:* During the last decade the relationship between the number of recruits and the abundance of adults has been studied to explain coral distribution patterns and reef community structure and recolonization (Rylaarsdam 1983, Harriott 1985, Wallace 1985). Their results indicate that (1) juvenile coral recruitment is proportional to adult abundance (Connell 1973, Harriott 1985), (2) that the composition of the adult community is not a direct function of recruitment (Bak and Engel 1979, Rylaarsdam 1983), or (3) that post-recruitment events such as survival or competition are important factors influencing coral distribution (Bak and Engel 1979, Jackson 1983, Harriott 1985). The severe mortality event observed at Cocos Island reefs will provide an opportunity to test which of the above hypotheses applyes to the eastern Pacific.

At Cocos and Galápagos Islands, widespread mortality occurred on all reefs during the 1982/83 El Niño. This contrasts with other areas in the eastern Pacific region where coral survival was considerably higher at least in some areas of the reefs. It is from those areas that local, and probably regional recovery may occur (Glynn 1990). In general for eastern Pacific reefs, recovery has to be mainly through asexual reproduction (fragmentation) instead of larval recruitment. The reef building corals of the region (e.g. *Pocillopora damicornis* (Linnaeus), *P. elegans* Dana, *P. lobata, Pavona clavus* Dana, *G. planulata*), have shown high reproductive activity (Glynn *et al.* 1991, Smith 1991), but low sexual recruitment has been observed (Birkeland 1977, Wellington 1982, Richmond 1987, Glynn 1990, Glynn *et al.* 1991). Asexual reproduction seems to be the predominant form of propagation for pocilloporid corals and in some localities for massive species (e.g. *P. lobata*) where colonies are fragmented by a triggerfish and then dispersed (Guzmán and Cortés 1989). No coral population remained at any of the three reefs at

Cocos Island that was large enough to provide new individuals by fragmentation, at any depth or for any coral species. On average, less than 2 % live coral coverage was observed for all major reef-building species, and colony size was less than 6 cm for all species but *P. meandrina* (Table 2). The once dominant species, *P. lobata,* still the most abundant at certain depths, have surviving areas (no new recruits) that are less than 150 cm^2 per colony (average size 5.3 cm, Table 2). Other species, *e.g. Psammocora* spp. and *P. varians,* which were present in low numbers, seem to be sexual recruits that settled and started growing over the dead *Porites* framework. These coral species, which have only a minor reef-building role, have shown moderate gonadal activity in Panamá and Costa Rica (Glynn 1990). *P. varians* is the species which may take over Cocos reefs at a fast rate, if it remains undisturbed.

The reefs around Cocos Island are located thousands of kilometers from the nearest sources of coral larvae. On one hand, if recruitment is derived from outside sources, the closest source (6,500 km) is the central Pacific Line Islands. Coastal reefs on Central and South America are down current from Cocos Island. Glynn and Wellington (1983) suggested that jump dispersal played an important role in the colonization of eastern Pacific off-shore reefs (e.g. Galápagos, Cocos, Malpelo, Clipperton and Revillagigedo). Cocos Island is on the track of the North Equatorial Counter Current and the Cromwell Current (undercurrent), both of which have been considered potential sources of drifting adult organisms (Jokiel 1989) and coral larvae to the eastern Pacific (Dana 1975, Glynn and Wellington 1983, Scheltema 1986, Richmond 1987). In this case, large areas of denuded subtrate are available for recruitment, and the potential for colonization by new species for the region may increase.

On the other hand, if long-distance dispersal is not feasible, the reefs have to be self-seeded (*sensu* Sammarco and Andrew 1988). This may be occurring now for some of the species. It is well known that the ability of corals to reproduce is a function of both colony size and age (Hughes and Jackson 1980, Szmant-Froelich 1985). Thus, fragmentation and partial mortality can reduce the fecundity of the surviving populations. We found that the reefs around the island were being settled by small sexual recruits of the minor reef-building coral species. These recruits were probably produced locally. A few surviving colonies of *Pocillopora* and *Porites,* both major reef-builders, are the other reef constituents (Table 2); however, colony sizes were too small and the surviving parts of colonies showed marks of recent injury or mortality caused by corallivores.

b) *Corallivore activity: A. planci* and *A . meleagris* are common on Cocos Island, and their densities varied among the studied reefs. Both species are wide-ranging predators and can feed on the dispersed, surviving prey; their effect is thus intensified after El Niño, as observed in Panamá (Glynn 1985a). At Chatham Reef in 1973, Stames (in Glynn 1974) reported an *A. planci* population size of 10 individuals or a density of 28 ind./ha (extrapolated from 1/360 m^2). This is the only report from before the 1982/83 warming event. The mean density found in this study was about half the previous figure, but the amount of coral destruction they cause at Cocos seem to be significant. The most important observation was that the seastar was feeding mainly on *P. lobata,* previously a non preferred prey in the reefs of the region (Guzmán and Cortés 1989). *A. planci* has been reported to feed proportionately more on rare corals or less abundant species than dominant species in Panamá (Glynn 1974, 1985b) and Costa Rica (Guzmán 1988, Guzmán and Cortés 1989). Thus the predator is thought to exploit its resources in a coarse-grained fashion, and normally, to the detriment of the less common species (Glynn 1974). At Cocos, *P. lobata* was the dominant coral and the seastar used to feed on other species like *G. planulata* (Fig. 2c), a rare coral species after El Niño. The seastar continues to feed upon the preferred species but as their availability has decreased, it also preys on the once abundant, non-preferred coral. This will decrease the chances of survival of new recruits and surviving colonies (Fig. 7). Changes in feeding preferences may persist for some time once the seastar is conditioned to eat corals that they may initially refuse (Huxley 1976). An indication of the potential impact of *A. planci* on Cocos reefs may be seen in the following calculations. Based on an area

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