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Degradation of Coral Reefs at Moorea Island (French Polynesia) by *Acanthaster planci*

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ABSTRACT

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Present and past *Acanthaster planci* grazing are considered the main causative agent of coral destruction at Moorea. *Acanthaster planci* showed a feeding preference for all growth-forms of *Acropora*. The genus *Montipora* (chiefly encrusting species) and *Pocillopora* were both commonly grazed. Foliate *Pavona* were grazed to a lesser extent, and *Montastrea*, *Favia*, *Synarea* and *Porites* were rarely grazed. The knowledge of the selective grazing and the coral composition can provide a reasonable picture of past and future *Acanthaster* predation.

ADDITIONAL INDEX WORDS: *Acanthaster planci damage, selective grazing, past and present infestations, effects on coral communities, Moorea Island, French Polynesia, Pacific Ocean.*

INTRODUCTION

Moorea island is situated 17°32′ South and 149°50′ West, 25 km distant from Tahiti in the Society archipelago in French Polynesia. It is a high island, entirely surrounded by a coral reef rim, cut by eleven passes. Like most of the high islands, the Moorea coral reef complex is divided into 4 "ensembles" or units: outer slope, barrier reef, lagoon and backreef channel, and fringing reef (BATTISTINI *et al.*, 1975; JAUBERT *et al.*, 1976; RICHARD, 1982). Each unit includes zones and biotopes characterised by coral reef communities (FAURE, 1982).

Since 1979, information has been obtained concerning the processes involved in reef complex degradation (SALVAT *et al.*, 1979; BOUCHON 1979, 1982). Possible causative agents of this disturbance are: organic pollution correlated with coastal urban development; increased terrestrial runoff resulting from human land-cleaning activities (bulldozing, road-building) in association with heavy rainfall; chemical pollution connected with large-scale use of pesticides and herbicides; dredging and exploitation of coral materials and sand from the lagoon; microbial disease; and *Acanthaster planci* infestations.

Extensive field observations suggest that present and past *Acanthaster planci* grazing is the main causative agent of coral destruction. In spite of the absence of past data, observations on present destruction of corals, added to results of selective and past predation by *Acanthaster*, suggest in retrospect that a large amount of coral destruction at Moorea is attributable to the recent and recurrent population explosions of *Acanthaster*.

SURVEY METHODS

Numerous (skin and scuba) diving surveys had been carried out in 1982, 1984, and 1987 all around the island. Initially, we adopted the unit time (10 or 20 minutes) survey method, and counted the number of starfish, the densi-

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ties/m² of coral colonies, and noted also the number of mini-aggregations of animals and solitary starfish, percentage of feeding and non feeding animals. At the same time, we noted the coral living species where *A. planci* is seen feeding and the distribution of dead corals. Knowledge of the specific coral composition and selective predation can provide a reasonable picture of past and future *Acanthaster* predation. Also quadrats from 3 to 5 m² were recorded on the outer slope (12 m and 27 m), the barrier reef and the fringing reef. From these data, information on four major variables are obtained: the number of colonies of each species, the size frequency distribution and the average colony size for each species, and the percent coverage.

OBSERVATIONS AND RESULTS

Damage to Reef Flats and Lagoonal Communities, Predation, and Concern for *Acropora cythera, A. hyacinthus* Communities

The first zone of actual predation was located on the northwest coast of Moorea east of "Pointe Teepe" (near "Pass Taotoi") (Figure 1). The damage observed amounted to more than 35% of the 2500-3000 m² of living substrates being destroyed, mainly the present *Acropora hyacinthus*, and *A. cytherea* coral tables, on both sides of the channel. A total of 30-50 *A. planci* was counted in 20 minutes. According to CHESHER (1969), PEARSON & ENDEAN (1969), ENDEAN (1973), 40 starfish seen per 20 minutes of search is indicative of an explosive population. During daylight in some situations, mini-aggregations were usually located close to the base of *Acropora* tables as described by ORMOND & CAMPBELL (1974). One fifth of the specimens were found feeding on the top of the coral tables.

The second zone was situated near Afareaitu (southwest of Moorea) on the barrier reef, between "Teruaupu and Tupapaurau passes" (Figure 1). The corals preyed upon were young recolonizing colonies of *A. hyacinthus* and *A. cytherea*, frequently settled on the skeletons of a very dense field of tabular corals broken away from their points of attachment and reversed. Young growth density is about 3-8/10 m² and average colony size was 30 cm. All were subject to predation of *A. planci*. Although the density of *A. planci* and feeding scars were low (10-15 specimens/20minutes), the asteroid population seemed sufficient to destroy second generation growth corals and to prevent recovery and recolonization of corals. The combined damage, both past and present, amounts to more than 95%. The present observations suggest two hypotheses to explain the actual status of this zone. These are: (1) a residual population of starfish left when the horde of the *A. planci* migrated after the bulk of their coral prey was killed, as suggested by ENDEAN & STABLUM (1973 a-b) on the Great Barrier Reef, and (2) a secondary outbreak independent of the first one, or the descendant of the residual population, according to the size of grazed coral growth (30-50 cm) as proposed by ENDEAN (1977).

The latter hypothesis is supported by two facts: first, estimates show that the destruction cycle (whitening, algal coating, and ultimately

Table 1. *5 m2 Quadrat on barrier reef, Tiahura reef, Moorea.*

SPECIES	Colonies size (diameter) in cm >50	30-50	20-30	10-20	5-10	<5	N° Colonies	Coverage in cm²	% Total cover	% Relative cover	Average Colony size in cm
Porites lobata	1	1			1	1	4	2555	5.1	30.7	27
Porites sp.	1						1	2430	4.9	29.2	50
Millepora platyphylla			2	2	7		11	1830	3.8	22.0	13
Montipora sp. 1				1	4		5	500	1	6	9
Napopora irregularis				1	1	9	11	230	0.4	2.7	7.7
Pavona varians				1			1	200	0.4	2.4	15
Montipora sp. 2					1		1	150	0.3	1.8	7.5
Acropora hyacinthus						3	3	150	0.3	1.8	4
Montastrea curta				1			1	150	0.3	1.8	15.2
Pavona cactus					1		1	135	0.2	1.6	7.3
	2	1	2	6	15	13	39	8330	16.7	100	11.9

Table 2. *5 m2 quadrat on fringing reef, Tiahura reef, Moorea.*

SPECIES	Colonies size (diameter) in cm >50	30-50	20-30	10-20	5-10	<5	N° Colonies	Coverage in cm^2	% Total cover	% Relative cover	Average Colony size in cm
*Synarea convexa**	1*	1*	1				3	5 305	10.6	38.7	38.5
Acropora cytherea	1		1	2	1	1	6	2 850	5.7	20.7	19.2
*Montipora sp. 1**	2*		1	3	2		8	2 254	4.5	16.3	23.2
Pocillopora damicornis				5	3	1	9	1 750	3.5	12.7	11.3
*Montipora sp. 2**	2*			1			3	1 120	2.3	8.1	38.5
Porites lobata			1	1			2	500	1.0	3.5	22.5
	6	1	4	12	6	2	31	13 729	27.6	100	23.7

*Colonies partially necrotised.

Table 3. *4 m^2 Quadrat on outer slope (butresses zone-12 m, Tiahura reef, Moorea.*

SPECIES	Colonies size (diameter) in cm >30	20-30	10-20	5-10	<5	N° Colonies	Coverage in cm^2	% Total cover	% Relative cover	Average Colony size in cm
Montastrea curta			4	13	4	21	1 388	3.47	23	8.45
Porites lobata		2		5		7	1 214	3.03	19.8	12.50
Montipora sp.		1	2		4	7	925	2.31	15.1	13.60
Leptastrea purpurea		1	1	3	4	9	867	2.16	14.1	9.20
*Pocillopora eydouxi**	1*				5	6	492	1.23	8.1	9.17
Acropora sp.				7		7	324	0.81	5.3	7.5
Pavona varians				5	2	7	272	0.68	4.5	6.8
Fungia fungites				4		4	185	0.47	3	7.5
Psammocora sp.				1	7	8	185	0.47	3	5.3
Synarea convexa			1			1	177	0.45	2.9	5
Astreopora sp				1		1	47	0.12	0.7	7.5
Acanthastrea echinata				1		1	47	0.12	0.7	7.5
Favia stelligera					1	1	20	0.08	0.4	5
	1	4	8	40	27	80	6 145	15.3	100	8.56

*Colony 1/2 necrotised

Table 4. *3 m^2 Quadrat on outer slope (spurs and grooves zone)-27 m. Tiahura reef, Moorea.*

SPECIES	Colonies size (diameter) in cm >30	20-30	10-20	5-10	<5	N° Colonies	Coverage in cm^2	% Total cover	% Relative cover	Average Colony size in cm
Synarea convexa	1	2	8	2		13	3 919	13	47.5	16.54
Pavona varians			3	7	7	17	994	3.32	12.1	7.8
Porites lutea		1	1			2	884	2.91	10.7	20
Leptastrea purpurea			1	9	2	12	663	2.11	7.7	7.8
Montastrea curta				7	7	14	464	1.55	6	6.25
Napopora irregularis			1	3	1	5	336	1.12	4.1	8.5
Montipora sp.			1	3		4	316	1.05	4	9.40
Fungia paumotensis				6		6	278	0.93	3.4	7.50
Pachyseris speciosa			1			1	178	0.6	2.16	15
Pocillopora eydouxi				2		2	93	0.31	1.13	7.5
Cyphastrea sp.				1	2	3	68	0.22	0.82	5.8
Acanthastrea echinata					3	3	60	0.20	0.73	5
Psammocora sp.					2	2	20	0.07	0.24	5
	1	3	16	40	24	84	8 243	28.05	100	8.63

eroding and breaking of tabular corals) lasts of about 23 years. Recolonizing corals are then able to settle on the breaking skeleton of tabular *Acropora* according to ENDEAN (1973) and NISHIHIRA & YAMAZATO (1974). Second, the results will depend on the extent of initial destruction and environmental growth, conditions the growth rate of corals such as *A. hyacinthus* and *A. cytherea* which is about 5-10 cm/year (STODDART, 1969; ENDEAN, 1971;

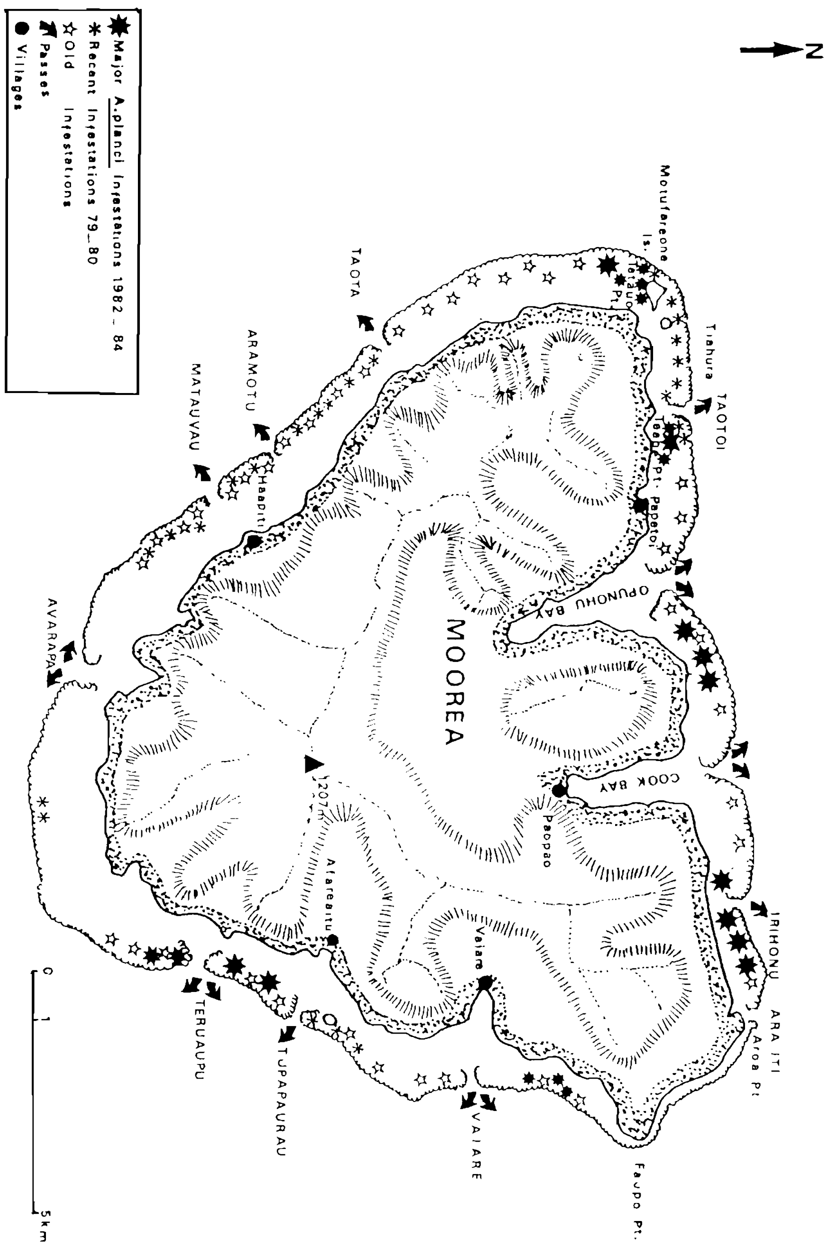

Figure 1. Locations and sites of coral reef destruction by *Acanthaster planci* on Moorea island.

GLYNN, 1973; NISHIHIRA & YAMAZATO, 1974; PEARSON, 1981). Thus, the first starfish attack might have occurred six to eight years ago (1974-1976). In spite of a life duration of about 8 years (ENDEAN, 1973; CHESHER, 1969) and the fact that *A. planci* can survive 3 to 6 months without food, it is difficult to imagine how a residual starfish population withstood such a time without any manifestation of grazing. Therefore the hypothesis of a residual population appears untenable.

Concerning *Acanthaster* predation on mixed communities, massive reef destruction was noted in November-December 1982 on the middle part of the barrier reef situated 1.500 m in the south of the Motufareone island (WNW Moorea) with a density of 3 to 4 starfish/m^2 and more than 50 animals/20 minutes. All species of *Acropora*, both tabular and foliate, are commonly grazed (*A. cytherea*, *A. hyacinthus*, *A. abrotanoides*, *A. formosa*), as one branching growth form such as *A. digitefera*, *A. humilis*, *A. variabilis*. Species of the very common genus *Montipora* are also entirely or partially grazed, either as monospecific colonies or coral heads, or in the shape of polygenic coral patches mixed with *Porites*, *Favia*, *Acropora* or *Pocillopora*. In the latter case, the *Porites* located in the middle and tops of the patches are entirely avoided, while basal and sides of patches composed of foliates and incrusting *Montipora* were severely grazed. The genus *Pocillopora* was also among the more frequent preys of the starfish. The central part of the largest colonies were generally void of feeding scars and alive, perhaps because of the impossibility for a starfish to spread its stomach and insert gastric folds between central branches, or because of defense by crustacean symbionts of *Pocillopora* as observed by GLYNN (1981). Other genera and species were generally avoided or rarely and locally grazed (less than 5%) *e.g.*, *Leptastrea purpurea*, *Gardineroseris planulata*, *Pavona varians*, *Porites lobata*, *Montastrea curta*, *Platygyra daedalea*.

The composition of grazed corals on the barrier reef, 1 km east of "Passe Taotoi" still include not only most of the *Acropora*, *Montipora* and *Pocillopora* species, but also numerous colonies of *Pavona cactus*. Thus, when usual preys are totally destroyed, some other scleractinians corals: *e.g.*, *Synarea convexa*, *Porites lobata*, *Montastrea curta*, *Favia speciosa*, *Napopora irregularis*, and occasionally the hydrocorallid *Millepora platyphylla* are moderately grazed by *A. planci*. A double spatio-temporal gradient of destruction occurred in this area. The first was found from the reef front (where dead coral *in situ* were covered with coralline algae), the middle part of reef flat (corals coated with filamentous algae), to the inner part of the barrier reef and back-reef channel (where we found *A. planci* and fresh feeding scars). Therefore the infestation began at the reef front, and then overran the reef flat to backreef channel and lagoon and the edge of the fringing reef. The second occurred from west to east. This means that the infestation began on the margin of the "Taotoi pass" and invaded the present zone one km to the east.

Concerning lagoon communities, the only lagoon infestation was located on the edges here and there of the backreef channel to the east of "Pointe Teepe", covered with *Synarea convexa* and *Pavona cactus*. Concentrations of *A. planci* were not yet significant in December 1982 (1 animal/2-3 m^2) and were initiated by small group of immigrates coming from the neighbouring barrier reef of the previous area.

Occasional specimens and fresh feeding scars have been found at other stations such as, in the north, between the bays of Opunohu and Cook, behind, the backreef channel, and on the southern barrier reef between "Arapa and Teruaupau passes." In February 1984 an important aggregation of starfish ($> 2/m^2$) was noted, in the same area resulting in widespread destruction of corals.

Predation in the Past

Massive destruction of corals caused by *A. planci* outbreaks, has occurred in the past in several areas at Moorea, but has gone unnoticed until only recently.

In the northwest, at scattered locations on the two "Motu" Tiahura and Motufareone (see Figure 1), large areas of the fringing reef have been recently subjected to selective predation by starfish. For the first time, juvenile ($<$ 12 cm) and pre-adult (12-15 cm) starfish were found in 1978 on the barrier reef front (O. NAIM, personal communication), then in 1980, both juvenile and adult populations have been observed at the same station (communication, C. PAYRI, C. BIRKELAND). Our observations and data on living and grazed on corals, revealed a specific selection by *A. planci* for the two genera *Pocillopora* and *Acropora*, of which the actual total coverage is about 0.3% and a relative cover of 1.8%. All grazed colonies were recently killed and had skeleton still *in situ*. Owing to the massive destruction by *Acanthaster* of *Acropora*, *Montipora* and *Pocillopora*, the actual coral assemblage was qualitatively greatly disturbed with a relative preponderance of the genus *Porites* (60%) and the hydrocoral *Millepora* (22%) with a total coverage of 16.7% (according to BOUCHON, it covered more than 45% in 1979). At the same time, coral cover seems to be higher near the lagoon channel, where it was about 30%. Some *Synarea convexa* and *Montipora* spp. are presumed to have been partially devastated by dredging operations from two extraction zones of sand and coral material 1962-1975 (SALVAT *et al.*, 1979). Yet, because of the lack of knowledge of the past history of *Acanthaster* in this area, it is actually very difficult to distinguish the relative importance of starfish and dredging in the coral damage.

In western areas, from "Pointe Tetauo" to "Pass Aramotou", most of the tabular *Acropora* were already dead with certain exceptions (for instance the north part of "Pass Aramotou"). Most of coral more than 75%, were broken off the substrate and recolonizing corals had settled on the dead skeletons of tabular corals. The average size of recruiting corals was more than 30 cm diameter. In the south of Taota, all recolonizing colonies were dead and covered with coralline algae. Some of them were carrying young buds of a second juvenile generation. Thus the first attack (see actual predation at Afaraeitu), may have occurred before 1974-76.

In the southwestern area of Moorea, in the "Pass Aramotou," the barrier coral community was dominated by *Porites* spp. due to the destruction of *Acropora*, *Montipora* and *Pocillopora* species. Further south, the rate of coral mortality was lower in 1982-1984. Near "Pass Avarapa," the barrier reef seemed to be void of past predation in 1984 was severely destroyed in 1987 behind the channel, the actual coverage by corals is about 10%. Significant destruction of *Acropora*, *Montipora* is noted in localized areas where others are moderately grazed on or avoided such as: *Pavona cactus*, *Psammocora contigua*, *Porites lobata*, *P. lutea*, *Pocillopora damicornis* (ecomorph *acuta*).

In the southern area from "Pass Avarapa" to the bay Aharoa, the barrier reef was very prosperous and very few specimens of starfish and feeding scars have been noted in this area in 1982-1984. But massive destruction (> 80%) has occurred between 1984-1987 in the same area. From the bay Aharoa to "Pass Teruaupu," a quantitative gradient of coral destruction occurred on the barrier. Nearly 50% of tabular and staghorn *Acropora* are dead near of Aharao; 95% near Teruaupu. Some rapidly growing *A. hyacinthus* were observed, having an average diameter of 30 cm.

The barrier reef along the channel of Afareaitu, in the southest of Moorea, was massively destroyed consequent to a secondary infestation (1982) following the first one (1974-1976?) The coral communities along the edge of "Pass Tupapaurau" up to "Motu" Ahi, were less devastated in correlation with a high coral species diversity and the obvious avoidance of the prevalent *Porites* sp. in the prey selection by *A. planci*. In contrast, the coral community at the littoral edge of the channel is completely destroyed. Most of the large *Acropora* patches and colonies had broken off at the substrate and reversed, then were covered with fine sediment or coated with algae.

Observations in the northern areas of Moorea suggest in retrospect, that selective predation occurred in the past (locally massive destruction of *A. hyacinthus* and evidence of recolonization), on the outer and middle parts of the barrier reef between "Pass Aroa" (NNE) to "Pointe Teepe" (NWW). Some fresh feeding scars had been observed on the reef back channel and lagoon, principally between bay of Cook and Opunohu in 1982. In the same area massive reef destruction was noted (> 80%), in February 1984 with a density of 3-5 starfish m^2.

Surveys on the outer slope were conducted on the northern (Pte Aroa-Motufareone - Tiahura) and eastern (Pointe Faupo, Afareaitu) parts of the island.

Relatively few *Acanthaster* were counted (3-8) during each dive, but selective damage between 3 to 25 m, with a maximum from 8-15 m, suggest that massive destruction could be attributable to *A. planci* in the recent past.

Two quadrats were placed in the Tiahura area: one at a depth of 12 m, the other at 27 m. At 12 m scleractininian coverage was 15.3% with a total number of 80 colonies (chiefly belonging to the genera *Porites*, *Leptastrea*, *Montipora* and *Pocillopora*), 83% of which measured less than 10 cm in diameter. The average colony size was 8.5 cm. Results were similar to those of C. BOUCHON (personal communcation) which were collected from a 50 m linear transect in September 1982. Coral cover was 46.3% in 1979, at the same depth. The selective elimination (all *Acropora* and most of the *Pocillopora*, both genera being in a normal state, widely distributed all along the avoided outer slope at the same depth, have been strongly damaged at Tiahura), such as reported on the reef flat, suggests that severe destruction could be attributable to *A. planci*.

According to G. VERGONZANE AND C. BOUCHON (personal communication), the outer slope of the Tiahura area was infested with *Acanthaster* in 1979. The average colony size of recolonizing corals (with the exception of larger ≥ 20 cm colonies which had survived the *Acanthaster* infestation), was about 7 cm. According to PEARSON (1981), the average speed of coral growth following the *Acanthaster* infestation on the Great Barrier Reef was 5-12 cm per 3 years (depending on growth form and depth). This seems to corroborate the observation of 1979 and 1982 at Tiahura at greater depths (27 m). The Scleractinian coral coverage, 28% is most important of which 13% for only *Synarea convexa*, but the average colony size is still low (8.6 cm). The larger colonies (≥ 15 cm), belong to the genera which are commonly avoided and not subject to predation by the starfish *Synarea*, *Porites*, *Pachyseris*. These corals are widely distributed (30 to 65%) on the middle part of the slope. The present results are very close to those of BOUCHON (unpublished report 1982: coverage rate 27.5%, average sizes 9.6 cm). When the "spurs and grooves zone" is replaced by a lower slope platform (Motufareone outer slope), a *Porites* sp; *Pocillopora eydouxi* community takes the place of the *Synarea* assemblage, but owing to the massive destruction of *Pocillopora* (with the exception of the largest colonies), the rate of coverage is greatly decreased (≤ 15%).

Far to the west, between Opunohu and Cook bays, the preying performance is similar to that reported for the Tiahura zone; *Acropora* and *Pocillopora* species are commonly grazed, and others such as *Montipora*, *Napopora*, *Favia* from 2 to 30 m are moderately damaged. Only the Aroa zone seemed to be obviously avoided when flourishing coral communities occured from:

(A) 0-15 m "buttresses zone" characterized by a vigorous coral growth. The prevalent corals included: *A. abrotanoides*, *A. humilis*, *A. variabilis*, *A. hyacinthus*, *A. digitifera*, *A. corymbosa* and *Pocillopora verrucosa*, *P. meandrina* and *P. damicornis*; 30 to 60% of the surface was occupied by living corals.

(B) 15-30 m "Spurs and grooves zone" predominated by a mixed community of *Napopora irregularis*, *Synarea convexa*, *Porites lobata*, *Porites* and *Astrepora* sp. The percentage of living coral was about 30-40%.

(C) Below 30 m "outer slope talus zone" predominated by *Porites* sp, *Pocillopora eydouxi*, *Pachyseris speciosa*, *Acropora granulosa*. Rate of coverage: 20-60%.

Northeast surveys conducted in December 1982, showed a luxuriant growth of corals with a rate of coverage of about 80% between 15-25 m. Far to the east (Afareaitu zone), both qualitative and quantitative coral exuberance still occur on the middle part of the slope (coverage ≥ 60%). On the contrary, the "buttresses zone" was characterized by a heavily decreasing coverage (less than 20%) and an avereage colony size (≤ 15 cm) of *Acropora* and *Pocillopora*. This fact suggests, that extensive predation of the genera *Acropora* and *Pocillopora*, occurred in the recent past, possibly at the same date (1974-1976?) as the neighbouring barrier reef (see presently occuring predation at Afareaitu).

DISCUSSION AND CONCLUSION

There is no question that present and past *A. planci* infestations have caused massive destruction to the coral communities of the reef ecosystem at Moorea, although their origin and spatio-temporal history are scarcely known and still greatly hypothetical. Therefore the hypothesis proposed by this study must be considered mainly as a plausible suggestion and only further works will determine the truth of this proposal.

Damage Caused to Coral Communities by *Acanthaster planci*

Prey Selection by Starfish. The observed predation at Moorea revealed selective predation as reported in other sites by CHESHER (1969), PEARSON & ENDEAN (1969), BARNES *et al.* (1970), ENDEAN (1973), ENDEAN & STABLUM (1973 a, b), RANDALL

(1973), PORTER (1972), GLYNN (1973, 1974, 1976, 1977, 1981), NISHIHIRA & YAMAZATO (1974), ORMOND & CAMPBELL (1971, 1974), PEARSON (1981). Our observations of *Acanthaster* grazing, at various locations around the island, show a specific preference for all growth forms of *Acropora*: tabular colonies (*A. cytherea*, *A. abrotanoides*), and straghorn and crustose forms (*A. humilis*, *A. digitifera*, *A. variabilis*, *A. formosa*). The genera *Montipora* (chiefly encrusting species) and *Pocillopora* (*P. damicornis*, *P. verrucosa*, *P. eydouxi*) were both commonly grazed. In the second place, foliate *Pavona* (*P. cactus*) were moderately grazed, when others such as *Montastrea curta*, *Favia speciosa*, *F. stelligera*, *Gardineroseris planulata*, *Synarea convexa*, *Porites lobata*, *P. solida*, *Napopora irregularis* and the hydrocoral *Millepora platyphylla* were commonly avoided or rarely grazed. The knowledge of the selective grazing strategy from areas actually subject to predation allow us to explain the important role of *A. planci* in the past degradations, and thus to understand the actual status of the reef ecosystems.

Relationship Between Degree of Exposure to Wave Action and Selective Predation. At Moorea, contrary to the surveys and results in the Red Sea by ORMOND & CAMPBELL (1971, 1974), there was no relationship between the specificity of grazing and the hydrodynamics. Variations in predation by the starfish were not associated with the degree of exposure, but with the species composition of coral communities and the relative dominance of species from one biotope to another. In other words, it is the relative prevalence of species, preference for calm water or rough water preferential and characteristic species, which directly depend on the degree of exposure and not the degree of selective grazing. For instance, significant destruction of the genera *Acropora* on the barrier reef front was noted at the expense of well adapted rough water species (*A. humilis*, *A. abrotanoides*), when prevalent tabular or staghorn calm water species (*A. hyacinthus*, *A. cytherea*, *A. formosa*) had been affected in the meantime on the fringing reef flat and lagoon area. On the contrary, according to ENDEAN & STABLUM (1973 a, b), a spatiotemporal gradient occurs independently of the species composition of communities from the reef front, across the barrier reef, to the lagoon and fringing reef.

Rate of Coral Destruction. The extent of damage in an area depends primarily on both the degree of infestation (number of *Acanthaster*/m^2) and the degree of coral coverage. It also greatly depends on the specific composition of the communities. Independently of the decreasing rate coverage and reduction of specific diversity, the heavy mortality of grazed species induces great qualitative changes in the communities (GOREAU *et al.* 1973) and provides space and settlement for other corals. In fact, as recorded by PEARSON (1981), *Pocillopora* and *Acropora* are opportunistic genera with a fast growth. The first genus at Moorea having a very large ecological distribution, the second one, a high specific diversity. It is noted, that during the recovery process, the commonest recolonizers are the same as the pioneer species. Yet the recolonization, both by coral larvae (from surviving corals on the same reef or other from undamaged reefs), and budding regeneration, could be greatly inhibited by other organisms (soft corals and macroalgae) (NISHIHIRA & YAMAZATO, 1974; FAURE, 1982). In the case of severe infestation (mainly in the case of a monospecific community such as *A. cytherea*), or after multiple events, the potential of the more opportunistic corals is unable to compete with various fast growing algae and the coral community is entirely replaced by an algal community (south of Afareaitu area).

OTHER CAUSATIVE AGENTS OF CORAL DAMAGE

Algal Spreading. According to PAYRI (1982 and pers. comm.), algal growth (mainly *Turbinaria* and *Boodlea*) was flourishing during the last decade, yet we share the view of BOUCHON (communication), that true and direct coral damage at Moorea caused by algae, has been very small, even if accumulations of *Boodlea* are locally and episodically able to overrun scleractinians. On most accounts, the algal spread is subsequent to the bleaching and killing of corals by *Acanthaster*. In the cases of partial degradation, growth of the undamaged portion seemed to be impeded by algae that settled on the necrotic parts. In the case of polygenic patches after the starfish predation, only

Porites and *Faviids* appeared to be entirely avoided by the starfish. However, it is sometimes noted that algae settled on neighbouring parts of the most commonly grazed, genera (*Montipora*, *Acropora*, *Pocillopora*), and grow over the edge of living parts. In other respects, on the outer slope where scleractinian communities are destroyed (5-25 m), macro algal communities do not occur. It must be borne in mind that the important algal rise during the recent years at Moorea is the result of creating cleared substrata as a result of *Acanthaster* grazing. According to NISHIHIRA & YAMAZATO (1974), and PEARSON (1981), community change after degradation by *Acanthaster* (or other causes) could occur in three ways: (1) recolonization of corals and recovery as locally recorded on the Great Barrier Reef (PEARSON, 1981), Arno atoll (BRANHAN, 1973), (2) development of alcyonarian facies as in the Mascarene archipelago, Mayotte (FAURE, 1974, 1982; FAURE *et al.*, 1984), and (3) development of algal facies, *e.g.* on Moorea (PAYRI, 1982, and personal observations).

Recovery of coral communities is determined by environmental conditions which follow the recovery of initial climatical scleractinian biocoenosis. The change in other ways results in permanent changes to the environment, preventing the recovery of corals and promoting the growth of edaphic biocoenosis (BENAYAHU & LOYA 1977), PEARSON, 1981, FAURE, 1982). Increasing runoff, with sediment loads prevent soft coral communities, and increase nutrients, favouring the macroalgal facies.

Sedimentation Effects. Two main causes of pollution by an increase in the particulate charge in lagoon waters occur in Moorea. (1) The extraction of coral materials and sand can be directly involved. In 1973, more than 150,000 m^3 of coral materials were dredged from 8 extraction points located on the fringing reef. The degradation induced by the exploitation of coral material from Moorea lagoon has been discussed by SALVAT *et al.* (1979). Our observations in the vicinity of the Haapiti extraction zone, corroborate the harmful effects on corals. However, a large amount of the scleractinian destruction occurs within a radius of about 50 meters around the dredging dikes and more distant coral communities with *Pocillopora damicornis*, *Psammocora contigua*, *Napopora irregularis*, *Pavona cactus*, and *Montipora* sp (being the removed domination) are more or less alive, and selective destruction such as that caused by *A. planci* population does not occur. (2) Increasing terrestrial runoff and sediment loads in coastal shallow water, are chiefly correlated with man-made disturbance such as deforestation, bulldozing, and road building. In fact, some colonies are totally or partially bleached or destroyed in the vicinity of the bays. Because of heavy siltation, well-adapted coral assemblages located in bays and estuaries are still avoided and destruction, such as reported above, near the dredging areas has not been observed.

We come to the conclusion, that in contrast to *Acanthaster planci*, which cause extensive and selective degradation to most of the reef biota, the direct occurrence of turbidity, induced by exploitation of coral sands and terrestrial sediments, is most likely to affect corals in restricted areas. We share the opinion of SALVAT *et al.* (1979), RICARD (1981), and PAYRI (1982), that reefs around Moorea are indirectly influenced by an increase of nutrients in stimulating blooms of phytoplankton and macroalgal development. Thus, the increase in the percentage of reef area covered by macrophytic algae (mainly *Turbinaria*, *Sargassum*, *Padina*, *Boodlea*) during the last 10 years will result in a cleared substrata and is a consequence of *Acanthaster* grazing and increase in nutrients which stimulate phytoplankton blooms.

OUTBREAKS OF *ACANTHASTER PLANCI* POPULATIONS DURING RECENT YEARS

According to BIRKELAND (1982): "The terrestrial runoff from heavy rains may provide enough nutrients to stimulate phytoplankton blooms of sufficient size to produce enough food for the larvae of *A. planci*. The increased survival of larvae, results in an outbreak of adults 3 years later and extensive coral damage when the postlarvae reach maturity." The same relationship between massive siltation and outbreaks of *Drupella* in Japan and the Philippines, is presented by MOYER *et al.* (1982) to explain the widespread destruction of scleractinian corals. At Moorea island it is probable that outbreaks could be more the result of the effects of dredging than terrestrial runoff. In the light of this hypothesis, we can explain the location of two actual severe predatory zones, both on the two sides of Taotoi passage, and other recent destructions in this area, as the result of the opening of a dredging site at Pointe Teepe in 1975. In this area, the first *Acanthaster* specimens had appeared in 1978 in the form of pre-adults (12-15 cm in diameter), on the reef front and then in the shape of adults (25-30 cm), on the outer slope in 1979. In 1980, starfish were found on this Barrier reef flat outer margin and they migrated progressively through the barrier reef, reef channel and fringing reef between 1980-82. At the same time, the infestation moved away from the proximity of the pass.

A similar hypothesis may explain present and previous *Acanthaster* outbreaks in other parts of the island. In addition to the extraction zones, it is evident that heavy terrestrial runoff connected with deforestation (pineapple cultures), construction works (airport and roads), may enrich lagoon waters in nutrients and indirectly facilitate *Acanthaster* population explosions.

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□ RESUME □

Les principales dégradations des peuplements coralliens à Morea sont dues à des attaques passées et en cours de la part de l'Astéride *Acanthaster planci*. kCette dernière, présente une prédation sélective avec une préférence pour toutes les formes de croussance d'*Acropora*. Les espècies des genres *Montipora* (Iprincipalement les formes encroûtantes) et *Pocillopora* sont également très affectées par la prédation. Certaines comme *Pavona* sont modérément utilisées, alores que d'autres comme *Montastrea, Vavia, Synarea, Porites*, sont rearement attaquées. La connaissance de la prédation sélective et celle de la composition des communautés Madréporiques, permettent de comprendre l'importance du rôle joué par *Acanthaster plance* dans les dégradations passées et futures.