Proceedings of the Fifth International Coral Reef Congress, Tahiti, 1985, Vol. 6

QUANTITATIVE STUDY OF SCLERACTINIAN CORAL COMMUNITIES OF TIAHURA REEF (Moorea Island, French Polynesia)

ETUDE QUANTITATIVE DES PEUPLEMENTS DE SCLERACTINIAIRES DU RECIF DE TIAHURA (Moorea, Polynésie française)

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ABSTRACT

Scleractinian coral communities were investigated, using a quantitative transect line method, across the reef complex of Tiahura (Moorea island) which is divided into two ensembles, a fringing reef and a barrier reef separated by a lagoon.

Species richness and coral coverage rate increased from the shore to seawards. The fringing reef flat was characterized by a poor coral community and the dominance of species belonging to the genera Porites, P. (Synarea) and Montipora. A richer community, dominated by Acropora and Pocillopora, was found on the barrier reef flat. On the outer reef slope, the coral community was divided into three zones: an upper Pocillopora and Acropora zone (0-10 m), a median area (15-20 m) dominated by Porites (Napopora) and Montastrea species, and a lower zone (30 m) dominated by massive species belonging to the genus Porites.

Three years after this investigation, Acanthaster planci (crown-of-thorns starfish) predation highly damaged the coral communities. A replicate study was conducted and demonstrated that a drastic drop in living coral coverage occurred on the reef and that branching forms like Pocillopora and Acropora were more particularly affected.

RESUME

Les communautés coralliennes du complexe récifal de Tiahura (Moorea) ont été étudiées le long d'une radiale à l'aide d'une technique quantitative de relevés par transects. Cet édifice récifal est divisé en 2 unités structurales : un récif frangeant et un récif barrière, séparés par un chenal.

La richesse spécifique en coraux ainsi que le taux de recouvrement du substrat augmentent du rivage vers le large. Le platier du récif frangeant est caractérisé par une communauté corallienne pauvre dominée par des espèces appartenant au genre Porites, P.(Synarea) et Montipora. Un peuplement de scléractiniaires plus riche, dominé par les genres Acropora et Pocillopora occupe les formations de platier du récif barrière. Sur la pente externe du récif barrière, 3 horizons de peuplement ont été mis en évidence : une zone supérieure (0-10m), à Pocillopora et Acropora; une zone intermédiare (15-20m) dominée par les genres Porites (Napopora) et Montrastrea et enfin, une zone profonde (30m) caractérisée par la dominance d'espèces massives de Porites.

Trois ans après cette étude, les communautés coralliennes de ce récif ont été profondément dégradées par la prédation due à l'échinoderme Acanthaster planci. L'étude quantitative a été renouvelée et a mis en évidence une chute massive du taux de recouvrement en corail vivant sur le récif. Les formes branchues appartenant aux genres Pocillopora et Acropora ont été plus particulièrement affectées par ce phénomène.

INTRODUCTION

The coral communities of French polynesian islands have been studied qualitatively for over twelve years by Chevalier (1969 to 1979) and more recently by Kühlmann (1982) and Bouchon (1983). The Scleractinian communities of Moorea island were described by Chevalier and Kühlmann (1983). In 1979, a first quantitative study of the Scleractinian assemblages of Tiahura reef was conducted on that island. The following years, an outbreak of the population of the starfish Acanthaster planci heavily damaged these communities. In 1982, the quantitative survey was replicated on Tiahura reef in order to provide a quantitative estimation of the alterations which appeared in the structure of the coral assemblages. Results of both studies are reported in the present paper.

STUDY AREA

The study reef is located at the northwestern part of Moorea island. Detailed morphological descriptions of that area are available in previous studies (Salvat et al., 1972 ; Jaubert et al., 1976) and will only be briefly described below. The reef complex of Tiahura is from 800 m to 900 m wide as measured from the shore to the outer reef front and is divided into 2 morphblogical units : a fringing reef and a barrier reef separated by a channel (figure 1). The fringing reef is about 250 m wide and is generally covered by 0.5 to 1 m of water. Near the beach, small scattered coral colonies are found and these become more and more abundant towards the channel where they form a true reef flat. The fringing reef ends abruptly with a small drop off, 5 m high, into the channel. The channel, about 80 m wide and 8 m deep, is generally run by a strong current (up to 5 knots) and its bottom is covered with rubble and dead pieces of coral. The barrier reef flat is about 500 m wide and is covered by 1.5 m to 2 m of water. Near the channel, the inner slope of the barrier reef is sandy and has no coral coverage. The middle part of the barrier reef flat is occupied by numerous and more or less anastomosed coral patches, the biggest ones reaching up to the surface. Near the reef front, the corals form a compact reef flat cut by surge channels. Seaward, the reef front is constituted by a flagstone, which emerges at low tide and covered by an algal lawn. To 7 m deep, the outer reef slope is a furrowed and gently sloping platform about 80 m wide with scattered coral colonies. Beyond that depth, the inclination of the slope suddenly increases and the platform is replaced by a spurs and grooves system which ends at 15 m in a 15 m wide sedimentary basin, parallel to the reef front. A buttresses and valleys zone extends from 15 to 30 m deep and is followed by a slightly inclined sandy slope to 45 m and steeper beyond.

The ecological factors prevailing on the Tiahura reef complex were studied by Jaubert (1976). The fringing reef flat is characterized by shallow waters having a low turn-over. Important daily variations in temperature (24-32°C), dissolved oxygen (2-12 mg/l), and high sedimentation rate and freshwater runoff occur in this area. On the fringing reef front and on the barrier reef flat, the turn-over of the water is better and the ecological conditions are more stable. The communities of the outer slope are mainly controlled by high wave energy in the upper part (0-5 m) and below, by decreasing light intensity according to depth.

METHODS

Following a preliminary qualitative survey of the Tiahura reef complex, a stratified sampling strategy was adopted to study the coral communities. Surveys were conducted across the reef at 9 stations distributed along an axis perpendicular to the shore line and successively located on the fringing reef (stations 1,2,3), the barrier reef (stations 4,5) and on the outer slope at a depth of 3 m (station 6), 10 m (station 7), 20 m (station 8) and 30 m (station 9) (figure 1). The distribution of Scleractinians was quantitatively studied using a line transect technique (Loya, 1972 ; Bouchon, 1981). At each station, 10 m long transects were established parallel to the shore line to avoid variations in ecological conditions. In 1979, 5 consecutive 10 m long transects were carried out at each station except for the deep portion of the outer reef slope (3 transects at -20 m and 2 transects at -30 m). These transects were replicated in 1982 at the same stations. Any coral colony underlying the line transect was recorded and its intercept length measured. The growth form of colonies was also noted as either encrusting, massive or branching.

The flattening of species versus transect length curves was obtained with transect lengths comprised between 20 and 30 m. For each station, the coverage rate by Scleractinians, the number of colonies per 10 m of transect, the species richness, the relative abundance of these species as well as the Shannon and Weaver index of diversity (H') and the Pielou's evenness (J') were computed. Data, even transformed, badly fit a gaussian distribution. So, non parametric statistical tests were used for data processing. Comparisons of raw distributions between stations studied in 1979 and 1982 were conducted with the Wilcoxon signed-ranks test. Relationships between coral assemblages were examined using the Spearman rank correlation coefficient. The matrix of correlation thus obtained was used for a cluster analysis. Sorting was based on the Lance and Williams (1967) flexible fusion strategy (with $\alpha = 0.625$ and $\beta = -0.25$) and executed on an Apple 2e computer with a program developed by the author.

RESULTS

The quantitative analysis of the results was conducted with values on the number as well as on the size of colonies for each species. Results obtained with both type of data were very similar. So, only those calculated with coverage values (which is for corals, a closer approach of the concept of biomass) were kept for the present paper (table 1, figure 1).

The coral community in 1979

Parameters relating to the distribution of coral across the reef are summarized in figure 1. In 1979, 57 species of corals were recorded on Tiahura reef. Species richness increased from the shore to seaward (figure 1) on the fringing reef and on the barrier reef flat (6-30 species). On the outer slope, a decrease was noticed at 3 m in a zone characterized by high wave action. Maximum species richness was found between 10 and 20 m (29-28 species) and a decrease appeared at 30 m (25 species), probably linked to reduced illumination. The coral coverage rate displayed a similar pattern of variations : it increased seaward

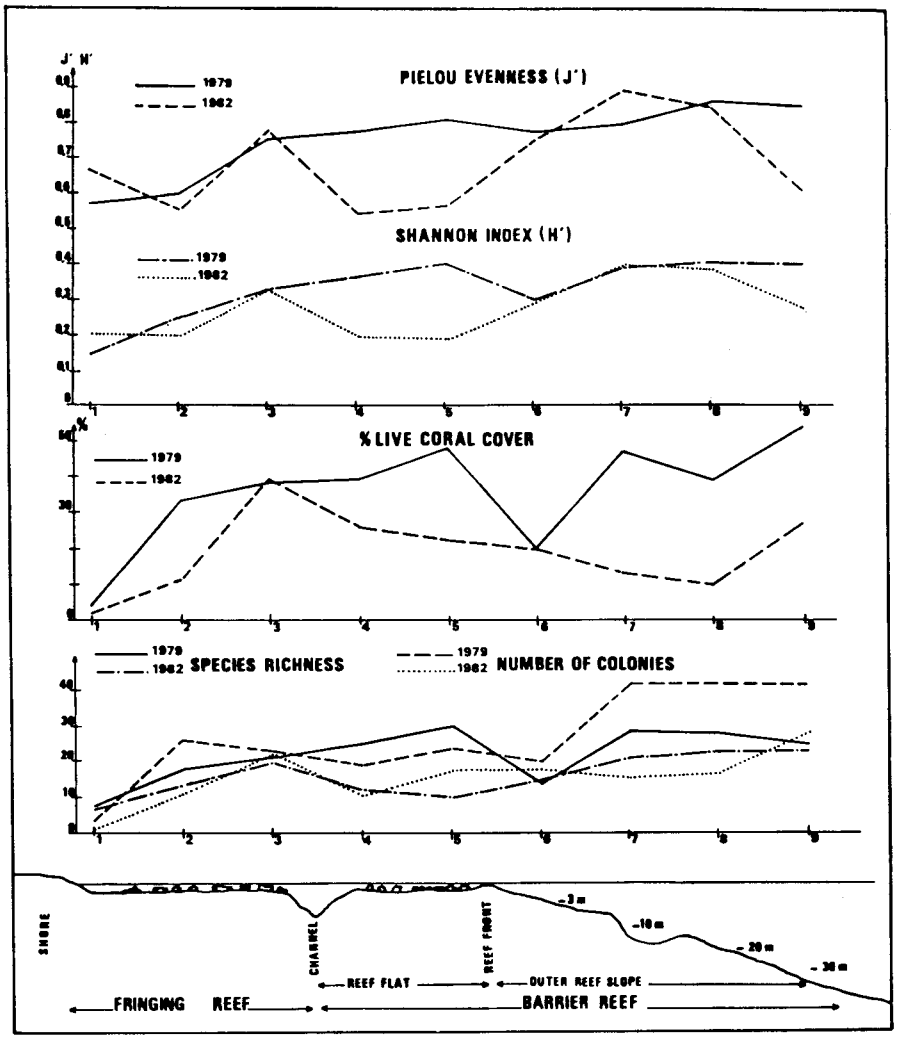

Figure 1 : Variations across the reef of species richness, number of colonies per 10 m of transect, coral coverage rate and Shannon and Pielou indices in 1979 and 1982 (stations 1 to 9).

across the fringing reef and the barrier reef flat (4 % to 49 %), dropped at -3 m on the outer slope (20 %) and increased again according to depth (54 % at -30 m). The variations of the Shannon-weaver index showed that the diversity of the coral communities increased seaward with a decline at 3 m on the outer slope. The Pielou's evenness regularly increased across the reef (0.57-0.84) reflecting a progressively structured coral community correlating with more favorable environmental conditions which prevailed on the outer slope.

The cluster analysis of quantitative data led to the separation of 4 ecological units (figure 2) : a fringing reef flat community ; a community of the fringing reef front and of the barrier reef flat ; a community of the upper part of the outer slope (0-10 m) and a coral assemblage in the deep part of the outer slope (20-30 m).

The fringing reef flat community reflected the severe ecological conditions of that zone : low values for species richness, coverage rate and Shannon and Pielou indices. The community was widely dominated by Porites (Synarea) rus, P. lutea, Montipora circumvallata and M. erythraea. The abundance of other species was negligible.

A richer community had settled on the fringing reef front and the barrier reef flat. Its maximum development was reached on the outer part of the barrier reef flat (30 species, 48 % of coverage). The dominant species belonged to the genus Porites (P. lutea and P. (Synarea) rus mainly) and Acropora. A. cytherea was a dominant species characteristic of the barrier reef flat.

Two different sub-communities appeared in the coral assemblage established on the upper part of the outer reef slope. The shallower part of this area is controlled by high wave energy. The genus Pocillopora (P. verrucosa, P. eydouxi, P. damicornis) then dominated the community (40 % in abundance) followed by Montipora erythraea (19 %) and Acropora humilis (13 %). The abundance of the Hydrocorallian Millepora platyphylla also constituted a characteristic feature of this zone. Below (10 m), the abundance of Pocillopora species remained important (24 %) but the community was dominated by the genus Acropora (39 %) with mainly A. variabilis, A. humilis and A. hyacinthus.

The deep part of the outer slope (20-30 m) was characterized by the predominance of Porites species (essentially P. lutea, P. (Napopora) irregularis and P. (Synarea) rus) which represented at 30 m, more than 53 % of the coral community.

Table 1 : Distribution and relative abundance (% in size of colonies) of the corals across Tiahura reef in 1979 and 1982.

STATIONS :	1		2		3		4		5		6		7		8		9	
	79	82	79	82	79	82	79	82	79	82	79	82	79	82	79	82	79	82
Psammocora contigua		3.5	2.1	2	1.4	1	0.3					0.3	1.1			2.8		
P. haimeana									0.3	0.5	0.5	0.2	0.4		0.4	0.7		0.4
P. nierstraszi									0.4									
P. profundacella							0.3											
Stylocoeniella armata			0.3	0.4	+													
S. guentheri																		1
Pocillopora damicornis	0.1	2.3	3.6	1.4	0.8	5.9			0.2		7.1	1	0.2					
P. eydouxi											2	13.2		18.3				
P. verrucosa					1.4	1.5	4.9	1.2	6.1		31.5	5.4	20.2	13.7	2.2	24.3	0.5	0.4
Acropora abrotanoides					5.9	19.1			2.3									
A. cerealis									4.6				3.7	5.5				
A. cytherea			1.8			0.5	5.7		12.5									
A. humilis					0.3	0.8		0.8	1.9		13.2	2.4	10.3	6.1	1.7			
A. hyacinthus						1	1	0.8	1.5		1.5	6.1	5.1					
A. intermedia									1.3									
A. nobilis									5.4									
A. palmerae											1	9.8	2	2.3				
A. robusta							2.6											
A. tenuis									0.4				0.9					
A. valida							1									1		1
A. variabilis									2.5				17.4	6.8	1.7			
Acropora sp. 1			0.9				2.6		2.1									
Astreopora myriophthalma															2.2		0.5	2
Montipora circumvallata •			15.4		9.7													
M. erythraea			9.7	2.7	12.2	16	8.3	0.8	7.1		19.3	26.7	0.4	1.5	1.7	1.7	1.9	1
M. cf informis														3.8				
M. verrucosa				2.7	1.9	9.8	4.4	3.5	2.7	0.5			0.4		0.4		0.9	
Pavona cactus	10	11.6	5.1	8		2.8			0.2									
P. maldivensis															1.3	0.7		
P. minuta													0.9		0.4		0.5	
P. varians					0.8	0.3	0.5		1.3	0.5	4.1	1.1	7.2	6.8	6.9	5.6	5.6	1.6
Leptoseris cf incrustans															0.4			0.6
L. mycetoseroides														0.8	0.9			
Gardineroseris planulata													0.9	5.3	4.8	4.9	1.9	
Pachyseris speciosa																	3.7	1
Fungia concinna									0.2				3.5	1.5	5.6	6.6	3.7	
F. danai													0.4	0.8			2.8	
F. klunzingeri			0.3		0.5													
F. paumotensis			0.3			0.3	1						0.2	0.8	2.2	1.7	3.7	1
F. repanda						2.1			0.4									
F. scutaria													5.3	0.6		1		
Herpolitha limax					0.5		0.3		0.8				1.5	1.5	9.5	10.4	6.5	2
Sandalolitha robusta					0.5								0.2		0.9		0.9	3.3
Porites australiensis			1.2		8.1		12.7		7.9						1.7	3.5	21.8	4.1
P. lichen																	2.8	1
P. lobata			1.5			2.8	8.3	47.4	10.2	23.2		1.5						
P. lutea	35.1	29.0	3	21.4	24.9	6.4	28.5	35.1	19	44.5	3		1.5		6.9	6.9	8.3	57
P. (Napopora) irregularis			1.5	2.1	3.8	3.1	3.9	1.2	4.6	27.3			4.4	6.5	19.5	8.7	3.7	
P. (Synarea) rus	52.7	52.3	51.6	56.9	19.2	22.9	8.5	7.7	1.9	0.9			0.9	2.4	3.5	5.2	16.7	4.1
Porites sp. 1							1											
Favia stelligera					1.1								2.9	2.6	3.5	1	2.8	0.4
Favites cf abdita								0.2										
Montastrea curta							0.5	0.4	0.4	0.3	6.1	6.4	5	7	6.9	5.2	3.7	2
Leptastrea purpurea	2.1	1.2	0.4	0.7	0.3	0.1	0.8	1.1	0.4	0.6		0.8				3.1		8.4
L. transversa				0.4	0.8	1.5	1		1		0.5	0.5	0.4		9.1	0.7	1.9	2.4
Cyphastrea microphthalma			+	0.5														
C. serailia	0.1														1.3	1.4	1.9	1.6
Acanthastrea echinata							0.5				1		0.4		3.5	1	2.3	1.8
Lobophyllia hemprichii							0.3								0.4		0.5	
Millepora platyphylla			1.2	0.9	5.9	2.1	1		0.2	1.8	9.1	24.8	2.2	5.3	0.4	1.7	0.9	1.6

The distribution of coral growth forms is given in figure 4. The importance of encrusting forms was very low in the shallow parts of the reef and increased on the outer slope according to depth. Massive colonies were dominant in the reef flat areas and the deep parts of the outer slope. They were mainly related to the genus Porites. Branching colonies were flourishing on the fringing reef flat (Porites (Synarea) rus), the barrier reef flat (Acropora species mainly) and on the outer slope at 10 m (Pocillopora and Acropora). Their importance declined with depth.

The coral community in 1982

After the outbreak of Acanthaster planci population , noticeable alterations appeared in the coral communities.

In 1982, 48 species of corals were recorded on the reef (3 of which, represented by a single specimen, had not been previously found in 1979). Twelve species recorded in 1979 were absent in the 1982 study. Among them, 5 species belonged to the genus Acropora (out of 13 species found in 1979). Others like Montipora circumvallata, Pavona minuta and Lobophyllia hemprichii, which were common in 1979, disappeared from the studied area.

The cluster analysis of the 1982 results (figure 2) and their comparison with those of 1979 (figure 3) revealed no important changes in the partitionning of the communities across the reef. However, the analysis of all the records enhanced the separation of the coral assemblage of stations 6 and 7 on the outer slope (Pocillopora and Acropora zone).

The results concerning species richness, number of colonies per 10 m of transect, substratum coverage, Shannon-Weaver and Pielou indices were compared with the Wilcoxon test. A significant difference was then found for each parameter between the 1979 and 1982 surveys

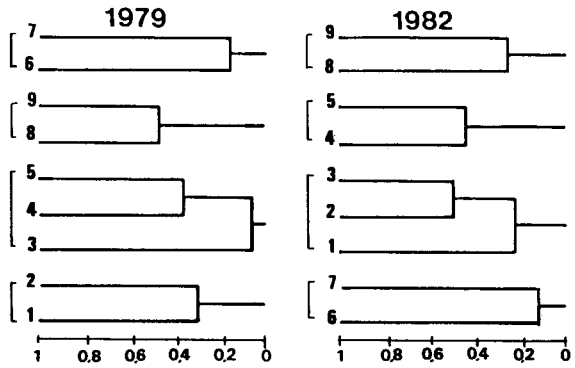

Figure 2 : Cluster analysis of the 9 stations surveyed on Tiahura reef in 1979 and 1982.

(level of significance 95 %). However, the different parts of the reef were not equally affected by the crown-of-thorns starfishes predation. The fringing reef front (station 3) and the upper part of the outer slope (station 6) are high water energy zones (current and waves) and do not represent a suitable habitat for Acanthaster. So, the coral communities of these areas were little damaged. In the inner part of the fringing reef flat, where coral colonies were already very scarce in 1979, no real important change occured. In the midzone of the fringing reef flat, the living coral coverage dropped from 33 % to 11 % and the number of colonies per 10 m of transect was reduced from 26 to 11 . Montipora circumvallata which was the second dominant species in 1979 in that area disappeared completely from the fringing reef. Major changes affected the coral communities of the barrier reef flat and especially in its 1979 richest part (station 5). Living coral cover and number of colonies per 10 m of transect respectively decreased from 48 % to 22 % and 24 % to 17 %. Species richness dropped in that area from 30 to 10 species. All the Acropora (10 species) disappeared from the area and especially A. cytherea which was the second dominant species in 1979.

On the outer barrier reef slope, maximum damage was recorded from 10 to 30 m (stations 7,8,9). The living coral cover decreased from about 70 % between 10 and 20 m and 54 % at -30 m. The decline in species richness was less drastic on the outer slope than on the reef flat. At 10 m, the Acropora species (dominant group in 1979) were selectively attacked (81 colonies in 1979, 18 in 1982) and A. variabilis which was a major component of the community severely declined. Deeper, where Acropora had already little importance in the communities of 1979, it seemed that the predation was less selective and more distributed over all the taxinomic groups, except for the genus Porites which remained the least affected group by Acanthaster predation on the whole Tiahura reef. The dominance of Porites species in the -30 m community explains the minor decrease in coral coverage which appeared in this zone compared with -10 m and -20 m. In 1982, no sign of recolonization of the reef by any coral species was noticeable.

The distribution of different coral growth forms on the reef first reflected the general decline in coral coverage by the general flattening of the curves (figure 4). Encrusting species showed little changes in their distribution. Massive colonies were mainly affected on the reef

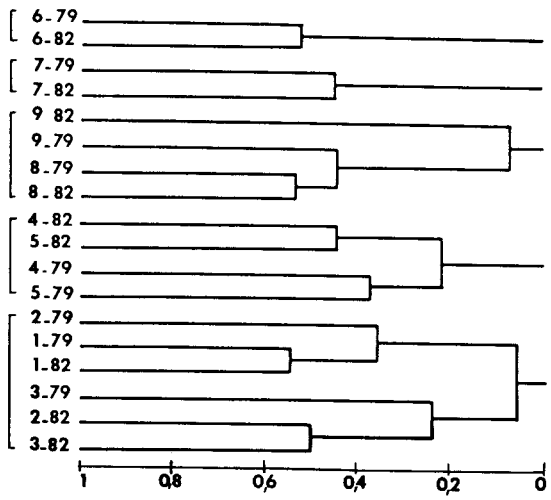

Figure 3 : Cluster analysis of the 9 stations of Tiahura reef (pooled data 1979/1982).

flats (strong decrease of Montipora circumvallata and M. erythraea). The coverage with branching colonies dropped in all the reef areas (except the fringing reef front) and was mainly due to selective predation on Acropora species.

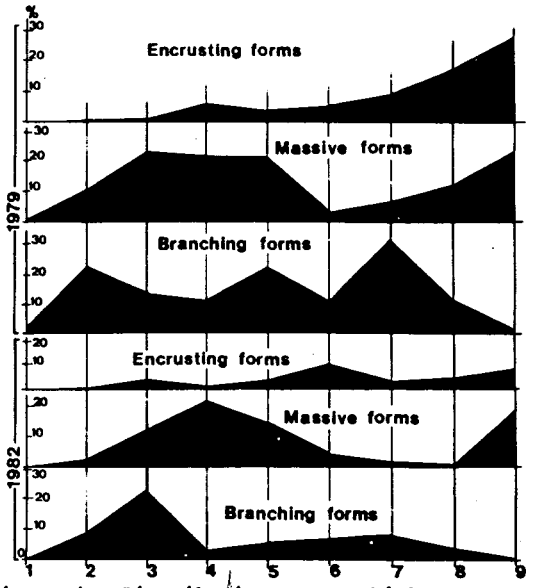

Figure 4 : Distribution across Tiahura reef of different coral growth forms in 1979 and 1982 (stations 1 to 9).

DISCUSSION AND CONCLUSION

In 1979, four coral assemblages existed on the Tiahura reef system. A first one, settled on the fringing reef was controlled by severe environmental factors, resulting in low values for living coral coverage and equitability and poor species richness. A more flourishing community developed on the barrier reef flat because of more favorable ecological conditions (high species richness, coverage rate, equitability). These results agreed with those of Chevalier and Kühlmann (1983) who suggested a general enrichment of the coral communities of Moorea reef flats from the shore to seawards.

The Scleractinian distribution on the outer reef slope is synergistically controlled by the decrease in hydrodynamic actions and available light energy according to depth. In Moorea, optimal conditions were reached between 10 and 30 m where the coral community was rich and diversified.

The partitionning of the communities found on the outer slope into an upper zone dominated by branching corals and a deeper zone characterized by massive growth forms is now classical for the Indo-Pacific area. Such a scheme of distribution has already been described for French Polynesia (Chevalier et al., 1969 ; Bouchon, 1983 ; Chevalier and Kühlmann, 1983). However, the species which contributed to that zonation differed according to the area. In Moorea, Pocillopora species were dominant between 0 and -5 m and Acropora species below. In Takapoto atoll (Tuamotu archipelago) this pattern was reversed (Bouchon, 1983). Deeper, the dominant massive species belonged mainly to the genus Porites in Moorea and Takapoto (Bouchon, 1983) but to the genus Montipora in Mururoa atoll (Chevalier et al., 1969) and Gambier islands (Chevalier, 1974). In Takapoto atoll, a deep community dominated by Leptoseris and Pachyseris was found below 30 m. Nothing similar was observed by the author in Tiahura reef or by Chevalier and Kühlmann (1983) on the other reefs of Moorea, although the surrounding waters of this island were less limpid than those of Tuamotu atolls.

Outbreaks of Acanthaster planci populations have been widely documented but the possible causes of such phenomena are still under discussion (Endean, 1977 ; Frankel, 1977 ; Cameron and Endean, 1982). The population explosion of starfishes which occured in Moorea is the first recorded for French Polynesia. An hypothesis is that outbreaks might have been induced by exceptionally heavy rains which happened during the years 1980 and 1981. Such a relation between terrestrial runoff and the outbreak of Acanthaster was suggested by Birkeland (1982) in Guam.

In Moorea, predation on corals by this starfish resulted in a general decrease in living coral cover, number of colonies and species richness. Attacks appeared to have been mainly directed against Acropora and Montipora species in areas where they predominated. Minimal damage was caused on the Porites species. Preferences of Acanthaster for the Acropora and Montipora species as well as their repulsion for Poritidae have already been reported (Weber and Woodhead, 1972 ; Goreau et al., 1972).

On the fringing reef and on the outer reef slope where the decrease in species richness was less drastic than on the reef flat, few changes in the equitability of the communities were noticed. This was due to the fact that the dominant species (Montipora and Acropora) were selectively destroyed and that the quantitative species composition thus became better balanced.

Porter (1972) suggested that Acanthaster planci predation might have an effect of regulation and balance on coral communities. However, the main Acropora species which disappeared (A. cytherea, A. hyacinthus, A. variabilis) are fast growing, pionner species and it is likely that they will first recolonize the devastated areas and restore the previous community structure as reported in Guam (Colgan, 1982). A long-term survey of Tiahura reef may elucidate the coral recovery strategy for this area.

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