Influence of the Degradation of Coral Assemblages on the Fish Communities of Martinique (French West Indies)

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ABSTRACT

In the West Indies, the fishery economy is mostly sustained by the coral reef fish communities. This traditional activity is mainly based on the use of fish traps. Few statistical data on the evolution of fish production in the West Indies are available, but most authors agree that a decrease in the production is now occurring.

One of the main causes of this decline may be the degradation of coral reefs due to man's activities. In Martinique, a correlation was found between the decrease of the fish stocks and the degradation of coral communities.

A moderate degree of alteration of the coral communities induced a decline of the fish density without noticeable changes in fish species richness. Severe degradation of the coral environment involved a drastic drop in fish density and the disappearance of numerous species.

RESUME

Dans les îles antillaises, l'économie des pêches est en grande partie fondée sur l'exploitation des poissons de l'écosystème récifal. Cette activité encore traditionnelle est surtout basée sur l'utilisation des nasses caraibes. Il existe très peu de données statistiques sur l'évolution de la production des pêches dans les Antilles mais la plupart des auteurs s'accordent pour reconnaître qu'il y a de nos jours une diminution de la production.

Une des causes principales de ce déclin peut provenir de la dégradation des récifs coralliens due aux activités humaines. En Martinique, il existe une corrélation entre la diminution des stocks de poissons et la dégradation des communautés coralliennes environnantes.

Un degré d'altération modéré des communautés coralliennes entraîne une diminution de la densité des poissons sans que le peuplement ne soit affecté de facon notable. Par contre, une dégradation plus sévère de l'environnement récifal s'accompagne d'une chute importante de la densité des poissons ainsi que de la disparition de nombreuses espèces.

INTRODUCTION

In the West Indies, the fishery economy is mainly sustained by the coral fish communities. This traditional activity is mainly based on the use of fish traps. Few statistical data on the evolution of fish production in the West Indies are available, but authors agreed that a decrease in the production is now occurring (Farrugio and St. Felix, 1975; Rogers, 1985). One of the main causes of this decline may be the degradation of coral reef environment due to man's activities.

In the framework of the CORANTILLES II project (study of the coastal marine communities of Martinique Island), investigations were made of the benthic communities and the fish assemblages on the different coral reef formations of Martinique Island.

The present paper reports on the scleractinian coral communities, their related fish assemblages and the respective signs of deterioration. Some links between these communities as well as the impact of the degradation of the coral communities on the fish assemblages are particularly emphasized.

THE STUDY AREAS

The coral reef formations of Martinique have already been described (Adey and Burke, 1976; Adey et al., 1977; Battistini, 1978; Laborel and Laborel-Deguen, 1979). During the CORANTILLES II project, the main marine biotopes existing on the coasts of Martinique were investigated. A detailed description of the study areas will be reported elsewhere (Bouchon and Laborel, in prep.) and only a brief description will be given here.

The coral reefs mainly developed on the eastern coasts of Martinique and the Caribbean coast is devoid of coral built formations. Intricate systems of coral reef patches, mangrove and seagrass beds occupy the bottom of the most important bays (Baie de Fort-de-France, Cul-de-Sac du Marin and Baie du Robert).

The eastern coast of Martinique (Atlantic side) is subjected to the direct action of the trade winds and to the surge induced by them. This windward coast supports a barrier reef of about 26 km long, from St. Marie in the north to Le Vauclin in the south. These reef formations were built by calcareous algae during the holocene and nowadays have been recolonized by scleractinian corals. In the sheltered waters between this barrier reef and the coast, seagrass beds of *Thalassia testudinum* have formed. Along the shore, more or less continuous fringing reef formations have developed. The northern and southern parts of the windward coast of Martinique are nearly devoid of coral reef formations.

The leeward coast of Martinique (Caribbean side) is sheltered from the trade winds and mainly consists of cliffs plunging steeply into the sea. Moreover, the Mt. Pelée volcano is an abundant source of sand and ash which prevents the development of reefs. Coral reefs are absent from that coast. Nevertheless, very rich coral communities occupy the drop-offs and other hard substrates all along the coast.

The southern coast of Martinique is under the moderate influence of trade winds. Between Le Diamant and St. Luce, this coast supports important coral reef formations, probably the richest on the island. These reefs extend about one kilometer offshore. Behind them, the shallow areas (1-5 m deep) are colonized by extensive seagrass beds (*Thalassia testudinum*) and the shore is fringed by mangroves.

In the recent past (20-30 years ago), the shoreline of the main bays of Martinique was occupied by important mangrove formations. The water in the bays was relatively clear and the bottom colonized by flourishing seagrass beds mixed with rich coral formations. For the last 20 years, land deforestation associated with the destruction of the coastal mangroves has induced a high rate of siltation inside the bays. Moreover, in the bay of Fort-de-France, sewage pollution acted synergistically with terrigeneous sedimentation. At the present time, the waters inside the bays are highly turbid and the bottom, hard and soft substrates, strongly silted. The original benthic communities (seagrass beds and coral patches) have disappeared or are decaying.

MATERIALS AND METHODS

During the CORANTILLES II field trip, 41 stations for fish communities and 67 for coral communities were studied around Martinique Island by SCUBA diving from the surface to 30 m. For the present study 14 stations, where quantitative data on fishes and semi-quantitative data on corals were both available, have been utilized. Their location around the island is shown in Figure 1. Some stations were located inside the Bay of Fort-de-France (Stations 1 to 6) others on the west coast (Stations 7 to 9) and the south coast (Stations 10 to 14). Data concerning corals and those concerning fishes at the 14 stations are given in Tables 1 and 2 respectively.

The scleractinian coral communities were investigated using a semi-quantitative technique. An index ranging from 1 to 5 was assigned to each species according to its abundance *in situ*. The sum of the abundance scores for each species present at a station was used to estimate the abundance of corals.

The fish communities were quantitatively studied at 14 stations using a transect technique (Bouchon-Navaro and Harmelin-Vivien, 1981; Bouchon-Navaro, 1983a, b). The fishes were counted by two observers along a transect 50 m long indicated by a rope unrolled by one diver. Each observer counted the fishes in a band 2 m wide. Thus, a total surface of 200 m^2 was studied at each station. Each fish encountered was grouped in one of the following numerical categories: Group 1, solitary individuals; Group 2, two to four individuals; Group 3, from five to nine individuals; Group 4, ten to twentynine individuals; Group 5, from thirty to fortynine; Group 6 from fifty to seventy. To calculate the number of individuals at each station, the average number of each group was used to provide the mean density of fishes per 200 m^2.

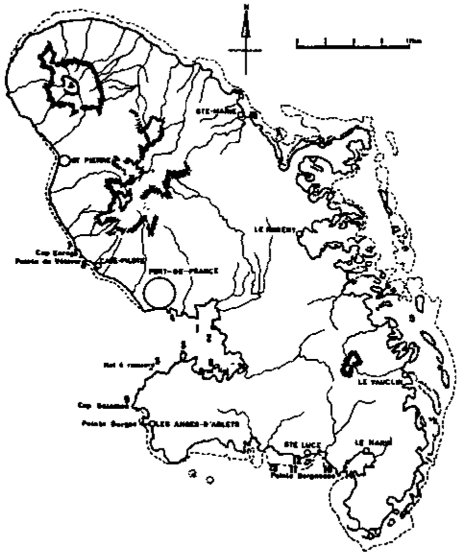

Figure 1. Martinique island: location of the sampling stations.

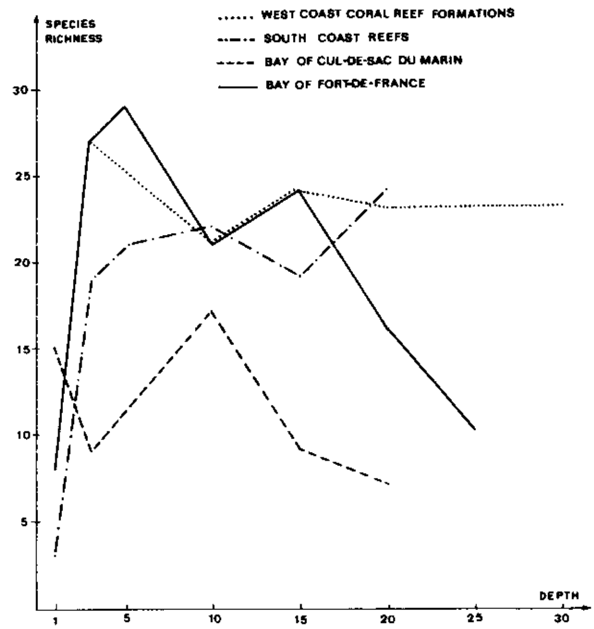

Figure 2. Distribution of coral species richness according to depth on the south coast, the west coast and the bays of Fort-de-France and Marin.

Table 1 : Semi quantitative distribution of the Scleractinian corals at 14 sampling stations on the coast of Martinique island.

STATIONS	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Stephanocoenia michelini	1	1	1	1	0	1	1	2	0	0	1	0	2	0
Madracis decactis	3	1	3	0	1	1	1	3	3	0	1	1	1	4
Madracis mirabilis	3	1	1	5	1	0	0	4	1	[illegible]	5	0	1	1
Acropora cervicornis	0	0	0	5	0	0	0	0	0	0	0	0	0	0
Acropora palmata	0	0	0	0	0	0	0	0	0	0	0	5	0	0
Agaricia agaricites	1	1	1	3	1	0	3	3	0	2	3	2	3	0
Agaricia lamarcki	0	0	0	0	0	0	0	0	1	0	0	0	0	5
Helioseris cucullata	1	1	1	1	0	1	1	0	2	1	1	0	1	1
Siderastrea radians	1	0	0	0	0	0	0	0	0	0	0	0	0	0
Siderastrea siderea	1	1	5	2	1	1	3	0	2	1	2	0	4	4
Porites astroides	1	1	1	1	1	1	3	1	0	3	3	3	4	3
Porites divaricata	1	1	0	1	0	0	0	1	0	0	0	0	1	0
Porites furcata	1	1	1	0	0	0	0	4	0	0	1	0	0	0
Porites porites	1	0	0	3	1	0	4	0	2	3	4	1	3	0
Favia fragum	0	0	0	1	0	0	0	0	0	0	0	1	0	0
Diploria clivosa	0	0	0	1	0	0	0	0	0	0	0	0	0	0
Diploria labyrinthiformis	1	1	0	1	1	0	0	0	1	1	1	0	2	0
Diploria strigosa	1	0	0	1	1	0	0	1	0	1	0	1	3	1
Colpophyllia amaranthus	1	1	1	1	0	1	2	1	2	2	1	1	2	2
Manicina areolata	0	0	0	0	1	0	0	0	0	0	0	0	0	0
Solenastrea bournoni	0	1	1	0	0	0	0	0	0	0	1	0	0	3
Montastrea annularis	1	0	1	5	0	0	1	0	1	0	4	4	3	1
Montastrea cavernosa	1	1	1	1	0	0	2	1	3	5	1	1	4	2
Phyllangia americana	0	0	0	0	0	0	0	0	1	0	0	0	0	0
Oculina diffusa	0	1	0	0	0	0	0	0	0	0	0	0	0	0
Meandrina meandrites	1	1	1	1	1	0	5	4	4	1	2	0	4	2
Dichocoenia stokesi	0	1	0	1	1	0	1	1	1	0	0	0	2	0
Dendrogyra cylindrus	0	0	0	0	0	0	0	0	0	1	0	0	1	0
Mussa angulosa	0	0	1	0	0	1	0	0	0	0	0	0	0	0
Scolymia cubensis	0	0	0	0	0	0	0	0	0	0	0	0	0	3
Scolymia lacera	0	0	0	0	0	0	0	0	0	0	1	0	0	0
Scolymia wellsi	0	0	0	1	0	0	0	0	0	0	0	0	0	0
Isophyllastrea rigida	0	0	0	0	0	0	0	0	1	1	0	0	0	0
Isophyllia multiflora	0	0	0	0	0	0	0	1	0	0	0	0	0	0
Isophyllia sinuosa	0	0	0	0	0	0	0	0	0	1	0	0	0	0
Mycetophyllia aliciae	1	1	1	1	0	0	0	0	1	1	0	0	1	0
Mycetophyllia danaana	0	0	0	1	0	0	0	0	0	0	0	0	0	0
Mycetophyllia ferox	0	0	0	0	0	0	0	0	0	2	0	0	0	0
Mycetophyllia lamarckiana	0	0	0	1	0	0	0	0	0	0	0	0	0	0
Eusmilya fastigiata	1	1	1	1	0	0	1	2	3	0	1	0	1	0
Millepora alcicornis	1	0	0	1	1	0	2	1	1	2	2	1	2	0
Millepora squarrosa	0	0	0	0	0	0	2	0	0	1	1	3	2	0
Stylaster roseus	0	0	0	0	0	0	0	0	1	0	0	0	0	0

Table 2 : Quantitative distribution of fishes at 14 sampling stations on the coast of Martinique island.

STATIONS	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Synodus intermedius	0	0	0	0	0	0	1	0	0	0	0	0	0	0
Synodus sp.	0	0	1	1	0	0	0	0	0	1	1	0	0	1
Myrichthys acuminatus	0	0	0	0	0	0	0	0	0	0	0	0	0	1
Gymnothorax moringa	0	0	0	0	1	0	0	0	0	0	0	0	0	0
Aulostomus maculatus	0	0	0	0	0	0	2	1	4	1	0	1	2	3
Flammeo marianus	1	0	0	0	0	0	0	0	1	0	0	0	1	0
Holocentrus ascensionis	0	0	0	0	0	0	0	0	0	0	1	0	1	0
Holocentrus rufus	1	0	5	3	0	1	0	2	1	9	3	0	0	0
Myripristis jacobus	0	0	0	1	0	0	5	0	0	9	0	1	0	16
Epinephelus cruentatus	0	0	0	0	0	0	0	0	0	0	1	0	0	1
Cephalopholis fulva	1	5	1	3	0	0	2	0	4	0	1	0	1	0
Epinephelus guttatus	1	1	2	0	0	1	0	0	0	0	1	0	0	1
Hypoplectrus chlorurus	0	0	0	0	0	0	0	0	0	0	0	0	0	2
Hypoplectrus guttavarius	0	0	1	0	0	0	0	0	0	0	0	0	0	0
Hypoplectrus nigricans	0	0	2	2	0	0	0	0	0	0	0	0	0	0
Hypoplectrus puella	6	0	3	3	0	5	2	0	0	7	6	0	4	5
Hypoplectrus cf. aberrans	0	0	0	0	0	0	0	0	0	0	0	0	0	1
Hypoplectrus sp.	0	0	1	0	0	0	0	0	0	0	0	0	0	0
Liopropoma rubre	0	0	0	0	0	0	0	0	0	0	1	0	0	0
Mycteroperca interstitialis	0	0	0	0	0	0	1	0	0	0	0	0	0	0
Paranthias furcifer	0	0	0	0	0	0	3	0	9	0	41	0	0	6
Serranus tabacarius	12	8	5	1	49	1	7	12	0	0	1	0	1	2
Serranus tigrinus	4	2	8	9	2	1	5	2	2	0	1	1	1	0
Priacanthus cruentatus	0	0	0	1	0	0	1	0	0	0	0	0	0	0
Amblycirrhitus pinos	0	0	0	0	0	0	0	1	2	0	1	0	0	0
Cirrhitus sp.	0	0	0	0	0	1	0	0	0	0	0	0	0	0
Caranx latus	0	0	0	0	0	0	0	0	0	1	0	0	0	0
Lutjanus mahogoni	0	0	0	0	0	0	1	0	1	0	0	0	4	0
Ocyurus chrysurus	0	0	0	0	0	4	0	0	1	1	0	0	0	2
Haemulon aurolineatum	0	0	4	0	0	0	20	0	0	0	0	0	0	0
Haemulon chrysargyreum	0	0	0	0	0	0	0	0	32	0	0	7	0	0
Haemulon flavolineatum	0	0	4	0	20	0	0	0	0	0	0	20	2	0
Haemulon sciurus	0	0	1	0	0	0	0	0	1	0	0	0	0	0
Equetus lanceolatus	0	0	0	0	0	0	0	1	0	0	0	0	0	0
Equetus punctatus	0	0	0	0	0	0	1	0	0	0	0	0	0	0
Odontoscion dentex	0	0	0	0	0	0	0	0	0	0	0	0	0	1
Mulloidichthys martinicus	0	0	1	2	0	0	0	0	1	1	0	7	0	1
Pseudupeneus maculatus	1	2	0	0	0	0	6	0	0	0	0	0	0	1
Pempheris schomburgki	0	0	0	0	0	0	0	0	0	0	0	3	0	0
Centropyge argi	1	0	1	0	0	0	0	0	1	0	0	0	2	0
Chaetodon capistratus	3	4	3	9	0	0	0	0	0	1	0	0	1	1
Chaetodon sedentarius	0	0	0	0	0	0	0	0	1	0	0	0	0	0
Chaetodon striatus	0	0	0	0	0	0	0	0	0	0	1	0	0	0
Holacanthus ciliaris	0	0	0	0	0	0	1	1	0	0	0	0	0	0
Holacanthus tricolor	0	0	0	0	0	0	0	0	1	0	0	0	0	0
Pomacanthus paru	0	0	0	0	0	0	0	1	0	0	0	0	0	0
Prognathodes aculeatus	0	0	0	0	0	0	0	0	2	0	0	0	0	0
Chromis cyanea	35	2	9	67	0	0	26	0	23	210	142	0	27	167
Chromis multilineatus	20	25	123	120	21	0	50	0	74	0	124	0	107	230
Eupomacentrus planifrons	2	0	11	78	0	8	0	0	0	77	13	54	12	47
Microspathodon chrysurus	0	0	0	0	0	0	0	0	0	2	1	15	0	0
Stegastes leucostictus	0	0	2	2	1	0	0	0	0	0	2	0	0	0
Stegastes partitus	87	19	60	13	33	0	239	104	126	44	107	4	43	55
Stegastes variabilis	0	0	0	0	0	4	0	0	0	0	0	0	0	1
Stegastes sp. 1	0	0	3	1	0	3	0	0	1	0	1	0	0	0
Stegastes sp. 2	0	0	0	0	0	0	0	0	0	0	0	3	0	4
Bodianus rufus	0	0	0	0	0	0	1	0	0	0	0	0	0	0
Clepticus parrai	0	0	20	0	0	0	0	0	0	0	2	0	0	31
Halichoeres bivittatus	0	0	1	1	10	8	0	2	0	0	0	0	0	0
Halichoeres garnoti	8	0	3	0	3	0	37	6	11	1	22	4	31	0
Halichoeres maculipinna	0	0	0	0	0	0	2	0	1	1	0	4	0	0
Halichoeres sp.	0	1	0	2	0	0	0	0	0	0	0	0	0	0
Thalassoma bifasciatum	15	1	9	10	24	0	6	11	13	31	15	19	8	4
Scarus croicensis	2	0	28	15	0	7	0	0	0	1	6	0	0	4
Scarus sp. 1	10	1	32	11	0	4	0	0	0	28	6	39	7	12
Sparisoma aurofrenatum	1	1	8	3	0	1	1	0	0	4	2	0	1	5
Sparisoma radians	0	0	0	0	0	0	7	0	0	0	0	0	0	0
Sparisoma viride	1	0	2	1	0	1	0	0	1	11	1	4	1	2
Sparisoma sp.	0	0	0	0	0	0	0	30	0	0	0	0	0	0
Ophioblennius atlanticus	0	0	0	0	0	0	0	0	0	0	0	5	0	0
Coryphopterus sp.	10	0	0	60	0	5	0	0	0	24	50	0	0	55
Gobidae sp.	0	0	0	0	0	1	0	0	0	0	0	0	0	0
Gobiosoma sp.	0	0	0	0	0	0	0	0	0	0	5	0	0	0
Eleotridae sp.	0	0	0	0	1	0	0	0	0	0	0	0	0	0
Acanthurus chirurgus	0	1	0	6	0	0	0	0	0	0	0	0	0	1
Acanthurus coeruleus	0	0	0	0	0	0	0	0	0	0	0	1	0	0
Balistes vetula	0	0	0	0	0	0	1	0	0	0	0	0	0	0
Cantherhines pullus	0	0	0	0	0	0	0	0	0	1	0	0	0	0
Lactophrys triqueter	0	0	0	0	0	0	0	0	0	0	0	0	0	1
Sphaeroides spengleri	0	0	1	1	1	0	2	0	0	0	1	0	0	0
Canthigaster rostrata	1	2	1	1	0	0	3	1	1	5	1	1	1	5

During the dives, the turbidity was estimated according to the visibility underwater and coded from 1 to 5 (1 = visibility exceeding 20 m; 2 = visibility comprised between 10 and 20 m; 3 = visibility comprised between 5 and 10 m; 4 = between 2 and 5 m; 5 = visibility less than 2 m).

Data concerning fish species richness and density, coral species richness and abundance and turbidity were treated with a correspondence analysis (Hill, 1974; Benzecri et al., 1982). For this purpose, data concerning species richness and abundance were ranked coded and presented in a two-way table. Data concerning turbidity and depth were used under a complete disjunctive form (see Fénélon, 1981)and as supplementary elements. In correlation with the correspondence analysis, the stations were classified with a cluster analysis (hierarchical ascending classification, Euclidean distance, and 2 order central moment fusion strategy) (see Fénélon, 1981).

In order to show the relationship existing between coral species richness, coral abundance, fish species richness, fish abundance, turbidity and depth, Spearman rank correlation coefficients were computed between these parameters.

RESULTS

The complete data on the coral assemblages and the fish communities obtained during the CORANTILLES II field trip respectively form the subject of other papers (Bouchon and Laborel, in prep.; Bouchon-Navaro and Louis, in prep.) and are only briefly described here for completeness.

(1) The Coral Communities

Around Martinique Island, 48 species of corals were found between the surface and 40 m (44 scleractinian and 4 hydrocorallian corals). Data obtained from 67 stations sampled by SCUBA diving revealed that coral distribution is mainly controlled by depth on Martinique coasts (Bouchon and Laborel, in prep).

A group of species, more or less ubiquitous, appeared in 70% of the censuses and constituted the core of the coral assemblages (*Siderastrea radians*, *Porites astroides*, *Colpophyllia natans* and *Meandrina meandrites*).

Between the surface and 10 to 15 m, the first coral community was observed and was dominated by a few species (*Stephanocenia michelini*, *Agaricia agaricites*, *Porites astroides*, *P. porites*, *Diploria labyrinthiformis*, *D. strigosa*, *Colpohyllia natans*, *Montastrea annularis*, *Dichocoenia stokesi*) and the hydrocorallian corals *Millepora alcicornis* and *M. squarrosa*. In the upper level (0-3 m), this community was characterized by the occurrence of shallow water species, such as *Acropora palmata*, *Siderastrea radians*, *Favia fragum* and *Diploria clivosa*. The settlement and the life history of this upper coral community is essentially under the control of waves and more especially hurricane swells. For example, the upper part of the south coast reefs (St. Luce area) was completely destroyed by hurricanes in

1979 and 1980. Nowadays, the Acropora palmata zone still shows no signs of recovery.

From 15 to 40 m, a deeper community dominated by the following species can be found: Madracis decactis, M. miriabilis, Agaricia lamarcki, Helioseris cucullata, Siderastrea siderea, Montastrea cavernosa, Meandrina meandrites, Mycetophyllia aliciae and Eusmilya fastigiata.

Lastly, a small group of species is adapted to the environment of Thalassia testudinum seagrass beds, namely, Porites divaricata, P. furcata, Manicina areolata, Solenastrea bournoni, Oculina diffusa and Millepora alcicornis.

The pattern of coral distribution reported for Martinique is typical of Caribbean areas.

Environmental conditions have deteriorated significantly in the last twenty years in the bays of Fort-de-France and Cul-de-Sac du Marin and their coral communities are now exposed to very turbid waters and high rates of siltation. The response of coral communities to these changes is first a decline in the abundance of colonies in moderately polluted areas without noticeable effects on the species richness and then a drastic decrease in the density of the colonies as well as in species richness under more severe conditions.

The effect of turbidity and siltation on the coral communities increases with depth (decrease in illumination and in water movement able to remove the mud from the coral colonies). This phenomenon is demonstrated in Figure 2 where the average species richness in four different areas of Martinique is plotted according to depth. On the west coast of the island as well as on the reefs of the south coast, the coral species richness is high down to 30 m. In the Bay of Fort-de-France and the Bay of Marin (even more turbid), the species richness of the communities dropped below 15 m and 10 m respectively. The last species able to survive under these environmental conditions are: Stephanocoenia michelini, Madracis decactis, Siderastrea siderea and several species belonging to the genus Scolymia.

The 14 sampling stations chosen for the present study represent the different stages of the coral communities encountered in Martinique (Table 3). Some of them, located in clear waters, possess very flourishing coral assemblages with high species richness and abundance indices (Stations 7, 9, 10, 11, 13). Station 8 was situated in a sandy area with scattered coral patches. Station 12 was situated in an area destroyed by Hurricanes David and Frederic. Others located in the Bay of Fort-de-France and Bay of Marin, in zones of moderate sedimentation, still supported rich coral communities (Stations 1, 3, 4, 5 and 14). The last stations (2, 7, 5) were situated in the most altered areas of the Bay of Fort-de-France subjected to heavy siltation and high turbidity. The coral assemblages in these zones were particularly poor and damaged.

(2) The Fish Communities

A total of 143 fish species was identified in the coral formations of Martinique during the CORANTILLES II field trip

(Bouchon-Navaro and Louis, in prep). The most numerous species belonged to the following families: Serranidae (20 species), Pomacentridae and Labridae (10 species), Pomadasyidae and Chaetodontidae (8 species). The richest fish fauna was observed between 15 and 30 m on the leeward drop-offs situated in the north (Cap Enragé, Caye du Vétiver) or the south of the Fort-de-France Bay (Cap Salomon).

Table 3. Quantitative data concerning coral and fish communities as well as indices of turbididty at 14 sampling stations on the coast of Martinique. (CSR - coral species richness; FSR = fish species richness; CAB = coral abundance; FAB = fish abundance per 100 m^2; TURB - turbidity)

STATION	LOCATION	DEPTH	CSR	FSR	CAB	FAB	TURB
1	Banc Mitan	15 m	20	22	24	217	3
2	Banc Fort-St-Louis	15 m	18	15	18	72	4
3	Banc Boucher	15 m	16	32	22	349	3
4	Grande Sêche	6 m	24	28	41	419	3
5	Blanc Ilet Ramier	10 m	12	12	12	162	3
6	Gros Ilet	10 m	7	17	7	50	5
7	Cap Enragé	10 m	15	27	32	427	1
8	Pointe du Vétiver	17 m	15	14	30	171	1
9	Cap Salomon	20 m	18	25	31	305	1
10	Pointe Borgnèse	5 m	14	23	29	471	2
11	Sainte Luce	15 m	19	31	36	551	2
12	Sainte Luce	3 m	12	19	24	193	1
13	Trois Rivières	10 m	21	20	49	254	1
14	Banc Crique	20 m	13	32	32	661	3

An analysis of all the qualitative surveys carried out in Martinique showed that two different fish assemblages exist on the reef formations of Martinique (Bouchon-Navaro and Louis, in prep.).

The first fish community was found between 1 and 3 m on the reef flats, the Acropora palmata zones and shallow rocky areas. A similar fish community was observed in the seagrass beds. The number of species recorded in this community was generally low. Moreover, on the reef flats and the seagrass beds, a higher percentage of restricted species was found. The most frequent species of the community belonged to the Pomacentridae (Abudefduf saxatilis), the Labridae (Halichoeres maculipinna) and the Scaridae (Scarus sp.). Schools of acanthurids (Acanthurus bahianus, A. chirurgus) were also frequently seen in shallow waters. Two pomacentrid species (Microspathodon chrysurus and Stegastes planifrons) and one blennid (Ophioblennius atlanticus) were also commonly observed in the Acropora palmata zones. In the seagrass beds, the number of species recorded was also very low and only small individuals were observed. The most common species found in the seagrass beds were the labrids (Halichoeres bivittatus and H. poeyi) and scarids(Sparisoma chrysopterum, S. radians, S. viride). Groups of juvenile acanthurids and schools of young pomadaysids (Haemulon flavolineatum) were frequently seen in the seagrass beds.

The second fish community was found on all the reef formations situated between 5 and 30 m. Species richness generally reached a peak between 15 and 20 m. The most frequent species of this community belonged to the Serranidae (Cephalopholis fulva, Hypoplectrus puella, H. chlorurus, Serranus tabacarius and Paranthias furcifer). Numerous labrid fishes were also recorded either as isolated individuals (Halichoeres garnoti, Bodianus rufus) or in schools (Clepticus parrai). Important schools of Chromis cyanea were also common everywhere between 5 and 30 m. This community is also characterized by the presence of members of the Scaridae (Scarus croicensis, Sparisoma aurofrenatus), Chaetodontidae (Prognathodes aculeatus) and Pomacanthidae (Holacanthus tricolor). In some areas, schools of Haemulon flavolineatum (Pomadasyidae) and groups of Myripristis jacobus (Holocentridae) were observed.

The fish fauna of Martinique is also composed of numerous ubiquitous species which were found from 3 m to 30 m deep in all biotopes: Aulostomus maculatus (Aulostomidae), Flammeo marianus (Holocentridae), Serranus tigrinus (Serranidae), Mulloidichthys martinicus (Mullidae), Thalassoma bifasciatum (Labridae), Canthigaster rostrata (Canthigasteridae). Some pomacentrids were common in any biotope (Chromis multilineatus and Pomacentrus partitus). Moreover, the fish fauna observed around the reef formations of Martinique was dominated by species of small size and very few schools of large individuals (Lutjanidae and Pomadasyidae) were encountered in the areas investigated.

At the above mentioned 14 stations a total of 81 species was censused. The distribution of their abundance is given in Table 2. The species richness and the fish densities recorded varied considerably according to the geographical zone. The fish densities ranged from 50 individuals per 100 m^2 (Station 6) to 661 individuals per 100 m^2 in the richest area (Station 14) (Table 3). In the sandy areas (Stations 5, 8) or in shallow zones damaged by hurricanes (Station 12), the fish density recorded was also relatively low. Species richness and fish density were lowest in the most silted areas of the bay of Fort-de-France (Stations 2 and 6) (Table 3). In other areas of the bay where the water was less turbid and where only the first signs of deterioration of coral assemblages appeared, fish species richness was not too much affected (for example, at Stations 3 and 4).

(3) Fish and Coral Correlations

A correspondence analysis was made on the data concerning coral and fish species richness, coral and fish abundance, turbidity and depth for 14 stations (Table 3).

The two first factorial axes concentrated respectively 67% and

23% of the inertia of the data, i.e., the weighted spread or dispersion of the data. The projection of the elements of the matrix on the plane of the two principal axes is given in Figure 3. Only the elements which had a good correlation (high squared cosine) with this axis are represented in Figure 3. The elements presenting the strongest contributions with the principal axis are in order: fish abundance, fish species richness and coral abundance. The most important contribution to the second axis is given by coral species richness and coral abundance. Most of the sampling stations present a high contribution to the inertia of the first axis and are well correlated with it.

A cluster analysis of the data separated the stations into two groups:

- the first one consisted of the stations which were poor in corals as well as in fishes. These stations are located either in the muddy parts of the Bay of Fort-de-France or in sandy areas (Pointe du Vétiver) and also in the upper part of the reef of Sainte Luce, the coral community of which was destroyed by hurricanes.

- the second one consisted of stations, rich in corals and fishes, situated in zones of good, or only moderately disturbed environmental conditions.

These two groups are well separated by the principal factor. Still on this axis, high turbidity levels are close to the poor stations and low turbidity indices to the rich stations. On the contrary, depth is very poorly correlated to the two principal axis and does not play an important role in this analysis.

In order to define the relationships existing between coral species richness and abundance, fish species richness and density, turbidity and depth, the Spearman rank correlation coefficient was computed between these elements. The results are given in Table 4.

A strong, significant correlation was found between, on the one hand, coral species richness and coral abundance and on the other hand, fish species richness and fish abundance. This indicates that, for the coral communities as well as for the fish communities, high abundance of organisms appeared in areas of high species richness at the studied stations.

There was no correlation between coral species richness and fish species richness. On the contrary, significant correlations were found between the abundance of corals and the fish species richness (90% confidence level) as well as the fish abundance (98% confidence level).

Moreover, a significant inverse correlation (95% confidence level) was found between turbidity and coral abundance. No significant correlation was found between turbidity and fish species richness or abundance.

Depth was only linked significantly with fish species richness, supporting the fact that during this study, the richest fish communities were observed between 15 m and 30 m.

These results, thus, strongly emphasized the existence of some

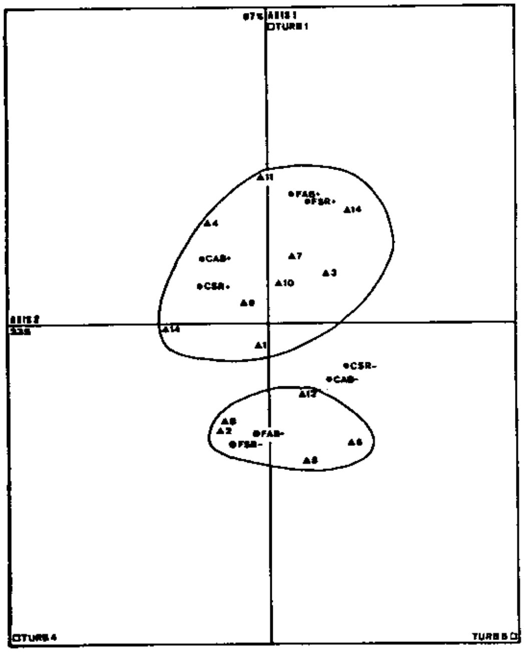

Figure 3. Correspondence analysis of the data from table 3. Projection on the two first factorial axes (CSR = coral species richness; CAB = coral abundance; FSR = fish species richness; FAB = fish abundance; TURB = turbidity).

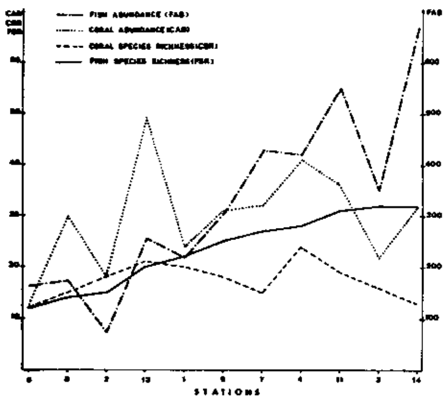

Figure 4. Variations of coral species richness, fish species richness, coral abundance indices and fish densities at the different stations. Stations are ranked according to increasing fish species richness.

Table 4 : SPEARMAN rank correlation coefficients (Rs) between coral species richness (CSR), coral abundance indices (CAB), fish species richness (FSR), fish abundance (FAB), turbidity (TURB) and depth (n.s. = non significant correlations).

	C S R	C A B	F S R	F A B	TURB	DEPTH
C S R						
C A B	Rs = 0.608 95 %					
F S R	Rs = 0.269 n.s.	Rs = 0.526 90 %				
F A B	Rs = 0.265 n.s.	Rs = 0.689 98 %	Rs = 0.639 98 %			
TURB	Rs = -0.058 n.s.	Rs = -0.594 95 %	Rs = -0.416 n.s.	Rs = -0.345 n.s.		
DEPTH	Rs = 0.245 n.s.	Rs = 0.110 n.s.	Rs = 0.464 90 %	Rs = 0.096 n.s.	Rs = -0.042 n.s.	

important links between the wealth of coral communities and that of the surrounding fish communities. Areas naturally poor in corals (sandy areas), accidentally impoverished (reef destroyed by hurricanes) or polluted (Bay of Fort-de-France), supported the poorest fish communities observed. Moreover, these results underline the negative influence of strong turbidity and high rates of siltation on coral communities.

In Figure 4, coral species richness and abundance and fish species richness and abundance are plotted for each station, ranked according to increasing fish species richness. Coral abundance, fish species richness and fish abundance each increased overall, but for the turbid stations of the Bay of Fort-de-France, decreases appeared in the curves for coral and fish abundance without alteration of fish species richness. This indicates that fish species richness is less affected than the abundance of fishes by a degradation of the neighboring coral communities.

DISCUSSION AND CONCLUSIONS

A large number of studies have dealt with the effects of environmental stress on coral communities. Alterations can be due to natural factors such as hurricanes (Randall and Eldredge, 1977; Woodley et al., 1981; Rogers et al., 1982), or human activities in terms of organic and chemical pollution (Smith et al., 1973; Johannes, 1975; Marszalek, 1982a) and sedimentation (Loya, 1976; Bak, 1978; Rogers, 1979, 1983; Chansang et al., 1982; Marszalek, 1982b). Sedimentation, as it has been emphasized in the present study, is detrimental to the wealth of coral communities. Although the corals may survive in turbid waters, their growth rate is reduced and in deeper waters they finally die. In the Bay of Fort-de-France, coral species richness dropped abruptly at about 10 to 15 m depth, showing the noxious effects of sedimentation and turbidity on corals with the progressive siltation of the bay.

The present study showed that an impoverished coral reef community, either due to natural conditions (sandy areas), natural degradation (effects of hurricanes) or anthropogenic action (siltation, sewage pollution) usually supported a poor fish community. Carpenter et al. (1982) have stressed the necessity "to clarify the relationships of fish diversity and abundance to habitat characteristics for fisheries management purposes." In the present report, a strong correlation was found between the abundance of corals and fish species richness and abundance. These results emphasize the close relationships existing between the two communities as has already been pointed out by other authors (Carpenter et al., 1982; Bell and Galzin, 1984; Bouchon-Navaro, 1985; Bouchon-Navaro et al., 1985).

The progressive degradation of coral reefs in the Caribbean islands represent a threat to the associated fisheries resulting from fish habitat destruction. Recent studies have shown that fishes are sensitive to habitat degradation such as massive coral mortality caused by hurricanes or storms (Woodley et al., 1981; Kaufman, 1983; Lassig, 1983; Walsh, 1983; Williams, 1984) or by <u>Acanthaster planci</u> predation (Sano et al., 1984; Bouchon-Navaro et al., 1985). Only a few studies have reported on the noxious effects of man induced siltation on the fish communities (Brock et al., 1966; Galzin, 1979; Amesbury, 1982). These authors noted a strong decline in fish species richness in polluted zones and also a total disappearance of the ichthyofauna in the most affected areas. By examining the effect of turbidity and siltation on the shallow-water reef fish assemblages in Truk Lagoon, Amesbury (1982) found that they suffered major impacts mainly in areas where the coral substrates were buried under significant amounts of sediment. He suggested that reef fish assemblages should not be used as indicators of early stages of degradation of reefs caused by turbidity and siltation. Observations made during the present study supports his conclusions. A very poor fish community (low species richness and abundance) was observed only in the most silted parts of the Bay of Fort-de-France. Quantitative censuses carried out at some stations situated in the relatively turbid waters of the Bay, and where only the first signs of deteriorations of coral communities were evident, revealed a fish fauna still relatively rich.

It seems, therefore, that the progressive siltation of the Bay of Fort-de-France is first affecting the density of the living organisms (fishes and corals) before having an impact on the species richness of these communities. These results show the usefulness of quantitative and long-term observations for monitoring the coral reef ecosystem. Moreover, they show the importance of protecting the coral reef communities to preserve the fishing potential of Caribbean islands.

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