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# CHANGES IN THE COASTAL FISH COMMUNITIES FOLLOWING HURRICANE HUGO IN GUADELOPE ISLAND (FRENCH WEST INDIES)

BY

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# CHANGES IN THE COASTAL FISH COMMUNITIES FOLLOWING HURRICANE HUGO IN GUADELOUPE ISLAND (FRENCH WEST INDIES)

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## ABSTRACT

Hurricane Hugo swept the island of Guadeloupe (French West Indies) on 16 and 17 September 1989. Sustained winds were of 140 knots and gusts exceeded 160 knots. This hurricane was one of the most devastating of the century for the Lesser Antilles.

The mangroves were completely defoliated and anoxic conditions of the water induced considerable fish mortality. Consequently, the fish community was modified in terms of species composition, structure and biomass. Four months later, the fish assemblages of the mangroves returned to conditions previous to the hurricane in species composition and community structure.

The impact on the marine phanerogams was more destructive on the *Syringodium filiforme* seagrass beds than on those of *Thalassia testudinum*. In this ecosystem, the effect of the hurricane was minor on the fish community. Changes in the fish community occurred four months later in the seagrass beds and were apparently induced by a delayed mortality of the *Thalassia testudinum*.

In the coral reef environment, the impact of the hurricane surge on the coral community mainly affected the branched coral species located between the surface and 15 m deep. The fish assemblages were not modified concerning their species composition. However, the proportion of juveniles in the community drastically dropped after the hurricane. Four months later, the proportion of juvenile fishes was still reduced.

The overall effects of hurricane Hugo on the coastal fish communities of the island of Guadeloupe were minor considering the magnitude of the hurricane.

## I. INTRODUCTION

In the Lesser Antilles, hurricanes are considered one of the major factors controlling the coastal marine ecosystems. In the island of Guadeloupe, these are represented by mangrove, seagrass beds and coral reefs.

Hurricane Hugo reached Guadeloupe in the night of 16 September 1989, travelled the length of the island until the following morning, with the 37 Km-diameter eye passing over

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the Grande Terre (Fig. 1). The atmospheric pressure dropped to 941,5 millibars and the wind was recorded at 140 knots with squalls exceeding 160 knots. In some areas, rainfall reached 300 mm in one day. Such a rainfall rate has a probability of occurence lower than 1 per 50 years (Anon., 1990).

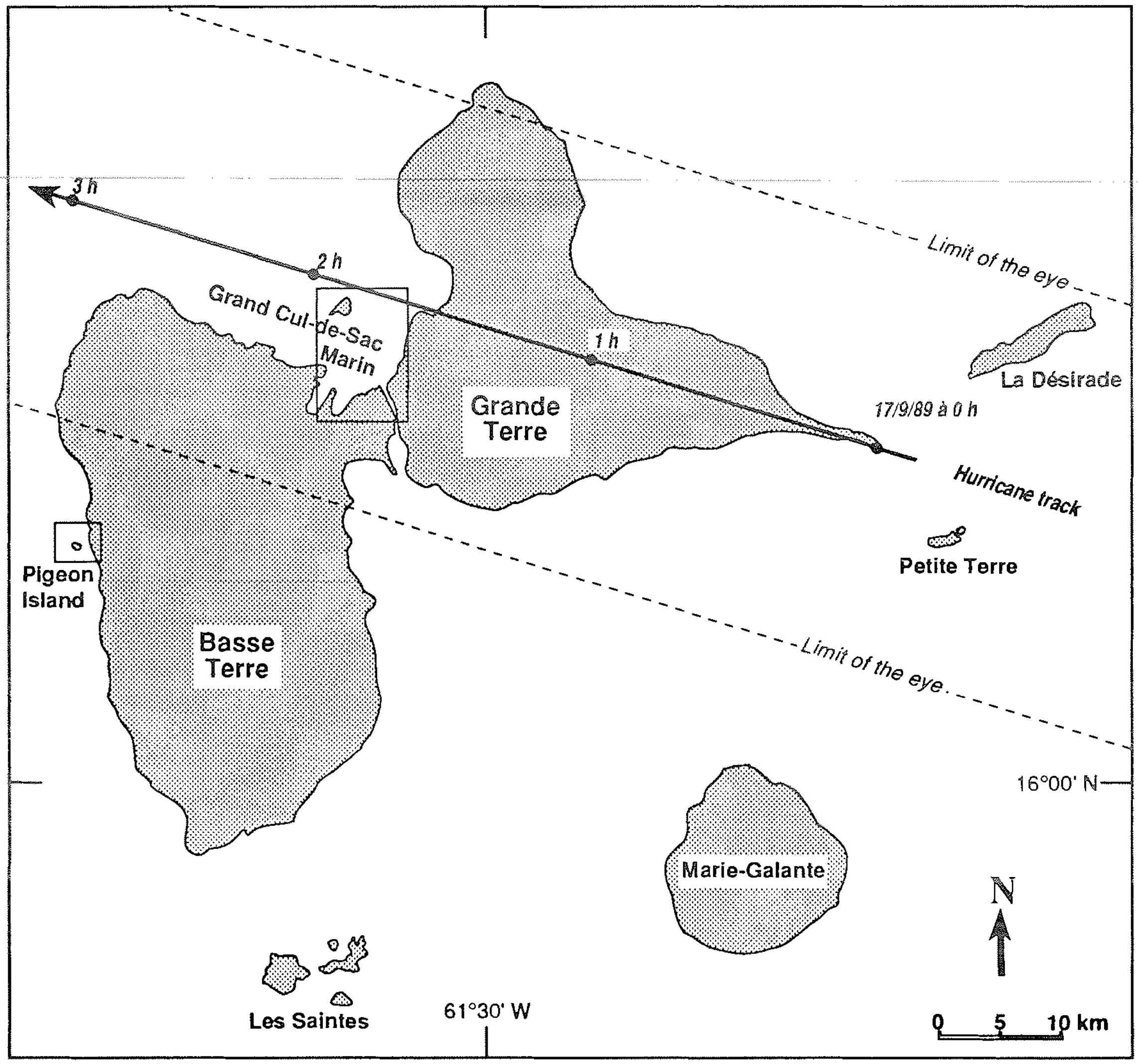


Figure 1 : Guadeloupe Island. Track of the hurricane. Location of the study areas.

Only few observations were available concerning the effects of the hurricane on the sea conditions.The theoretical calculation of the storm tide predicted a 3 m rise of the mean sea level (Anon., 1990). Our examination of the high-water marks after the storm indicated that the tide did not exceed 1,5 m. Offshore, the predicted amplitude of the swell was 5 m (Anon., 1990). On the shore, the structure of the waves is normally variable and depends on the morphology of the sea bottom and the incidence of surge along the coast. Unfortunately, no observations were made during the hurricane. However, the amplitude of the waves observed for similar hurricanes in the Caribbean area varied between 10 and 12 m (Stoddart, 1974 ; Woodley *et al.*, 1981 ; Kjerfve et Dinnel, 1983).

The general impact of Hurricane Hugo on the different coastal communities of the island of Guadeloupe was previously reported by Bouchon *et al.* (1991). The present work summarizes the observations made on the changes in the fish communities during the months preceding and following the hurricane.

## II. STUDY AREAS AND METHODS

Observations were made in the Grand Cul-de-Sac Marin bay, for the fish in the mangrove and the seagrass beds. The coral reef fish community was studied near Pigeon Island, on the west coast of Guadeloupe (Fig. 1). These areas were chosen because previous data were available for them and provided a basis for comparison.

After the hurricane, the first observations were made on 24 September, 1989 at Pigeon Island and on 25 September in Grand Cul-de-Sac Marin.

The fish communities were studied with different sampling techniques because of the varied habitat. In the mangrove, where the water was turbid, fishes were sampled with a special fishing net called "capéchade". This device consisted of a fence net (45 m long and 2 m high), placed perpendicular to the mangrove front and three hoop-nets that trap the fishes. From the mouth to the extremity of the hoop-nets, the mesh-size decreased from 13.8 mm to 6 mm (Fig. 2). The sampling station was located in the "Manche à Eau", a mangrove lagoon (Fig. 3) and important nursery zone for the fishes in Guadeloupe (Louis et Guyard, 1982). In the seagrass beds, fishes were collected with a seine net, 50 m long and 2 m high, used to encircle the sampling area. Two stations were chosen in Grand Cul-de-Sac Marin : one at Lambis Point and the other at Christophe Islet (Fig. 3).

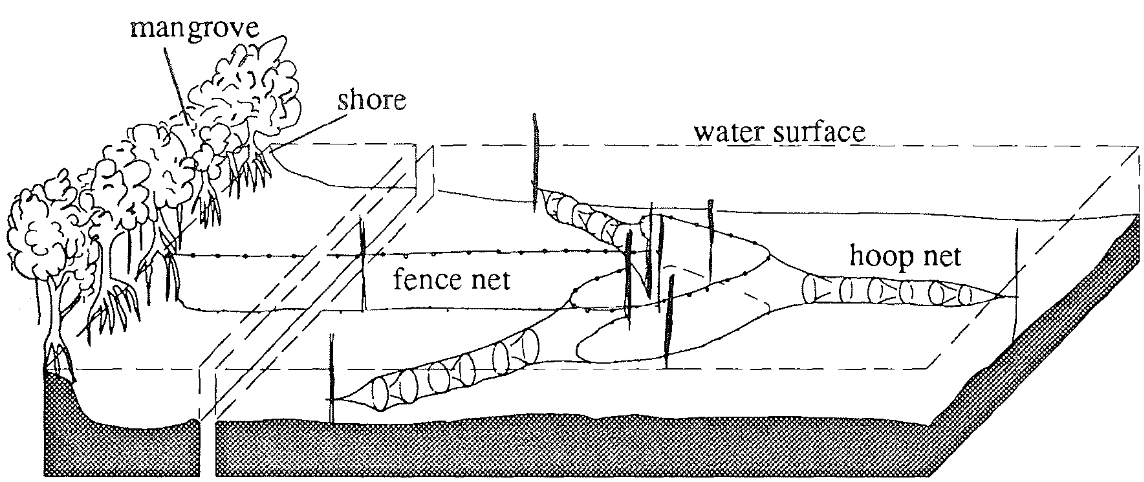


Figure 2 : A "capéchade" : the fishing device used in the mangrove.

The sampling area for the coral reef fish community was located near Pigeon Island at 15 m deep (Fig. 1). The fishes were counted, by SCUBA diving, inside a quadrat of 300 m² (150 m long, 2 m wide) defined by transect lines on the bottom. The water column investigated was about 3m high. Each fish censused was assigned one of three size-classes (juvenile, medium-size, big-size) based on the size range of each species (Bouchon-Navaro and Harmelin-Vivien, 1981).

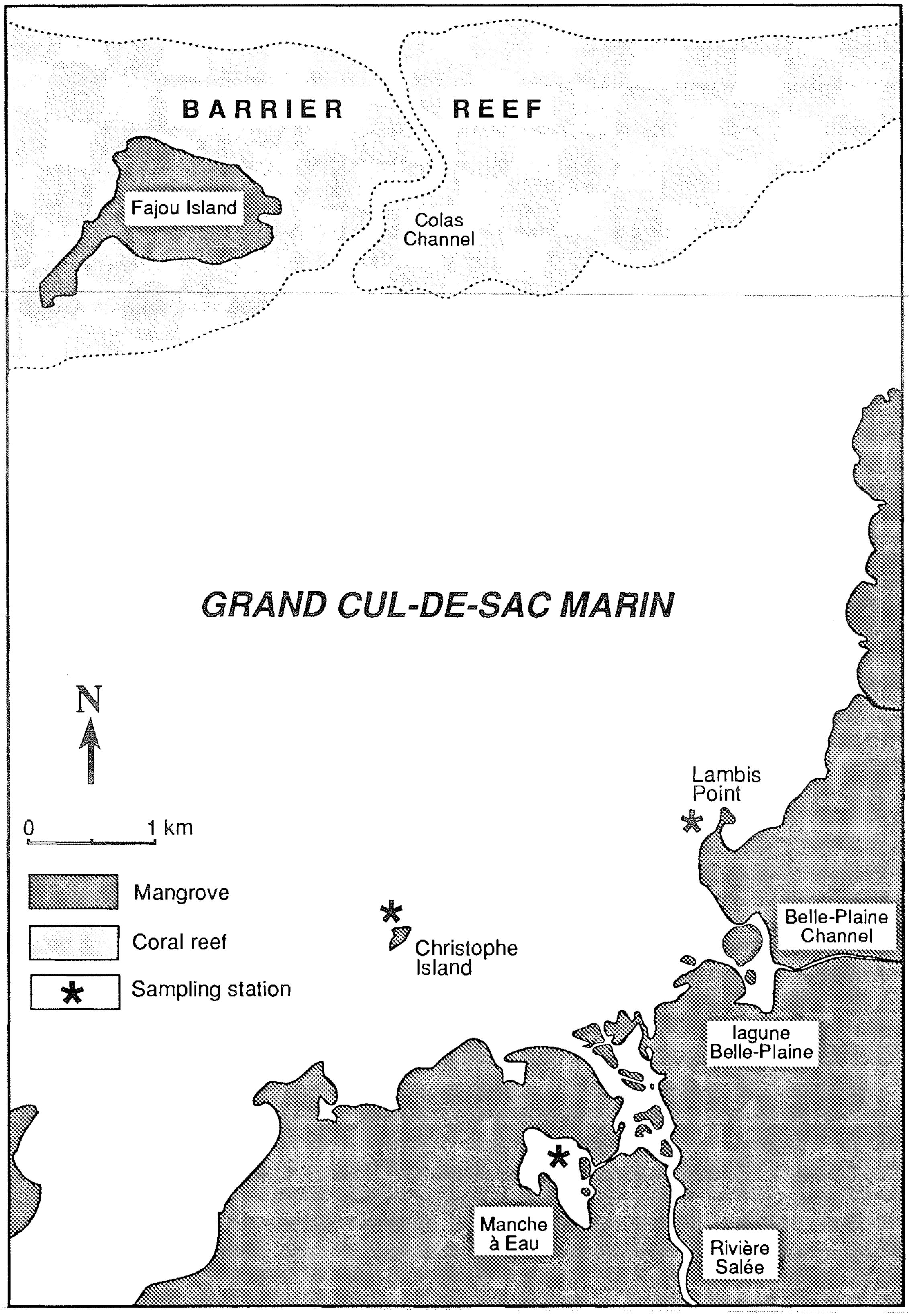


Figure 3 : Location of the sampling stations in Grand Cul-de-Sac Marin Bay.

From the data, several biological indices were computed such as species richness, species diversity (H') calculated according to Shannon and Weaver (1948), and evenness index (E) of Pielou (1969) that gives an indication on the community structure. E fluctuates between 0 (only one species in the community) and 1 (all the species of the community have the same importance). These indices were calculated using biomass values for the mangrove and seagrass fishes and the number of individuals for the reef fishes.

Data did not fit a gaussian distribution, even when using current transformation techniques (Log, square root, hyperbolic...). Three non parametric statistical tests were used to analyse the data : the Wilcoxon signed-ranks test, the Spearman rank correlation and the Friedman two-way analysis of variance by ranks (Siegel, 1956). Results are given with their exact probability of occurence. We considered that the results of the tests were statistically significant when probabilities were $\leq 0.05$.

## III. RESULTS

### A. Mangrove areas

The hurricane was accompanied by a storm tide which was followed by a rise in sea level of at least one meter. The mud from the bottom in shallow waters was stirred up by the waves. Considerable amounts of freshwater runoff flushed the mangroves. These phenomena induced a drop in salinity (to 7‰) and quite anoxic conditions ($0.2\ mg.O_2.l^{-1}$) that lasted several days (Bouchon *et al.*, 1991).

After the hurricane, numerous dead fishes were floating at the surface of the water in the mangrove. Some fishes were observed dead on the substrate between the mangrove roots and up to 20 m inshore. The dead fish species were the following : *Gerres cinereus, Eucinostomus gula, Eugerres brasilianus, Bairdiella ronchus, Lutjanus apodus, Haemulon bonariense, Mugil curema, Sphyraena barracuda, Chaetodipterus faber, Archosargus rhomboidalis, Diodon holacanthus* and *Sphoeroides testudineus.*

Fish surveys were conducted from 24th September 1989 (one week after the hurricane) and the data could be compared to data acquired previously at the same station. In the Manche-à-Eau lagoon, the results were compared to data from June 1989 (3 months before the hurricane) and additional samples made in January 1990 (4 months after the hurricane) and in March 1990 (6 months later) (Annex I).

The Friedman two-way analysis of variance by ranks was used to compare the fish biomass among the four samples. A global statistical significant difference was found between the samples ($X_r^2 = 11.709$ ; $p = 0.0084$).

The Wilcoxon signed-ranks test was used to compare the samples pairwise (Tab. 1). The results show that the fish community observed before the hurricane (June 1989) was different from the one observed after the hurricane (September 1989). Surveys conducted in January and March 1990 were also different from the September 1989 sample. But in January and March 1990, 4 and 6 months after the hurricane, fish biomass returned to the previous situation of June 1989.

A drop in fish biomass was observed just after the hurricane. In January 1990, fish biomass had returned to the pre-hurricane values. Decreases in the number of species and number of individuals, as well as the diversity indices, were also noticed one week after the hurricane.

The fish community observed in the mangrove lagoon during the study period comprised 32 species. A Spearman rank- correlation coefficient calculated with the pre and post-hurricane data showed a significant inverse correlation between the quantitative fish dominances (Z = -2.817, p = 0.048). Before the hurricane, the dominant species in biomass were : *Sphoeroides testudineus, Bairdiella ronchus, Archosargus rhomboidalis, Eucinostomus argenteus* and *Eucinostomus gula.* These species usually correspond to the fishes permanently residing in the mangrove (Louis and Guyard, 1982). After the hurricane, these species were no longer present in the surveys, except for A. *rhomboidalis* (three individuals collected). Moreover, gobiid fishes which were not commonly sampled in the mangrove (chiefly *Gobionellus oceanicus*) were dominant in the community.

Thus, significant changes in the fish community were observed just after the hurricane in the mangrove : 4 and 6 months later, the community had returned to its previous situation.

Table 1 : Results of the Wilcoxon tests concerning the fishes of Manche-à-Eau lagoon ( Z = values of the Wilcoxon test ; p = probability of realization of Ho ; * = significant values).

| | June 89 | September 89 | January 90 | March 90 |
|---|---|---|---|---|
| June 89 | | Z = -2.354 | Z = -0.457 | Z = -0.943 |
| September 89 | p = 0.019 * | | Z = -2.623 | Z = -2.650 |
| January 90 | p = 0.648 | p = 0.009 * | | Z = -1.628 |
| March 90 | p = 0.346 | p = 0.008 * | p = 0.104 | |

## B. Seagrass beds

In seagrass areas, a total of 50 fish species were collected in October 1988 (one year before the hurricane), in October 1989 (10 days after), in January 1990 (4 months after) and in March 1990 (6 months after the hurricane) (Annex II).

At Christophe Islet, the Friedman analysis of variance revealed a significant difference between the fish biomass in the four samples ( $X_r^2$ = 17.891 ; p = 0.0013).

The Wilcoxon test was used to test the difference between the samples pairwise (Tab. 2). Only samples collected in January 1990 appeared significantly different from those of October 1989 and March 1990. No significant difference was found in biomass between the samples collected in October 1988 and the 3 samples collected after the hurricane. Thus, there was no change in fish biomass immediately after the hurricane.

Table 2 : Results of the Wilcoxon tests on the fish community of Christophe Islet
(Z = values of Wilcoxon test ; p = probability of realization of Ho ; * = significant values).

| | October 1988 | October 1989 | January 1990 | March 1990 |
|---|---|---|---|---|
| October 1988 | | Z = - 1.589 | Z = - 1.663 | Z = 0.368 |
| October 1989 | p = 0.1120 | | Z = - 4.086 | Z = - 1.305 |
| January 1990 | p = 0.0964 | p = 0.0001 * | | Z = - 3.346 |
| March 1990 | p = 0.7132 | p = 0.1919 | p = 0.0008 * | |

At Lambis Point, the Friedman test also revealed a significant difference between the samples ($X_r^2$= 13.05 ; p = 0.011). The Wilcoxon test showed a significant difference only between the samples of October 1988 and January 1990, and between those of January 1990 and March 1990 (Tab. 3). As for the previous station, there was no change in fish biomass just after the hurricane.

Conversely, a comparison of the Spearman rank correlation coefficients ($r_s$) indicated that the fish community structure differed significantly before and after the hurricane in both stations ($r_s$ = -1.086, p = 0.277 at Christophe Islet and $r_s$ = 0.311, p = 0.756 at Lambis Point). These differences are partly due to the appearance in the samples of schooling transient fishes (*Anchoa lyolepis, Diapterus rhombeus*). Their suppression from the analysis increased the values of the correlation coefficients.

Table 3 : Results of the Wilcoxon tests on the fish community of Lambis Point.
(Z = values of Wilcoxon test ; p = probability of realization of Ho ; * = significant values).

| | October 1988 | October 1989 | January 1990 | March 1990 |
|---|---|---|---|---|
| October 1988 | | Z = - 0.886 | Z = - 2.739 | Z = 0.444 |
| October 1989 | p = 0.3754 | | Z = - 1.305 | Z = - 0.243 |
| January 1990 | p = 0.0062 * | p = 0.1919 | | Z = - 2.341 |
| March 1990 | p = 0.6567 | p = 0.8078 | p = 0.0192 * | |

## C. The coral reef areas

Pigeon island, a volcanic formation, is devoid of true coral reefs, but its steep slopes support the most flourishing hermatypic coral community of Guadeloupe. Concerning the fish communities, the results presented hereafter cover a 9 month period from April 1989 to January 1990. During this period, 12 censuses were made respectively before and after the hurricane. These censuses were separated by a 12-day interval. A total of 89 fish species were observed (Annex III).

The Wilcoxon signed-rank test was used to compare the biological parameters obtained from the data collected before and after the hurricane, i. e., species richness, the total density of fishes; the number of juveniles; the number of medium-size fishes; the number of big-size fishes; the number of species possessing juveniles; the Shannon-Weaver diversity and the evenness index (Tab. 4).

A significant difference was found for the total density of fishes, the number of juveniles, H' and the Pielou evenness. The other parameters such as the species richness, the number of big and medium-size fishes were not significantly different before and after the hurricane. Since there were no significant changes in the amount of medium and large fishes, only the juveniles were responsible for the observed changes in total abundance.

Table 4 : Results of the Wilcoxon test concerning the fish community of Pigeon Island ( Z = values of the Wilcoxon test ; p = probability of realization of Ho ; * = significant values).

| | Z | Probability |
|---|---|---|
| Species richness | - 0.3 | 0.7525 |
| Total density per 300 $m^2$ | - 3.0 | 0.0047 * |
| Number of juveniles | - 3.0 | 0.0022 * |
| Number of medium size individuals | - 0.2 | 0.8753 |
| Number of big size individuals | - 1.0 | 0.2892 |
| Number of species with juveniles | - 1.0 | 0.5733 |
| Shannon index | - 3.0 | 0.0060 * |
| Pielou evenness | - 3.0 | 0.0037 * |

Moreover, a Spearman ranks correlation coefficient was computed between the profiles of fish abundances before and after the hurricane. The correlation was highly significant showing that there were no noticeable changes in the species composition or their dominance ranks within the community.

Figure 4 shows the change in numbers of juveniles for the 24 samples distributed before and after the hurricane. An important drop in the abundance of juveniles can be observed just after the hurricane. The density observed remained low even four months after the hurricane and these conditions would probably persist until the next period of recruitment that occurs in summer.

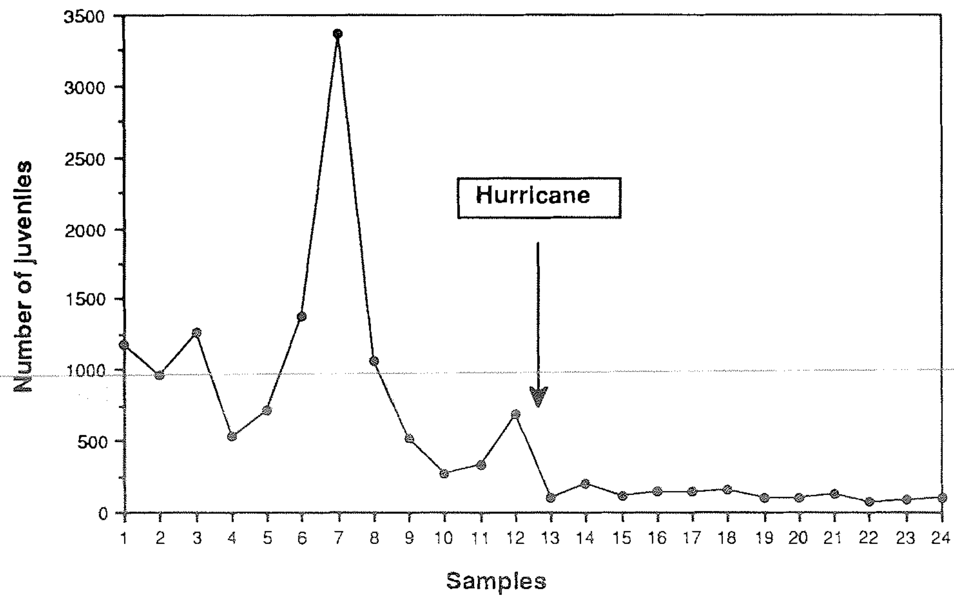


Figure 4 : Change in number of juvenile fishes before and after the hurricane.

## IV. DISCUSSION AND CONCLUSION

The effects of severe storms or hurricanes on the fish communities have been documented from many parts of the world. For the Atlantic region, reports can be found for Florida (Robins, 1957 ; Breder, 1962 ; Springer and McErlean, 1962 ; Tabb and Jones, 1962 ; Beecher, 1973 ; Bortone, 1976 ), Jamaica (Woodley *et al.*, 1981 ; Kaufman, 1983 ; Williams, 1984 ), Puerto Rico (Glynn *et al.*, 1964 ) and Texas (Hubbs, 1962. For the Indo-Pacific region, observations have been reported for Hawaii (Walsh, 1983), the Great Barrier Reef of Australia (Lassig, 1983), the Fiji Islands (Cooper, 1966), Japan (Araga and Tanase, 1966 ; Tribble *et al.*, 1982 ) and Reunion Island (Letourneur, 1991). However, as pointed out by Walsh (1983), the effects of catastrophic storms on fish communities is still unclear. Some authors reported a high fish mortality after a hurricane, while others observed noticeable changes in the fish communities. Some did not observe any significant alterations in the community due to the storm.

Among the authors who did not find noticeable changes in the fish communities after a hurricane are Springer and McErlean (1962) and Bortone (1976) in Florida. Springer and McErlean (1962) noticed that reef fish populations were not much disturbed after a hurricane although reef formations were destroyed. However, their observations occurred one month after the hurricane. Bortone (1976) concluded that no major changes occurred in the fish community as a result of Hurricane Eloise. He related this to the location of the study area (well oxygenated waters and not directly affected by the surge) and to the possible presence of protective shelters for the fishes.

Robins (1957) was the first to report on the effects of a severe storm on fishes. He observed numerous dead specimens washed onshore after a severe storm in Florida. In the same region, Hurricane Donna also caused a high fish mortality (Tabb and Jones, 1962). After Hurricane Edith at Puerto Rico, Glynn *et al.* (1964) reported dead fishes floating near the coast. Cooper (1966) presented a dismal picture of the reefs of Fiji Islands after the hurricane of February 1965 ; dead fishes were floating on the water and thousands were washed up on the beach. High fish mortality was also recorded in Japan after typhoons (Araga and Tanase, 1966 ; Tribble *et al.*, 1982). Araga and Tanase (1966) made quantitative observations on the stranded fishes and noticed that about 84 % of the species and 98 % of the individuals were inshore inhabitants. In general, the fish communities from the shallow coastal waters are mostly affected.

In the mangrove areas of Grand-Cul-de-Sac Marin, the trees were completely defiolated after the hurricane. However, the loss of wood biomass was variable according to the area. In the part of the mangrove areas dominated by the red mangrove, the estimation of the loss of biomass fluctuated between 25 and 75 % (Bouchon *et al.*, 1991). Fish mortality mainly occured in the mangrove areas where the fishes were exposed to low salinity, high levels of suspended sediments and oxygen depletion. The post-hurricane fish community was significantly different to the pre-hurricane community.

The impact of Hurricane Hugo on the seagrass beds was varied. The *Thalassia testudinum* beds, even those situated in shallow waters, were only slightly affected by the direct impact of the cyclonic surge. On the contrary, the *Syringodium filiforme* beds were much more affected. A large amount of *S. filiforme* leaves and roots were washed onshore. In the months following the hurricane, a delayed mortality of the *T. testudinum* meadows was observed in the Grand Cul-de-Sac Marin. In some places, *T. testudinum* was progressively replaced by *S. filiforme* (Bouchon *et al.*, 1991). In the seagrass beds, the observed changes in the fish community were more complex. They only appeared a few months after the hurricane. This may be related to the delayed mortality of *Thalassia testudinum.*

In the coral reef environment the observed changes were less important than would be expected from the strength of the hurricane. For the benthic community, the damage due to the cyclonic surge mostly affected branching species of corals, such as *Millepora alcicornis* (especially in shallow waters), *Madracis mirabilis*, *Acropora cervicornis*, *Porites porites* and *Eusmilia fastigiata*. These colonies, broken and tossed by the waves, smashed the other benthic organisms. Massive corals withstood the hurricane better than branching corals. The soft benthic organisms, such as sponges and gorgonians were greatly damaged especially in shallow waters (Bouchon *et al.*, 1991). During the weeks following the hurricane, a "bleaching" phenomenon affected many coral colonies. This bleaching consisted in the loss of their symbiotic unicellular algae (zooxanthellae). This is generally linked to a state of stress of the animals. Most of these corals finally died. Three months after the hurricane, the bleaching phenomenon progressively disappeared. Before the hurricane a dense algal community, dominated by species belonging to the genus *Dictyota*, were present at Pigeon Island. These algae were washed ashore by the storm waves. A few weeks after, an outbreak of a red algae belonging to the genus *Liagora* occurred. Three months after, the *Liagora* population disappeared and the *Dictyota* resettled (Bouchon *et al.*, 1991).

In the study area, Hurricane Hugo mainly affected the juvenile fishes. Their density on the study reef drastically decreased the week following the hurricane. The same observations were made by Lassig (1983) on the Great Barrier Reef of Australia who noted that "the cyclone had little effects on adults but caused high juvenile mortality and re-distribution of sub-adult individuals". Beecher (1973) also reported a high mortality of juveniles of a Pomacentrid fish, *Pomacentrus (=Stegastes) variabilis*, after Hurricane Agnes in Florida.

In Guadeloupe, no specific changes in reef fish behavior were noticed after the hurricane. This is contrary to what had been described in Jamaica after Hurricane Allen (Woodley *et al.*, 1981 ; Kaufman, 1983) where cryptic species were observed in the open waters and planktivorous species swam near the bottom. The territorial fishes such as *Stegastes planifrons* became more aggressive and schools of parrotfish were reduced in size. In Hawaii, Walsh (1983) reported that fishes from the reef flats moved down to the deeper zones.

During the weeks following the hurricane in Guadeloupe, some acanthurid species (*Acanthurus bahianus* and *A. coeruleus*) were observed browsing the algae belonging to the genus *Liagora* that abnormally proliferated in the coral community. Nevertheless, examination of the survey results showed that the density of herbivorous fishes in the study areas did not increase significantly after the hurricane. This is contrary to what had been noticed in Martinique following the proliferation of *Sargassum* (Bouchon *et al.*, 1988). In Jamaica, Williams (1984) and Kaufman (1983) had reported an increase in the number of *Stegastes planifrons*, an herbivorous species, after Hurricane Allen.

The consequences of a hurricane on fish communities depend on various factors: the violence of the phenomenon ; the geographical location of the study areas ; the reef topography ; the depth location of the observations ; and above all, the magnitude of the damage on the reef associated benthic communities. In the island of Guadeloupe, the immediate impact of Hurricane Hugo was important for the fish communities situated in the mangrove. However, in this habitat, the fish community is well adapted to variations in environmental factors and apparently recovered within a few months. The changes which occurred in the seagrass beds reflect a long term decay of this habitat. As for the reef fishes, the drastic drop of juveniles may have an influence in the structuring of the fish community in the long term.

## ACKNOWLEDGEMENTS

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## BIBLIOGRAPHY

Anon., 1990. L'ouragan Hugo. Pub. Service Météorologique Interrégional Antilles Guyane. Météo France, 32 pp.

Araga A., Tanase H., 1966. Fish stranding caused by a typhoon in the vicinity of Seto. *Publ. Seto Mar. Biol. Lab.*, 14 : 155-160.

Beecher H.A., 1973. Effects of a hurricane on a shallow-water population of damselfish, *Pomacentrus variabilis*. *Copeia*, 3 : 613-615.

Bortone S.A., 1976. Effects of a hurricane on the fish fauna at Destin, Florida. *Fla. Sci.*, 39 : 245-248.

Bouchon C., Bouchon-Navaro Y., Louis M., 1988. A first record of a *Sargassum* (Pheophyta, Algae) outbreak in a Caribbean coral reef ecosystem. Com. 41th Gulf Carib. Fish. Inst. Congress, St Thomas : 452-468.

Bouchon C., Bouchon-Navaro Y., Imbert D., Louis M., 1991. Effets de l'ouragan Hugo sur les communautés côtières de Guadeloupe (Antilles françaises). *Ann. Inst. océanogr.*, Paris, 67 (1) : 5-33.

Bouchon-Navaro Y., Harmelin-Vivien M., 1981. Quantitative distribution of herbivorous reef fishes in the gulf of Aqaba (Red Sea). *Mar. Biol.*, 63 : 79-86.

Breder C.M., 1962. Effects of a hurricane on the small fishes of a shallow bay. *Copeia*, 2 : 459-248.

Cooper M.J., 1966. Destruction of marine flora and fauna in Fiji caused by the hurricane of February 1965. *Pac. Sci.*, 20 : 137-141.

Glynn P.W., Aldomovar L.R., Gonzales J.G., 1964. Effects of hurricane Edith on the marine life in La Parguera, Puerto Rico. *Carib. J. Sci.*, 4 : 335-345.

Hubbs C., 1962. Effects of a hurricane on the fish fauna of a coastal pool and drainage ditch. *Tex. J. Sci.* , 14 : 289-296.

Kaufman L.S., 1983. Effects of Hurricane Allen on reef fish assemblages near Discovery Bay, Jamaica. *Coral reefs*, 2 : 43-47.

Kjerfve B., Dinnel S.P., 1983. Hindcast hurricane characteristics on the Belize barrier reef. *Coral reefs,* 1(4) : 203-207.

Lassig B.R., 1983. The effects of a cyclonic storm on coral reef fish assemblages. *Envir. Biol. fish*, 9 (1) : 55-63.

Letourneur Y., 1991. Modifications du peuplement de poissons du platier récifal de Saint-Pierre (île de La réunion, Océan Indien) consécutives au passage du cyclone Firinga. *Cybium,* 15 (2) : 159-170.

Louis M., Guyard A., 1982. Contribution à l'étude des peuplements ichtyologiques dans les mangroves de Guadeloupe (Antilles françaises). *Bull. Ecol.*, 13 (1) : 9-24.

Pielou E.G., 1969. An introduction to mathematical ecology. Wiley, Interscience, New-York : 286 pp.

Robins C.R., 1957. Effects of storms on the shallow-water fish fauna of Southern Florida with new records of fishes from Florida. *Bull. Mar. Sci. Gulf and Caribbean*, 7 (3) : 266-275.

Shannon C.E., Weaver W., 1948. The mathematical theory of Communication. Urbana Univ. Press, Illinois : 117 pp.

Siegel S., 1956. Nonparametric statistics for the behavioral sciences. Mc Graw-Hill, New York : 312 pp.

Springer V.G., McErlean A.J., 1962. A study of the behavior of some tagged South Florida coral reef fishes. *Am. Mid. Nat.*, 67 : 386-397.

Stoddart D.R., 1974. Post-hurricane changes on the British Honduras reefs : resurvey of 1972. Proc. 2nd Inter. Coral Reef Symp., Brisbane, 2 : 473-483.

Tabb D.C., Jones A.C., 1962. Effects of Hurricane Donna on the aquatic fauna of North Florida Bay. *Trans. Am. Fish. Soc.*, 91 : 375-378.

Tribble G.W., Bell J.L., Moyer J.T., 1982. Subtidal effects of a large typhoon on Miyake-Jima, Japan. *Publ. Seto Mar. Biol. Lab.*, 27 : 1-10.

Walsh W.J., 1983. Stability of a coral reef fish community following a catastrophic storm. *Coral reefs*, 2 : 49-63.

Williams A.H., 1984. The effects of Hurricane Allen on back reef populations of Discovery bay, Jamaica. *J. Exp. Mar. Biol. Ecol.*, 75 : 233-243.

Woodley J.D., Chornesky E.A., Clifford P.A., Jackson J.B.C., Kaufman L.S., Knowlton N., Lang J.C., Pearson M.P., Porter J.W., Rooney M.C., Rylaarsdam K.W., Tunnicliffe V.J., Whale C.M., Wulff J.L., Curtis A.S.G., Dallmeyer M.D., Jupp B.P., Koehl M.A.R., Neigel J., Sides E.M., 1981. Hurricane Allen's impact on Jamaïcan coral reefs. *Science*, 214 : 749-755.

Annex I : Numbers (N), biomass (W) and diversity indices for the fish samples collected with the specific hoop-net.

| FAMILIES | SPECIES | June 89 | | Sept. 89 | | Jan. 90 | | March 90 | |
|---|---|---|---|---|---|---|---|---|---|
| | | N | W (g) | N | W (g) | N | W(g) | N | W (g) |
| MEGALOPIDAE | *Megalops atlantica* | | | 8 | 8198 | | | | |
| ENGRAULIDAE | *Anchoa lyolepis* | 31 | 180.2 | | | 4759 | 6900.1 | 662 | 1847.6 |
| | *Anchovia clupeoides* | | | | | 2 | 11 | | |
| CLUPEIDAE | *Harengula clupeola* | | | | | 2301 | 6127.4 | 309 | 1828 |
| | *Harengula humeralis* | 2 | 17.7 | | | 2 | 12.2 | 3 | 11.9 |
| | *Opisthonema oglinum* | 1 | 38.7 | | | | | 3 | 105.9 |
| MURAENIDAE | *Gymnothorax funebris* | 4 | 9740 | | | | | | |
| BELONIDAE | *Tylosurus acus* | | | | | 1 | 133.7 | | |
| HEMIRAMPHIDAE | *Hyporhamphus unifasciatus* | | | | | 38 | 305.5 | | |
| CICHLIDAE | *Sarotherodon mossambica* | | | 1 | 140.3 | | | | |
| MUGILIDAE | *Mugil curema* | | | | | | | 2 | 0.9 |
| SPHYRAENIDAE | *Sphyraena barracuda* | 4 | 636 | | | 4 | 183.6 | 7 | 558.5 |
| CENTROPOMIDAE | *Centropomus undecimalis* | 5 | 210.3 | 3 | 1.4 | | | | |
| | *Centropomus ensiferus* | | | | | 2 | 30 | | |
| CARANGIDAE | *Caranx latus* | 6 | 83.3 | | | 2 | 152 | 9 | 317.5 |
| | *Oligoplites saurus* | | | | | 6 | 45.1 | 6 | 60.6 |
| | *Chloroscombrus chrysurus* | 1 | 46.4 | | | | | | |
| LUTJANIDAE | *Lutjanus apodus* | | | | | 1 | 917 | | |
| POMADASYIDAE | *Haemulon bonariense* | 1 | 57.9 | | | | | 2 | 91 |
| SPARIDAE | *Archosargus rhomboidalis* | 49 | 9350.1 | 3 | 656.5 | 25 | 3646.8 | 154 | 23022.3 |
| SCIAENIDAE | *Bairdiella ronchus* | 233 | 16037.3 | | | 202 | 4858.9 | 270 | 5629.1 |
| GERREIDAE | *Diapterus rhombeus* | 162 | 4120.1 | | | 967 | 4433.1 | 1220 | 7955.4 |
| | *Eucinostomus argenteus* | | | 1 | 3 | 164 | 344.3 | 592 | 2157.9 |
| | *Eucinostomus gula* | 119 | 2077.8 | | | 312 | 1484.3 | 444 | 2934.4 |
| | *Eugerres brasilianus* | 12 | 1368.1 | | | 1 | 10.7 | 4 | 43.3 |
| | *Gerres cinereus* | | | 6 | 10.2 | 24 | 150.1 | 162 | 1110.1 |
| EPHIPIDAE | *Chaetodipterus faber* | | | | | | | 1 | 128.5 |
| BOTHIDAE | *Citharichthys spilopterus* | | | | | | | 1 | 22.9 |
| GOBIDAE | *Bathygobius soporator* | | | 13 | 27.1 | | | | |
| | *Gobionellus oceanicus* | | | 119 | 672 | | | 1 | 24.8 |
| | *Gobionellus sp* | | | 6 | 26.1 | | | | |
| TETRODONTIDAE | *Sphoeroides testudineus* | 245 | 24017.3 | | | 7 | 193.1 | 15 | 680.8 |
| Total | | 875 | 67981.2 | 160 | 9734.6 | 8820 | 29938.9 | 3867 | 48531.4 |
| Species richness | 32 species | | 15 | | 9 | | 19 | | 20 |
| Shannon Index | | | 2.48 | | 0.89 | | 2.91 | | 2.57 |
| Pielou Index | | | 0.63 | | 0.28 | | 0.69 | | 0.58 |

Annex II (continued) : Numbers (N), biomass (W) and diversity indices for the fish samples collected with a seine net in the seagrass beds of Grand Cul-de-Sac Marin Bay.

| FAMILY | SPECIES | LAMBIS POINT | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | Oct. 88 | | Oct. 89 | | Jan. 90 | | March 90 | |
| | | N | W (g) | N | W (g) | N | W(g) | N | W (g) |
| ALBULIDAE | *Albula vulpes* | | | | | | | | |
| CLUPEIDAE | *Harengula clupeola* | | | | | | | | |
| ENGRAULIDAE | *Anchoa cf lyolepis* | | | 81 | 922.2 | 98 | 309.1 | 6 | 27.1 |
| SYNGNATHIDAE | *Cosmocampus elucens* | | | | | 2 | 1.9 | | |
| | *Syngnathus sp* | | | | | | | 3 | 6.1 |
| HOLOCENTRIDAE | *Holocentrus rufus* | | | | | | | | |
| SPHYRAENIDAE | *Sphyraena barracuda* | | | | | 3 | 105.4 | | |
| SERRANIDAE | *Hypoplectrus puella* | 1 | 9.7 | 5 | 28.1 | 2 | 17.5 | | |
| | *Serranus flaviventris* | 6 | 32.3 | 2 | 6.3 | 6 | 17.3 | 10 | 37.3 |
| CARANGIDAE | *Caranx latus* | | | | | | | | |
| | *Oligoplites saurus* | | | | | 1 | 8.3 | | |
| | *Selene vomer* | | | | | | | | |
| LUTJANIDAE | *Lutjanus analis* | | | | | | | | |
| | *Lutjanus apodus* | 5 | 31.3 | 2 | 12.1 | 8 | 106.1 | 1 | 15 |
| | *Lutjanus griseus* | 1 | 3.2 | | | | | | |
| | *Lutjanus synagris* | | | 4 | 24.5 | 1 | 63 | | |
| | *Ocyurus chrysurus* | 138 | 633.7 | 90 | 287.5 | 183 | 975.6 | 153 | 396 |
| POMADASYIDAE | *Haemulon aurolineatum* | | | | | | | | |
| | *Haemulon bonariense* | | | | | | | | |
| | *Haemulon chrysargyreum* | 1 | 12.3 | 3 | 43 | | | | |
| | *Haemulon flavolineatum* | | | | | 11 | 60.6 | 7 | 14.2 |
| | *Haemulon plumieri* | | | 2 | 23.8 | 6 | 85.3 | 7 | 42.4 |
| | *Haemulon sciurus* | | | 2 | 2.6 | 2 | 7.6 | 9 | 57.3 |
| SPARIDAE | *Archosargus rhomboidalis* | 2 | 10.5 | 1 | 9 | 6 | 193.3 | 12 | 83.9 |
| | *Calamus sp* | | | | | | | 1 | 2.6 |
| SCIAENIDAE | *Bairdiella ronchus* | | | | | | | | |
| GERREIDAE | *Diapterus rhombeus* | | | 9 | 390.5 | | | | |
| | *Eucinostomus argenteus* | 1 | 1.5 | | | 11 | 60.4 | | |
| | *Eucinostomus gula* | 18 | 85.5 | 34 | 151.7 | 22 | 157.3 | 2 | 20.4 |
| | *Gerres cinereus* | | | | | 19 | 152.2 | 3 | 12.8 |
| BOTHIDAE | *Citharichthys spilopterus* | | | | | | | | |
| SOLEIDAE | *Achirus lineatus* | | | | | | | 2 | 0.3 |
| | *Pseudupeneus maculatus* | | | | | | | 1 | 23.8 |
| SCORPAENIDAE | *Scorpaena grandicornis* | 1 | 4.2 | | | | | | |
| CHAETODONTIDAE | *Chaetodon capistratus* | 32 | 88.2 | 2 | 7.1 | 1 | 3.1 | | |
| LABRIDAE | *Lachnolaimus maximus* | | | | | 1 | 0.8 | | |
| SCARIDAE | *Sparisoma chrysopterum* | 2 | 0.4 | 4 | 15.1 | | | 4 | 3.1 |
| | *Sparisoma radians* | | | | | | | | |
| GOBIDAE | *Gobidae sp.1* | | | | | | | | |
| | *Gobidae sp. 2* | | | | | | | | |
| | *Gobidae sp.3* | | | | | | | | |
| | *Gobionellus oceanicus* | | | | | | | | |
| ACANTHURIDAE | *Acanthurus bahianus* | | | | | | | | |
| | *Acanthurus chirurgus* | | | | | | | | |
| MONACANTHIDAE | *Monacanthus ciliatus* | 1 | 3.3 | | | | | | |
| TETRODONTIDAE | *Sphoeroides nephelus* | 1 | 1.4 | 1 | 8.4 | | | | |
| | *Sphoeroides greeleyi* | | | | | | | | |
| | *Sphoeroides spengleri* | 4 | 43.2 | 1 | 13.9 | 5 | 42.5 | 2 | 1.6 |
| | *Sphoeroides testudineus* | | | | | 1 | 6 | 1 | 5.2 |
| DIODONTIDAE | *Diodon holacanthus* | 1 | 85 | 2 | 528.6 | 2 | 249.3 | 1 | 293.8 |
| Total | | 215 | 1045.7 | 245 | 2474.4 | 391 | 2622.6 | 225 | 1042.9 |
| Species richness | 50 species | | 16 | | 17 | | 21 | | 18 |
| Shannon Index | | | 2.14 | | 2.58 | | 3.18 | | 2.7 |
| Pielou Index | | | 0.54 | | 0.63 | | 0.72 | | 0.65 |

Annex II : Numbers (N), biomass (W) and diversity indices for the fish samples collected with a seine net in the seagrass beds of Grand Cul-de-Sac Marin Bay.

| FAMILY | SPECIES | CHRISTOPHE ISLET | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | Oct. 88 | | Oct. 89 | | Jan. 90 | | March 90 | |
| | | N | W (g) | N | W (g) | N | W(g) | N | W (g) |
| ALBULIDAE | *Albula vulpes* | | | | | 1 | 5.8 | 1 | 20.3 |
| CLUPEIDAE | *Harengula clupeola* | | | | | 27 | 81 | | |
| ENGRAULIDAE | *Anchoa cf lyolepis* | | | 8 | 13.9 | 347 | 995.3 | 360 | 550.5 |
| SYNGNATHIDAE | *Cosmocampus elucens* | | | | | | | | |
| | *Syngnathus sp* | | | | | | | | |
| HOLOCENTRIDAE | *Holocentrus rufus* | 1 | 43.6 | | | | | | |
| SPHYRAENIDAE | *Sphyraena barracuda* | 2 | 143.5 | 6 | 8.9 | 4 | 134.5 | | |
| SERRANIDAE | *Hypoplectrus puella* | 1 | 2.8 | | | 8 | 77 | 2 | 14.7 |
| | *Serranus flaviventris* | 10 | 42.7 | 3 | 3.8 | 17 | 51.6 | 4 | 13.1 |
| CARANGIDAE | *Caranx latus* | | | 1 | 2 | 1 | 6 | | |
| | *Oligoplites saurus* | | | | | | | | |
| | *Selene vomer* | | | 5 | 11.9 | | | 1 | 5 |
| LUTJANIDAE | *Lutjanus analis* | 1 | 21.9 | | | | | | |
| | *Lutjanus apodus* | 3 | 13 | | | 1 | 24.1 | | |
| | *Lutjanus griseus* | | | | | | | | |
| | *Lutjanus synagris* | | | 75 | 55 | 43 | 278.2 | 12 | 88.5 |
| | *Ocyurus chrysurus* | 152 | 595.2 | 9 | 69.3 | 115 | 583.8 | 5 | 18.1 |
| POMADASYIDAE | *Haemulon aurolineatum* | | | | | 4 | 4.5 | | |
| | *Haemulon bonariense* | 1 | 8.8 | 1 | 5.1 | | | 2 | 10.1 |
| | *Haemulon chrysargyreum* | 2 | 17.6 | | | | | | |
| | *Haemulon flavolineatum* | | | | | 13 | 18.2 | 2 | 5.2 |
| | *Haemulon plumieri* | | | | | 14 | 114.1 | | |
| | *Haemulon sciurus* | | | | | | | | |
| SPARIDAE | *Archosargus rhomboidalis* | 2 | 81.7 | 1 | 31.8 | 2 | 45.5 | | |
| | *Calamus sp* | | | | | | | | |
| SCIAENIDAE | *Bairdiella ronchus* | | | | | 3 | 16.9 | | |
| GERREIDAE | *Diapterus rhombeus* | | | 128 | 945.3 | 398 | 1173.6 | 99 | 344.9 |
| | *Eucinostomus argenteus* | | | 12 | 23.5 | | | 31 | 135.4 |
| | *Eucinostomus gula* | 70 | 293.7 | 258 | 358.6 | 200 | 609.9 | 103 | 472 |
| | *Gerres cinereus* | | | | | 2 | 8.6 | 8 | 63.4 |
| BOTHIDAE | *Citharichthys spilopterus* | | | 1 | 15.7 | 9 | 23.7 | 4 | 19.1 |
| SOLEIDAE | *Achirus lineatus* | | | | | 20 | 355.7 | 11 | 4 |
| | *Pseudupeneus maculatus* | | | | | | | 1 | 14.3 |
| SCORPAENIDAE | *Scorpaena grandicornis* | | | | | | | | |
| CHAETODONTIDAE | *Chaetodon capistratus* | 7 | 14.6 | | | 1 | 6.6 | | |
| LABRIDAE | *Lachnolaimus maximus* | 1 | 49 | | | | | | |
| SCARIDAE | *Sparisoma chrysopterum* | 1 | 58.3 | | | | | | |
| | *Sparisoma radians* | | | | | 5 | 51.6 | | |
| GOBIDAE | *Gobidae sp.1* | | | 17 | 5.7 | | | | |
| | *Gobidae sp. 2* | | | | | | | 2 | 0.4 |
| | *Gobidae sp.3* | | | 4 | 0.9 | | | 1 | 0.1 |
| | *Gobionellus oceanicus* | | | | | 5 | 1.5 | | |
| ACANTHURIDAE | *Acanthurus bahianus* | 1 | 17.2 | | | 1 | 2.9 | | |
| | *Acanthurus chirurgus* | 1 | 8.4 | | | 1 | 1.2 | | |
| MONACANTHIDAE | *Monacanthus ciliatus* | | | | | | | | |
| TETRODONTIDAE | *Sphoeroides nephelus* | | | | | | | 1 | 0.2 |
| | *Sphoeroides greeleyi* | 1 | 4.3 | | | 2 | 0.9 | | |
| | *Sphoeroides spengleri* | 1 | 12 | 1 | 0.6 | 1 | 0.5 | | |
| | *Sphoeroides testudineus* | | | 1 | 0.5 | 2 | 9 | 1 | 1 |
| DIODONTIDAE | *Diodon holacanthus* | 2 | 139 | | | 4 | 987.9 | | |
| Total | | 260 | 1567.3 | 531 | 1552.5 | 1251 | 5670.1 | 651 | 1780.3 |
| Species richness | 50 species | | 19 | | 17 | | 29 | | 20 |
| Shannon Index | | | 2.98 | | 1.83 | | 3.29 | | 2.66 |
| Pielou Index | | | 0.7 | | 0.45 | | 0.68 | | 0.61 |

Annex III : Number of indivuals per species observed before (1 to 12) and after (13 to 24) the hurricane at Pigeon island.

| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| *Lycodontis moringa* | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| *Muraena miliaris* | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| *Synodus intermedius* | 0 | 0 | 1 | 2 | 3 | 0 | 1 | 0 | 0 | 1 | 2 | 1 | 0 | 0 | 0 | 1 | 0 | 2 | 1 | 0 | 1 | 2 | 0 | 0 |
| *Neoniphon marianus* | 1 | 0 | 3 | 2 | 1 | 1 | 1 | 1 | 4 | 4 | 0 | 0 | 1 | 2 | 2 | 10 | 5 | 7 | 6 | 4 | 2 | 2 | 1 | 0 |
| *Holocentrus rufus* | 2 | 4 | 2 | 4 | 3 | 3 | 2 | 3 | 5 | 0 | 2 | 0 | 7 | 4 | 6 | 4 | 5 | 4 | 6 | 3 | 6 | 3 | 0 | 1 |
| *Myripristis jacobus* | 16 | 18 | 17 | 18 | 17 | 35 | 33 | 27 | 54 | 22 | 13 | 15 | 36 | 22 | 26 | 48 | 44 | 25 | 16 | 13 | 22 | 14 | 14 | 14 |
| *Aulostomus maculatus* | 4 | 5 | 2 | 3 | 2 | 1 | 5 | 4 | 2 | 5 | 3 | 4 | 6 | 11 | 4 | 5 | 4 | 6 | 9 | 5 | 4 | 4 | 3 | 5 |
| *Fistularia tabacaria* | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 |
| *Scorpaena plumieri* | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| *Cephalopholis cruentatus* | 3 | 6 | 2 | 1 | 7 | 3 | 5 | 6 | 2 | 4 | 4 | 5 | 4 | 5 | 6 | 5 | 9 | 14 | 6 | 1 | 6 | 1 | 1 | 4 |
| *Cephalopholis fulva* | 0 | 0 | 1 | 1 | 3 | 1 | 1 | 1 | 1 | 1 | 1 | 4 | 0 | 3 | 4 | 7 | 3 | 4 | 3 | 3 | 3 | 1 | 1 | 0 |
| *Epinephelus adscensionis* | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| *Hypoplectrus chlorurus* | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 0 | 0 | 0 | 0 | 0 |
| *Hypoplectrus cf guttavarius* | 2 | 3 | 1 | 0 | 0 | 3 | 1 | 0 | 0 | 3 | 2 | 0 | 1 | 0 | 1 | 1 | 1 | 2 | 1 | 2 | 0 | 1 | 3 | 2 |
| *Hypoplectrus nigricans* | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 1 | 0 | 1 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 1 | 1 |
| *Hypoplectrus puella* | 3 | 7 | 6 | 7 | 9 | 7 | 8 | 11 | 4 | 4 | 6 | 6 | 4 | 9 | 9 | 4 | 6 | 6 | 8 | 8 | 5 | 7 | 4 | 3 |
| *Hypoplectrus sp. 1* | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| *Mycteroperca interstitialis* | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| *Paranthias furcifer* | 23 | 0 | 0 | 0 | 0 | 0 | 5 | 0 | 1 | 1 | 0 | 4 | 1 | 0 | 1 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| *Serranus tabacarius* | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 |
| *Serranus tigrinus* | 3 | 2 | 2 | 7 | 7 | 6 | 5 | 5 | 6 | 3 | 7 | 2 | 5 | 4 | 6 | 5 | 4 | 7 | 4 | 7 | 5 | 2 | 5 | 3 |
| *Heteropriacanthus cruentatus* | 1 | 0 | 0 | 1 | 0 | 0 | 0 | 1 | 2 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 1 | 1 | 0 | 2 | 0 |
| *Carangoides ruber* | 1 | 0 | 1 | 0 | 0 | 2 | 0 | 0 | 3 | 2 | 0 | 1 | 1 | 0 | 1 | 1 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 |
| *Caranx latus* | 0 | 0 | 0 | 0 | 0 | 0 | 3 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| *Selar crumenophthalmus* | 8 | 0 | 0 | 0 | 0 | 0 | 40 | 0 | 240 | 40 | 0 | 0 | 275 | 4 | 0 | 20 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| *Inermia vittata* | 0 | 20 | 20 | 0 | 0 | 0 | 40 | 0 | 115 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| *Lutjanus apodus* | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 2 | 0 | 0 |
| *Lutjanus jocu* | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 |
| *Lutjanus mahogoni* | 0 | 1 | 2 | 2 | 0 | 0 | 0 | 1 | 0 | 0 | 3 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |

Annex III (Continued) : Number of indivuals per species observed before (1 to 12) and after (13 to 24) the hurricane at Pigeon island.

| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| *Ocyurus chrysurus* | 4 | 2 | 7 | 3 | 1 | 3 | 0 | 1 | 4 | 5 | 5 | 8 | 9 | 3 | 5 | 29 | 10 | 3 | 10 | 9 | 10 | 5 | 9 | 11 |
| *Anisotremus virginicus* | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 |
| *Haemulon carbonarium* | 0 | 1 | 0 | 0 | 1 | 0 | 0 | 1 | 0 | 1 | 1 | 0 | 0 | 0 | 1 | 2 | 0 | 0 | 0 | 1 | 1 | 1 | 3 | 1 |
| *Haemulon chrysargyreum* | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 1 | 0 |
| *Haemulon flavolineatum* | 3 | 2 | 2 | 1 | 2 | 0 | 0 | 3 | 1 | 1 | 2 | 4 | 1 | 1 | 2 | 2 | 1 | 2 | 2 | 2 | 2 | 0 | 3 | 3 |
| *Haemulon plumieri* | 0 | 0 | 1 | 0 | 1 | 0 | 0 | 0 | 0 | 2 | 1 | 0 | 0 | 0 | 1 | 2 | 0 | 0 | 1 | 0 | 0 | 0 | 1 | 6 |
| *Haemulon sciurus* | 1 | 0 | 1 | 2 | 1 | 1 | 0 | 0 | 1 | 0 | 1 | 0 | 1 | 1 | 0 | 0 | 0 | 1 | 2 | 0 | 1 | 0 | 0 | 0 |
| *Calamus bajonado* | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 1 | 1 | 0 | 1 |
| *Calamus calamus* | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 2 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 1 |
| *Equetus punctatus* | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| *Mulloides martinicus* | 5 | 5 | 3 | 3 | 6 | 5 | 28 | 12 | 13 | 13 | 8 | 21 | 8 | 6 | 12 | 0 | 14 | 8 | 2 | 0 | 0 | 2 | 0 | 1 |
| *Pseudupeneus maculatus* | 0 | 1 | 0 | 1 | 1 | 1 | 1 | 0 | 0 | 1 | 1 | 1 | 2 | 2 | 1 | 1 | 0 | 2 | 1 | 1 | 1 | 2 | 0 | 0 |
| *Kyphosus sectatrix* | 0 | 0 | 1 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 |
| *Chaetodon aculeatus* | 1 | 1 | 1 | 1 | 2 | 4 | 2 | 3 | 2 | 1 | 2 | 4 | 4 | 1 | 3 | 0 | 4 | 1 | 1 | 2 | 2 | 1 | 1 | 1 |
| *Chaetodon capistratus* | 16 | 9 | 21 | 9 | 15 | 7 | 10 | 13 | 4 | 1 | 6 | 9 | 14 | 9 | 21 | 13 | 12 | 14 | 13 | 7 | 7 | 8 | 11 | 15 |
| *Chaetodon striatus* | 0 | 2 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| *Holacanthus tricolor* | 2 | 0 | 0 | 0 | 1 | 0 | 2 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 3 | 1 |
| *Pomacanthus paru* | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 0 | 2 | 0 | 0 | 1 | 0 | 0 | 0 |
| *Abudefduf saxatilis* | 1 | 1 | 5 | 6 | 0 | 1 | 1 | 2 | 2 | 1 | 2 | 1 | 1 | 3 | 2 | 3 | 0 | 2 | 3 | 0 | 1 | 3 | 1 | 0 |
| *Chromis cyanea* | 791 | 446 | 190 | 282 | 250 | 304 | 287 | 139 | 136 | 134 | 168 | 217 | 76 | 87 | 88 | 160 | 112 | 112 | 77 | 126 | 90 | 60 | 96 | 72 |
| *Chromis multilineata* | 115 | 78 | 528 | 68 | 79 | 120 | 616 | 87 | 134 | 40 | 60 | 310 | 100 | 139 | 83 | 203 | 40 | 230 | 239 | 117 | 40 | 120 | 81 | 123 |
| *Microspathodon chrysurus* | 2 | 1 | 1 | 1 | 0 | 0 | 0 | 0 | 1 | 2 | 0 | 1 | 0 | 0 | 1 | 1 | 1 | 2 | 0 | 1 | 2 | 0 | 0 | 3 |
| *Stegastes partitus* | 124 | 136 | 86 | 162 | 218 | 298 | 153 | 216 | 59 | 154 | 226 | 158 | 96 | 140 | 200 | 186 | 208 | 206 | 86 | 142 | 134 | 154 | 116 | 118 |
| *Stegastes planifrons* | 27 | 28 | 25 | 34 | 28 | 25 | 22 | 23 | 23 | 34 | 36 | 27 | 21 | 24 | 30 | 28 | 36 | 37 | 36 | 27 | 27 | 24 | 25 | 25 |
| *Amblycirrhitus pinos* | 0 | 0 | 0 | 0 | 1 | 0 | 1 | 0 | 1 | 0 | 0 | 0 | 0 | 1 | 2 | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 0 | 0 |
| *Sphyraena barracuda* | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| *Bodianus rufus* | 0 | 0 | 0 | 4 | 3 | 0 | 3 | 9 | 2 | 0 | 0 | 1 | 1 | 0 | 1 | 1 | 1 | 1 | 1 | 2 | 0 | 0 | 1 | 2 |
| *Clepticus parrae* | 496 | 381 | 3015 | 159 | 95 | 615 | 3159 | 648 | 212 | 48 | 155 | 590 | 434 | 14 | 12 | 409 | 40 | 0 | 1579 | 40 | 1 | 20 | 20 | 8 |
| *Halichoeres garnoti* | 25 | 21 | 18 | 23 | 15 | 19 | 12 | 13 | 19 | 18 | 21 | 16 | 5 | 20 | 20 | 23 | 24 | 21 | 12 | 14 | 20 | 20 | 16 | 17 |

Annex III (continued) : Number of indivuals per species observed before (1 to 12) and after (13 to 24) the hurricane at Pigeon island.

| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| *Halichoeres radiatus* | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 0 | 1 | 0 | 1 | 0 | 0 | 1 | 0 | 1 | 0 | 0 | 1 | 0 |
| *Lachnolaimus maximus* | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| *Thalassoma bifasciatum* | 68 | 48 | 83 | 153 | 141 | 288 | 224 | 197 | 158 | 128 | 115 | 138 | 48 | 82 | 39 | 55 | 58 | 70 | 67 | 45 | 83 | 30 | 39 | 48 |
| *Scarus guacamaia* | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| *Scarus iserti* | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 |
| *Scarus taeniopterus* | 11 | 30 | 42 | 46 | 38 | 57 | 45 | 38 | 18 | 27 | 19 | 8 | 35 | 22 | 19 | 23 | 9 | 20 | 22 | 18 | 21 | 18 | 15 | 7 |
| *Scarus vetula* | 1 | 2 | 1 | 0 | 3 | 0 | 0 | 3 | 0 | 1 | 2 | 2 | 0 | 0 | 1 | 1 | 2 | 1 | 1 | 1 | 0 | 0 | 0 | 0 |
| *Sparisoma aurofrenatum* | 10 | 17 | 24 | 18 | 20 | 20 | 27 | 23 | 9 | 16 | 19 | 16 | 9 | 19 | 16 | 17 | 21 | 24 | 15 | 8 | 16 | 9 | 9 | 12 |
| *Sparisoma chrysopterum* | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 1 | 0 |
| *Sparisoma rubripinne* | 0 | 3 | 0 | 1 | 5 | 2 | 0 | 3 | 2 | 4 | 1 | 0 | 0 | 2 | 2 | 1 | 1 | 1 | 1 | 0 | 5 | 0 | 1 | 0 |
| *Sparisoma viride* | 5 | 5 | 5 | 2 | 5 | 8 | 8 | 2 | 2 | 4 | 11 | 8 | 4 | 11 | 11 | 8 | 5 | 11 | 4 | 6 | 11 | 7 | 5 | 4 |
| *Sparisoma atomarium* | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| *Coryphopterus personatus* | 0 | 0 | 0 | 82 | 80 | 100 | 375 | 895 | 235 | 505 | 315 | 495 | 60 | 80 | 140 | 60 | 24 | 48 | 36 | 40 | 28 | 20 | 0 | 0 |
| *Acanthurus bahianus* | 2 | 1 | 4 | 1 | 3 | 3 | 0 | 0 | 1 | 1 | 2 | 0 | 2 | 1 | 1 | 2 | 40 | 2 | 40 | 2 | 1 | 2 | 1 | 1 |
| *Acanthurus chirurgus* | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 20 | 0 | 0 | 0 | 0 | 75 | 0 | 75 | 0 | 0 | 0 | 0 | 0 |
| *Acanthurus coeruleus* | 0 | 0 | 3 | 2 | 1 | 1 | 1 | 0 | 1 | 5 | 3 | 9 | 3 | 3 | 2 | 6 | 78 | 4 | 79 | 4 | 4 | 2 | 2 | 3 |
| *Scomberomorus regalis* | 0 | 0 | 92 | 0 | 2 | 0 | 0 | 13 | 1 | 0 | 1 | 0 | 0 | 0 | 0 | 1 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 |
| *Bothus lunatus* | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| *Cantherhines macrocerus* | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 1 | 0 | 0 | 1 | 0 |
| *Cantherhines pullus* | 6 | 2 | 1 | 0 | 2 | 2 | 1 | 0 | 1 | 2 | 2 | 1 | 3 | 2 | 2 | 0 | 1 | 0 | 2 | 0 | 0 | 0 | 0 | 1 |
| *Melichthys niger* | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 3 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 1 | 2 | 0 | 0 | 0 | 0 | 0 |
| *Acanthostracion polygonius* | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| *Lactophrys bicaudalis* | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| *Lactophrys triqueter* | 3 | 1 | 0 | 2 | 1 | 1 | 1 | 0 | 0 | 3 | 0 | 0 | 0 | 3 | 1 | 3 | 2 | 1 | 2 | 2 | 2 | 0 | 0 | 0 |
| *Canthigaster rostrata* | 0 | 2 | 3 | 2 | 1 | 2 | 5 | 1 | 1 | 5 | 0 | 2 | 1 | 2 | 4 | 6 | 3 | 1 | 4 | 1 | 3 | 4 | 0 | 1 |
| *Cyclichthys antennatus* | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 |
| *Diodon holacanthus* | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| *Juvéniles sp1* | 0 | 115 | 20 | 20 | 200 | 20 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |