Potential Effect of Mangrove Regression for Fish Species of Commercial Interest in Guadeloupe

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ABSTRACT

Mangroves are known to represent a suitable habitat for fish species of commercial interest in their adult phase life and above all to play a role of nursery for many species coming from neighbouring ecosystems like seagrass beds or coral reefs. In most of the Caribbean areas, mangroves are regressing due to coastal management, land reclamation and wood cutting. A study on 32 mangrove sites of the bay of the Grand Cul-de-Sac Marin in Guadeloupe Island showed the existence of significant positive correlation between mangrove extent and the biomass of their associated fish assemblages. Among the 42 commercial fish species observed in the lagoon, 94.4% of the individuals are juveniles. Canonical factorial analyses of their distribution showed that: I) their spatial distribution is determined by the proximity or not of coral reefs and seagrass beds; II) their temporal distribution is under the influence of dry and wet seasons characteristics of the climate in Guadeloupe. These variations can be explained by ontogenetic migrations between the different ecosystems. The general regression of the mangrove surfaces in the Caribbean may conduct to an alteration of the juvenile fish assemblages that they shelter, in terms of diversity and biomass, and in the long term to a depletion of the coastal fish stocks.

KEY WORDS: Caribbean, mangrove, fish communities

Efecto Potencial de la Regresión de los Manglares para las Especies de Peces de Importancia Comercial en Guadeloupe

Los manglares están reconocidos como un hábitat para diferentes especies de peces que tienen una importancia comercial en fase adulta y por encima de todo de desempeñar un papel de criadero para numerosas especies que provienen de ecosistemas vecinos como son las praderas de Fanerógamos marinas o los arrecifes coralinos. En la mayoría de las zonas del Caribe, la superficie ocupada por los manglares disminuye en respuesta al desarrollo costero, utilizaciones territoriales o agrícolas y la deforestación. Un estudio sobre 32 sitios de manglares localizadas en la bahía del Grand Cul-de-Sac Marin en la isla de Guadeloupe (Antillas francesas) mostró la existencia de una correlación significativa entre el espesor del manglar y biomasa de los peces asociados con estos manglares. En Guadeloupe, 42 especies de peces observadas en los manglares son de importancia comercial. Entre estas especies de interés económico, el 94,4 % de los individuos son juveniles. Análisis canónicos de correspondencia realizados sobre la distribución de estas especies mostraron que : 1) esta distribución espacial esta influenciada por la proximidad o no de los arrecifes coralinos y de las praderas de Fanerógamas ; 2) la repartición temporal de las especies es influida por la temporada seca o la época lluviosa que son características del clima en Guadeloupe. Estas variaciones pueden explicarse por migraciones ontogénicas entre los diferentes ecosistemas. La regresión de la superficie ocupada por los manglares en el Caribe podría conducir a una alteración de las poblaciones de juveniles que estos ecosistemas protegen, en términos de diversidad, biomasa y a largo plazo a una reducción de los stocks de peces de importancia comercial.

PALABRAS CLAVES: Caribe**,** manglares, peces

Effet Potentiel de la Régression des Mangroves sur les Éspeces de Poissons D'importance Commerciale en Guadeloupe

Les mangroves sont reconnues pour constituer un habitat pour différentes espèces de poissons qui, en phase adulte, ont une importance commerciale et par-dessus tout de jouer un rôle de nurserie pour de nombreuses espèces provenant des écosystèmes voisins tels que les herbiers de Phanérogames marines ou les récifs coralliens. Dans la plupart des zones de la Caraïbe, les surfaces de mangroves diminuent suite à des aménagements côtiers, des utilisations foncières ou agricoles et des déboisements. Une étude sur 32 sites de mangroves localisés dans le lagon du Grand Cul-de-Sac Marin en Guadeloupe a montré l'existence d'une corrélation significative entre l'épaisseur de la mangrove en bordure lagonaire et les biodiversités et biomasses des assemblages de poissons associés à ces mangroves. En Guadeloupe, sur les 83 espèces de poissons observés, 27 sont d'importance commerciale. Parmi ces espèces d'intérêt économique, 88,7% des individus sont des juvéniles. Des analyses canoniques des correspondances réalisées sur les distributions de ces espèces a montré que : I) cette distribution spatiale est reliée à la proximité ou non des récifs coralliens et des herbiers ; II) la répartition temporelle des espèces est influencée par la saison sèche ou la saison des pluies qui sont caractéristiques du climat en Guadeloupe. Ces variations peuvent s'expliquer par des migrations ontogéniques entre les différents écosystèmes. Les régressions des surfaces de mangroves dans la Caraïbe pourraient conduire à une altération des peuplements de juvéniles de poissons que ces écosystèmes abritent, en terme de diversité et de biomasse et à plus long terme à une réduction des stocks de poissons d'importance commerciale.

MOTS CLÉS: Mangrove, Caraïbe, communautés de poissons, habitat

INTRODUCTION

Mangrove areas throughout the world have been reduced by 35% since the 1980s (Valiela *et al.* 2001). At a regional scale, Caribbean mangrove surfaces have declined by 10% over the two past decades (Ellison and Farnsworth 1996, Spalding 1997, Valiela *et al.* 2001). With this important global loss, mangrove is considered as one of the world's most threatened tropical ecosystems (Valiela *et al.* 2001). The destruction of mangroves is occurring globally with remarkable recent losses of mangrove habitat due to anthropogenic alterations: conversion of mangroves for aquaculture, agriculture, salt flats, urbanization or forestry uses (wood, charcoal) (Ellison and Farnsworth 1996, Valiela *et al.* 2001). Against this alarming background, there is now an increasing concern for the sustainable management of mangrove ecosystems and the need to understand interrelationships between mangrove habitat and their associated fishes (Blaber 2007). Many studies in the Caribbean have highlighted the ecological importance of mangroves as nursery habitats for fish species of recreational and commercial importance (Heald and Odum 1970, Mumby *et al.* 2004, Nagelkerken *et al.* 2000, to cite a few). Explanation of these strong associations between juvenile fish species and mangroves are commonly related to three hypotheses which are based on the increase of shelters, food avaibility and lower predation rates in mangrove habitats (Laegdsgaard and Jonhson 2001). Identify the associations between fish assemblages and environmental descriptors are thus needed to understand the processes structuring mangrove fish communities and to evaluate the influence of environmental or anthropogenic changes on these distributions.

The specific objectives of the present study were to examine the distribution of commercially important fish species observed in a mangrove lagoon in Guadeloupe (FWI). This research was conducted in order to answer several questions:

i) What are the distribution patterns of these fish communities in a mangrove shoreline lagoon ?
ii) Are their distributions influenced by environmental variables ?
iii) What is the importance of mangrove habitat for the fish species of commercial interest ?

METHODS

Study Area

Guadeloupe island is located in the Lesser Antilles and is formed by two islands ("Grande-Terre" and "Basse-Terre") separated by a narrow channel named "Rivière Salée" (Figure 1). Investigations were conducted in the lagoon of the Grand Cul-de-Sac Marin (GCSM) located in the north part of Guadeloupe Island (Figure 1). This shallow lagoon of 11,000 ha is limited seaward by a 30 km long coral reef, one of the longest barrier reef of the Lesser Antilles (Bouchon and Laborel 1990), and landward by mangrove forests, dominated by *Rhizophora mangle* (Linnaeus), covering an area of 2 700 ha (Chauvaud *et al.* 2001) (Figure1). The depth of the lagoon varies from a few decimetres on shallows and corals keys to 20 meters in the channels. Several of these cays (Fajou, Carénage, Christophe and Macou islets) are colonized by mangroves (Figure 1). The climate is typical of tropical areas and is characterized by a dry season (from December to April) and a wet season (from July to November).

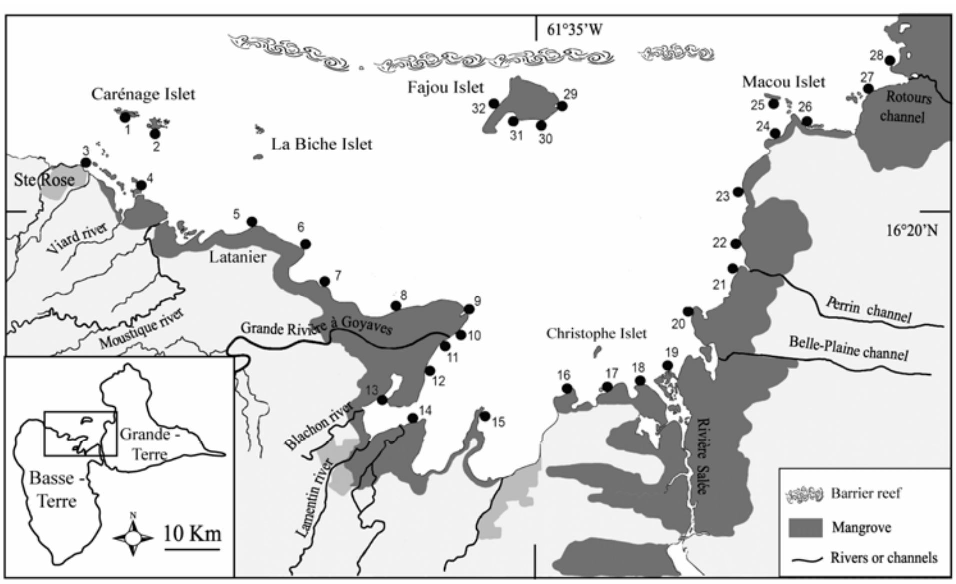

Figure 1. Map of the lagoon of the Grand Cul-de-Sac Marin in Guadeloupe showing the location of the 32 mangrove shoreline stations.

Study Design

A total of 32 mangrove shoreline sites were sampled during the dry and the wet seasons 2005 (Figure 1). The sampling area extended from Sainte-Rose on the west to Rotours channel on the east part of the GCSM and included the mangrove islets stations of Carénage, Fajou and Macou (Figure 1). Fish samples were collected with a net, identified to species level, counted, measured in total length to the nearest 0.1cm and weighted with an accuracy of 0.1g. Commercially important fish species were identified using FAO (Carpenter 2002a, Carpenter 2002b) and FishBase data bases (Froese and Pauly 2006). Juveniles were separated from adults according to specific length at maturity reported in the literature (Cervigón 1994, Cervigón 1991, Froese and Pauly 2006, Garcia-Cagide *et al.* 1994, Hawkins *et al.* 2007). Length at maturity was not available for five fish species: *Strongylura notata*, *Selene vomer*, *Trachinotus falcatus*, *Lutjanus cyanopterus*, *Haemulon bonariense* and *Lactophrys trigonus*. In order to separate juveniles from adults for these species, we used the method described by Froese and Binohlan (2000). These authors developed a method to estimate the length at maturity from the maximum length of the fish species (Froese and Binohlan 2000). The maximum length of these species was obtained from FishBase (Froese and Pauly 2006).

In order to characterize the mangrove habitat, a total of 21 environmental variables were measured in each site. The geographical location (latitude, longitude) of each site was determined using a Global Positioning System. Water temperature, salinity, pH, and dissolved oxygen were measured using a multi-parameter probe (Multi 340i®). Suspended materials, nitrate and phosphate concentrations were estimated using Strickland and Parsons (1972) methods. Chlorophyll$_a$ and pheophytin$_a$ concentrations were measured using the spectrophotometric method of Lorenzen (1967). The maximum horizontal distance at which a Secchi disk could be discerned is used to determine water transparency. Distances separating the sampling stations from the barrier reef and the nearest river or channel mouths were measured on a nautical chart in order to define the variables "reef proximity" and "river and channel proximities". The mangrove and forest extents facing each station, expressed by the measure of their width, were estimated by using a thematic map of the coastal land vegetation of Guadeloupe (Gabinaud *et al.* 1984). Mean rainfall was calculated for the three days preceding fish samplings from the data provided by Meteo-France. Four qualitative variables described each mangrove site: the water motion (calm or turbulent), the location inside or outside the marine reserve, the presence or absence of seagrass beds, and the sampling season (dry or wet season).

Data Analyses

Ordination analyses and hierarchical classifications were performed in order to examine the relationships existing between the fish assemblages and the environmental descriptors influencing their distribution. The CCA was performed by crossing matrices of "sites by environmental descriptors" and "sites by species" expressed in presence-absence, abundance and biomass. Rare fish species, which were represented by only one specimen observed in all the sampling sites, were removed from the multivariate analyses in order to avoid overweighting of these rare individuals (ter Braak and Verdonschot 1995). Abundance and biomass data sets were log transformed (Ln(x+1)) before canonical analyses in order to downweigh large numbers of taxa per station (ter Braak and Verdonschot 1995). The statistical significance ($p < 0.05$) of the effect of each variable was tested by a Monte Carlo test after 1,000 permutations (ter Braak and Verdonschot 1995). In the ordination biplot, fish species and stations are represented by dots, quantitative variables by vectors and qualitative descriptors by their centroids. The length of vectors translates their relative importance and their direction indicates an increase in the values of associated variables (ter Braak 1988). The CCA analyses were performed with the program CANOCO® (ter Braak 1988). Secondly, hierarchical clusterings were carried out to group mangrove fish species using the Ward algorithm and the Euclidian distance matrix computed from the coordinates produced by the factorial analysis as suggested by Roux (1985). These clusterings were performed with the Progiciel R®.

RESULTS

A total of 42 fish species of commercial importance were observed during the dry and wet seasons (Table 1). Among these species, juveniles represented 94.4% of the individuals and 48.9% of the total biomass observed in all the mangrove sites (Table 1). In terms of numerical abundance, five species accounted for more than 90% of the total catch: *Harengula clupeola* (43.1%), *Mugil curema* (28.1%), *Harengula humeralis* (8.1%), *Caranx latus* (6.2%) and *Hyporhamphus unifasciatus* (4.9%). Concerning biomass, five species represented more than 80% of the total biomass: *Dasyatis americana* (54.5%), *Centropomus undecimalis* (9.1%), *Harengula clupeola* (7.8%), *Caranx latus* (5.5%) and *Mugil curema* (4.1%) (Table 1).

CCA analyses were performed on fish presence-absence, abundance and biomass data sets. Out of 21 variables introduced in the analyses, a maximum of 10 environmental variables were statistically significant for fish abundance data compared to fish presence-absence and fish biomass matrices (respectively 7 and 6 variables). Moreover, the percentage of variance explained by significant variables was higher for fish abundance data (26.4%) compared with biomass (15.9%) and presence-absence (15.8%) data sets. Thus, ordination results are presented for fish abundance data sets. Figure 2 presents the projection of fish species sampling in mangrove stations and significant environmental variables on the CCA biplot. The codes of fish species in the CCA biplot are given in Table 1. The four groups of fish species assemblages identified by hierarchical clustering were projected on the CCA biplot (Figure 2). The first axis of the CCA opposed on the left side juveniles and adults fish species influenced by reef proximity and the presence of seagrass beds (group I), such as Acanthuridae, Holocentridae, Haemulidae, Lutjanidae or Serranidae (Figure 2). On the right part of the CCA biplot, two fish assemblages (II and III) were observed in mangrove sites influenced by channels and rivers mouths proximities (Figure 2). These fish communities were composed by juvenile and adult fish species generally observed in mangrove habitats, such as *Centropomus undecimalis, Hyporhamphus unifasciatus* and by juveniles of Carangidae (*Oligoplites saurus, Chloroscombrus chrysurus*) while the adults of these last species are generally observed on the coral reef. A fourth group of fish species (group IV) occurred in mangrove shoreline sites either influenced by reefs or rivers mouths proximities. This last group is composed by fish species which were abundant in all the mangrove shoreline sites (*Harengula clupeola, H.humeralis, Mugil curema*) or fish species either observed in mangroves or coral reefs as juveniles and adults (*Lutjanus apodus*). The second axis of

Table 1. Abundance (N%) and biomass (B%) of the 42 commercial fish species identified during the study. Juveniles (J) are separated from adults (A) according to fish species length of maturity.

Family	Species	Species code	N (%)		B (%)		Life stage
			J	A	J	A	
Dasyatidae	*Dasyatis americana*	Damer	0.25	0.11	24.76	29.77	J-A
Megalopidae	*Megalops atlanticus*	Matla	0.15		2.12		J
Clupeidae	*Harengula clupeola*	Hclup	40.23	2.94	6.16	1.66	J-A
	Harengula humeralis	Hhume	8.10	0.07	1.45	0.08	J-A
Mugilidae	*Mugil curema*	Mcure	27.93	0.22	0.70	3.49	J-A
Belonidae	*Strongylura notata*	Snota	0.08	0.01	0.10	0.03	J-A
	Strongylura timucu	Stimu		0.29		0.49	A
	Tylosurus crocodilus	Tcroc	0.11	0.08	0.21	1.90	J-A
Hemiramphidae	*Hemiramphus brasiliensis*	Hbras	0.01	0.03	0.03	0.12	J-A
	Hyporhamphus unifasciatus	Hunif	4.25	0.69	1.02	0.44	J-A
Holocentridae	*Holocentrus adscensionis*	Hadsc	0.07	0.04	0.06	0.22	J-A
	Holocentrus rufus	Hrufu	0.12	0.24	0.07	0.85	J-A
	Myripristis jacobus	Mjacob	0.01		0.001		J
Centropomidae	*Centropomus undecimalis*	Cunde	0.34	0.04	1.61	7.58	J-A
Serranidae	*Epinephelus striatus*	Estri	0.04		0.18		J
Carangidae	*Caranx latus*	Clatu	6.19		5.50		J
	Chloroscombrus chrysurus	Cchry	0.53		0.05		J
	Oligoplites saurus	Osaur	1.31	0.03	0.27	0.05	J-A
	Selene vomer	Svome	0.12	0.01	0.04	0.06	J-A
	Trachinotus falcatus	Tfalc	0.04		0.01		J
Lutjanidae	*Lutjanus analis*	Lanal	0.11		0.70		J
	Lutjanus apodus	Lapod	0.44	0.04	1.17	1.05	J-A
	Lutjanus cyanopterus	Lcyan	0.01		0.04		J
	Lutjanus griseus	Lgris	0.28	0.01	0.54	0.13	J-A
	Lutjanus jocu	Ljocu	0.01		0.18		J
	Lutjanus synagris	Lsyna	0.11		0.15		J
	Ocyurus chrysurus	Ochry	0.62		0.33		J
Haemulidae	*Haemulon bonariense*	Hbona	0.21	0.04	0.28	0.43	J-A
	Haemulon chrysargyreum	Hchry	0.53		0.26		J
	Haemulon flavolineatum	Hflav	0.69		0.36		J
	Haemulon parra	Hparra	0.01		0.02		J
	Haemulon plumieri	Hplum	0.09		0.10		J
	Haemulon sciurus	Hsciu	0.19	0.71	0.24	2.57	J-A
Mullidae	*Pseudupeneus maculatus*	Pmacu	0.03		0.00		J
Labridae	*Lachnolaimus maximus*	Lmaxi	0.01		0.05		J
Scaridae	*Scarus iserti*	Siser	0.03		0.01		J
	Sparisoma chrysopterum	Schry	0.01	0.03	0.005	0.10	J-A
Ephippidae	*Chaetodipterus faber*	Cfabe	0.05		0.02		J
Acanthuridae	*Acanthurus bahianus*	Abahia	0.53		0.02		J
	Acanthurus chirurgus	Achir	0.52		0.05		J
Scombridae	*Scomberomorus regalis*	Srega	0.01		0.03		J
Ostracidae	*Lactophrys trigonus*	Ltrig	0.01		0.12		J
	Species richness:	42					
	Total abundance of fish collected:	7557					
	Total biomass of fish collected:	172901.1					

the CCA biplot was correlated to the mangrove extent, rainfall values and separated stations according to their sampling period (dry or wet season) (Figure 2). A clear separation of species clusters was observed across this second CCA axis (Figure 2). Groups I-II and III-IV occurred respectively in the top and bottom parts of the CCA biplots (Figure 2). The groups I and II were mainly composed by fish species mainly observed during the dry season while the group III-IV gathered commercial fish species observed during the wet season (Figure 2).

Figure 3 presents the variation of mean fish biomass in different stations characterized by the values of mangrove extent facing the sites. A significant positive correlation was observed between the total biomass of fish species of commercial interest and the mangrove extent (Spearman correlation; $p < 0.05$).

DISCUSSION

In the mangrove shoreline GCSM lagoon of Guadeloupe, the total fish diversity generally observed is about 100 fish species (Baelde 1986, Louis 1983). Thus, commercially important fish species identified in the present study represented 42% of the global mangrove fish diversity. The importance of these fish species in mangrove ecosystems was comparable to seagrass beds and shallow coral reefs habitats where fish species of economical interest represented 56% and 51.9% of the total diversity, respectively (Bouchon-Navaro Pers. communication, Bouchon-Navaro 1997). In the GCSM mangrove lagoon, most of the commercial fish species caught were juveniles, indicating the importance of this ecosystem as habitat for juveniles. The predominance of juvenile life-stages in these ecosystems is generally attributed to two factors. First, the structural complexity of mangrove prop-roots and turbid waters provide shelters for juvenile fishes and then reduced the risk of predation (Blaber and Blaber 1980, Robertson and Blaber 1992). Secondly, mangrove

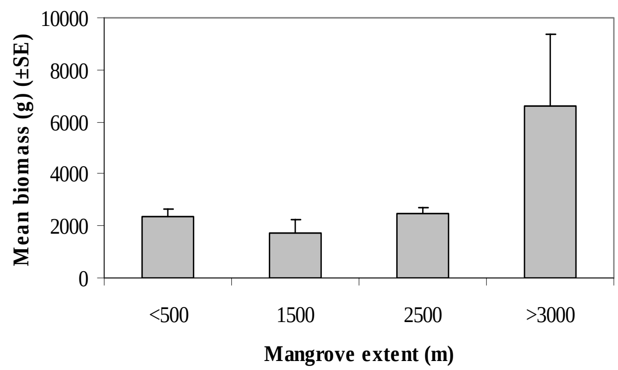

Figure 3. Mean biomass (±SE) variation along a gradient defined by mangrove extent values facing the shoreline sampling stations.

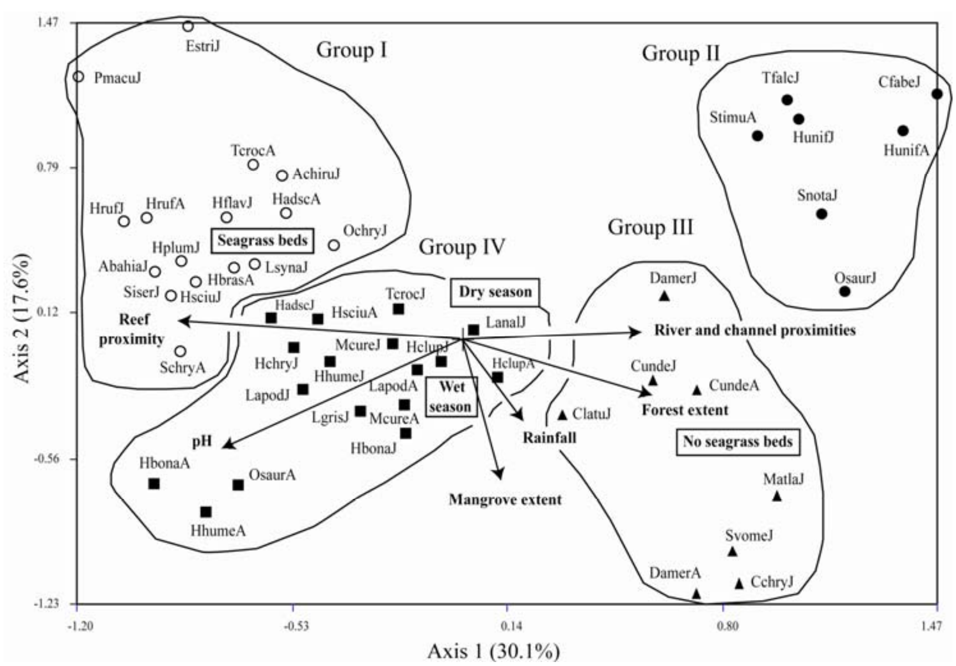

Figure 2. Canonical Correspondence Analysis (CCA) biplot of fish species abundance data and significant environmental variables (Axis 1 vs. Axis 2). Species labels consist of the first letter of genus and the first four letters of species names, the species codes are given in table 1. Juveniles (J) are separated from adults (A) fishes. The groups of fish species and stations obtained by hierarchical classification are projected on the

ecosystems increased food avaibility for fish species, either directly with the detritus food chain or indirectly by attracting numerous prey items through prop-root complex habitat (Heald 1969, Laegdsgaard and Jonhson 2001, Odum 1970).

As underlined by Beck *et al* (2001), the nursery value of an habitat could be site-specific and depend on environmental variables (such as biotic, abiotic, or landscape factors). In the mangrove lagoon of the GCSM, different spatial and temporal patterns of commercially important fish species were observed and related to environmental descriptors. These fish communities were mainly influenced by coral reef, channels or rivers mouths proximities; by the presence of seagrass beds and by seasonality. These distributions confirmed the influence of environmental variables upon spatial and temporal patterns of the fish communities and confirmed the fact that, at a regional scale, fish assemblages are mainly influenced by the diversity, the structure and the hydrology of their habitats (Blaber 2007). Considering biomass data, a significant positive correlation was observed between the biomass of fish species of economical value and the mangrove extent facing the shoreline stations. According to Mumby *et al* (2004), the biomass of fish species of economical value is more than doubled when adult habitat is close to mangroves, suggesting that mangrove ecosystems provide plentiful food and a refuge from predators that increased the survivorship of juveniles.

Valiela *et al* (2001) have underlined that the remaining 46% of the world's mangrove area are threatened by anthropogenic processes. As mangrove ecosystems support essential ecological functions for fish communities of commercial importance (as nurseries, feeding grounds and shelter), mangrove degradation could have significant negative consequences on fish yields and fisheries productivity in the Caribbean. Thus, urgent efforts of restoration, conservation and management must be undertaken to preserve this valuable coastal environment and their associated fish stocks.

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