MARINE ECOSYSTEMS IN THE NORTHWESTERN REGION OF CUBA

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INTRODUCTION

The southeastern limit of the Gulf of Mexico is the northwestern region of Cuba (NOAA 2003). The inflow and outflow of water into and from the Gulf of Mexico occur through straits that are limited, on one side, by Cuba. The Cuban archipelago, however, is typically Caribbean with regards to its marine ecosystems. This is why the coastal waters of Cuba constitute a component of very particular characteristics in the marine ecological context of the Gulf of Mexico. It is important, therefore, to make a complete presentation of this region.

From the mid 1960s to the mid 1980s a series of research projects was carried out covering the whole region and providing a general idea of its geological, oceanographic and biological characteristics (Kondratieva and Sosa 1967; Murina *et al* . 1969; Zenkovich and Ionin 1969; Ionin *et al*. 1972; Buesa 1974 a, b, c; Pavlidis and Avello 1975; Guitart 1975; Guitart *et al*. 1981; Popowski *et al*.1982; Lluis-Riera 1983; Fabré 1985, among others). A large part of the results were published in national journals which are very little known in general, so that they can be considered to a large extent as "grey literature". Subsequently, the attention of institutes and researchers turned to other zones of the Cuban platform with greater fisheries productivity or potential for tourism development. Recently, research has restarted in specific areas of the northwestern region, but with a more local focus and seeking detailed analysis of the ecological structure and processes in some ecosystems, mainly reefs (González-Sansón *et al*. 1997a, b, c; Guardia and González-Sansón 1997a, b, c, 2000 a, b; Aguilar and González-Sansón 1998, 2000, 2002; Aguilar *et al*. 2000; Guardia *et al*. 2001, among others). A recent balance indicates that the specific aspects of the northwestern region of the Cuban platform are incompletely known. On the other hand, the ecosystems present in this region are typical of the whole insular Caribbean, so that it is possible to extrapolate some processes that are somewhat better understood in other areas.

The purpose of this chapter is to present a critical review of the existing information on the northwestern region of Cuba, to propose some basic processes that are expected to rule the dynamics of the marine ecosystems, and to suggest some areas of research that should be pursued in the future to achieve a better understanding of the ecological processes, the impact of human activity, and the way to conserve and rationally manage living resources.

GENERAL CHARACTERISTICS OF THE REGION

For the purpose of this paper, the northwestern region of the Cuban insular shelf constitutes the southeastern limit of the Gulf of Mexico. This is located between 21º 51' 40'' and 23º 8' 52'' N, and between 84º 57' 54'' and 82º 21' 35'' W (Fig. 19.1). It includes what most Cuban authors refer to as the "northwestern platform", which extends from Cabo de San Antonio to Punta Gobernadora on the western side of the entrance to Bahía Honda (Fig. 19.2), plus the narrow coastal part of the platform that runs from Punta Gobernadora to the entrance of the Bahía de la La Habana (Fig. 19.3). The estimated total area of this platform is 4,050 km^2, considering that it runs from the high tide coastline to the 200 m isobar, where the inclination of the sea floor changes abruptly and a steep insular slope begins. The eastern part (Fig. 19.3) is a

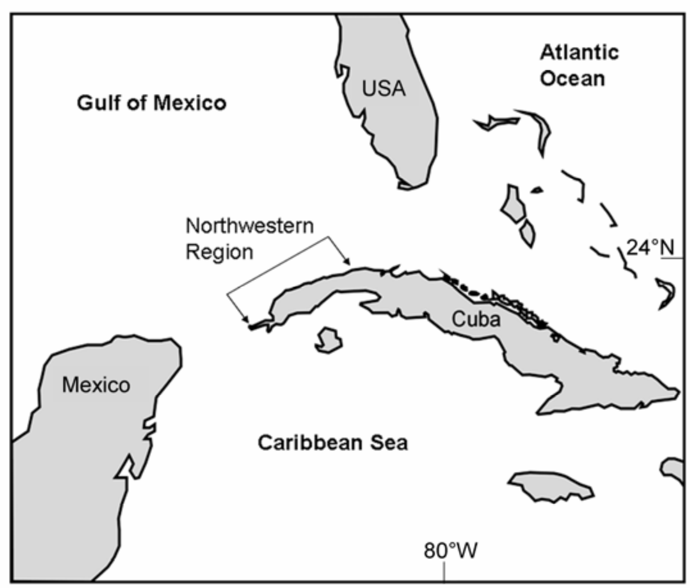

Fig. 19.1. Northwestern region of Cuba.

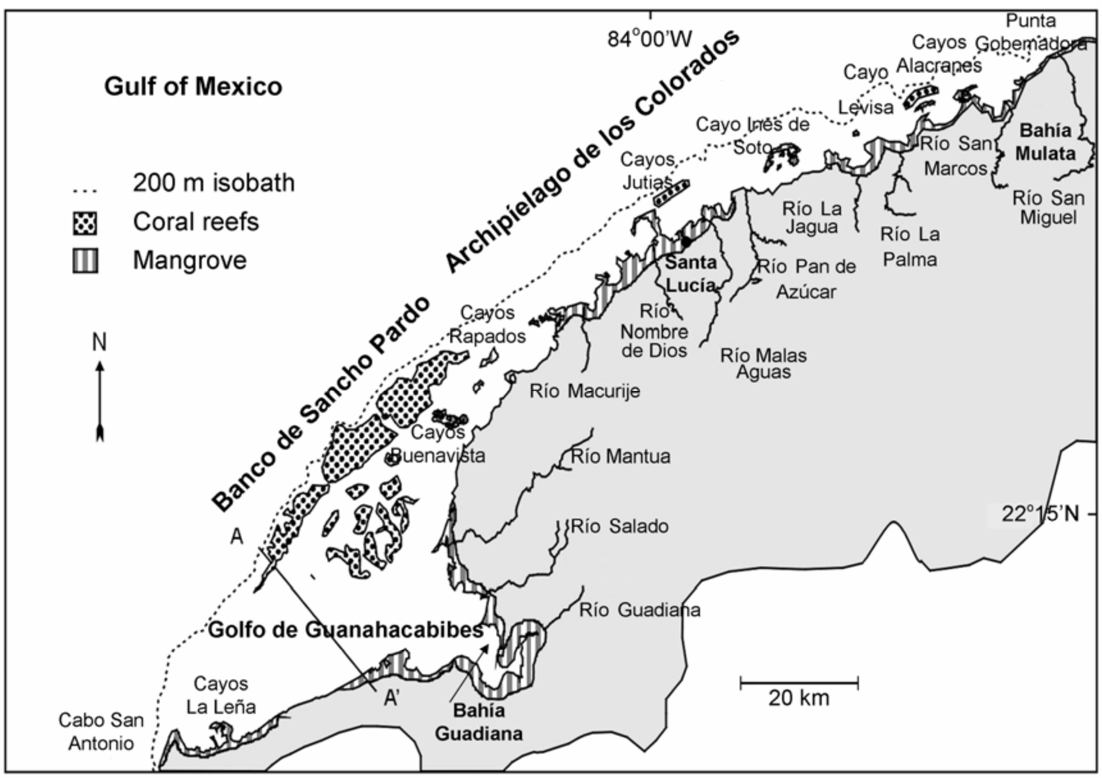

Fig. 19.2. Western part of the northwestern Cuban platform. Line AA' identifies the profile shown in Fig. 19.4.

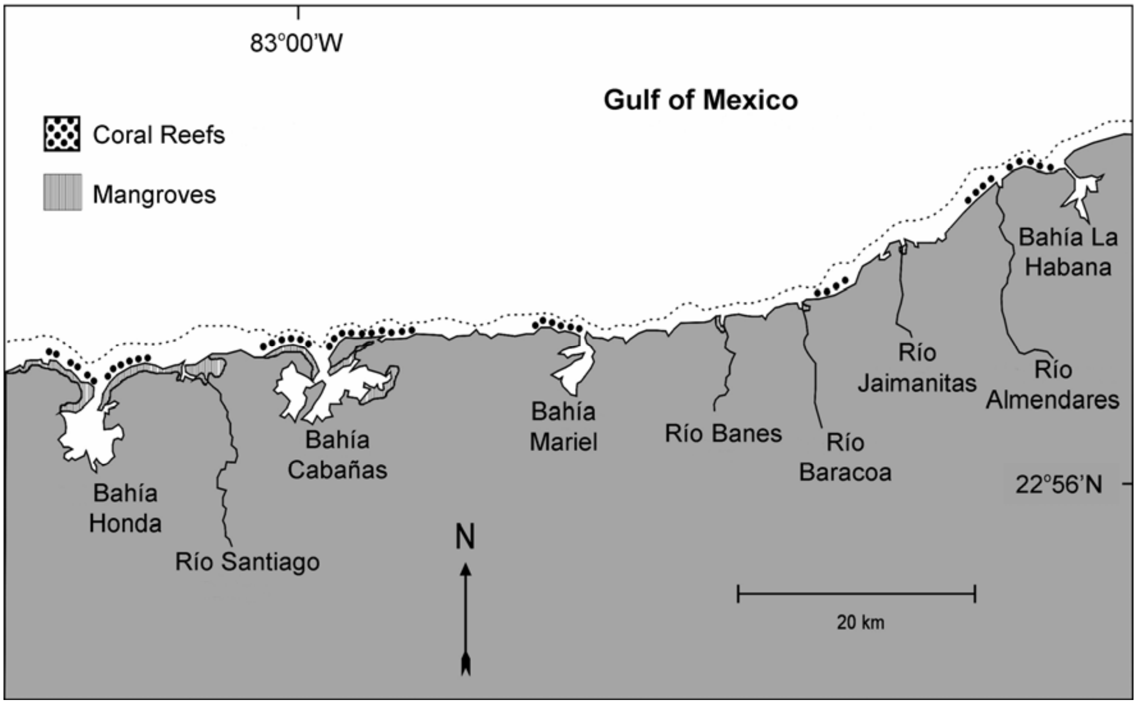

Fig. 19.3. Eastern part of the northwestern Cuban platform.

very narrow platform, less than one kilometer wide, while the western part (Fig. 19.2) is wider, reaching more than a 50 km width in the Golfo de Guanahacabibes. The average depth of this platform is 4 to 5 meters, even though some parts of the Golfo de Guanahacabibes exhibit depths of up to 18 m. There are around 160 small cays in this region which make up the Archipiélago de los Colorados.

The climate is characterized by a rainy season (May to October) and a dry season (November to April). The latter includes a season of northerlies or cold fronts which are more frequent between January and March. The predominant winds blow from east and northeast (trade winds).

ABIOTIC FACTORS

From a geomorphologic point of view, the platform of the northwestern region is an extension of emerged structures, formed fundamentally by calcium carbonate. In general, it consists of an abrasion-accumulation plain where recent sediments vary in quantity and nature depending on proximity to the coast. According to Pavlidis and Avello (1975), in the Golfo de Guanahacabibes the sediments closer to the coastline are of terrigenous origin and little carbonated, which is partly a result of the accumulation of organic components originated from the transport of humus from land and mangroves. In the central area of this gulf carbonated biogenic sediments predominate, dominated by the remains of calcareous algae of the genus *Halimeda*. Lastly, in the region located next to the reefs close to the edge of the platform the sediment is formed mainly by carbonated detritus products. These characteristics can, in general, be considered as typical of the whole platform, where sediments of marine origin predominate over the terrigenous (Zenkovich and Ionin 1969). Toward the easternmost part of the region, where the platform is very narrow, the accumulation of sediments carried by rivers is scarce (Ionin *et al*. 1972).

The coastal zone is formed mainly by the undulating northern plain, which extends between the sea and the Guaniguanico mountain range, with a mean width of about 15 km. All along the coast numerous short rivers flow into the sea, the longest being the Río Mantua (Fig. 19.2), which is 66 km long and has a basin of 293 km^2 (ICGC 1978). The discharge of these rivers produces a seasonal impact (in the rainy season) in relatively small areas of the platform near the coast. Thus, generally speaking, there is no significant effect of runoff in the region.

From a hydrological point of view, the most thorough research of the region was carried out by Lluis-Riera (1983). The following aspects were proven with information obtained from a network of 21 fixed stations (17 on the platform and 4 in oceanic waters), from which samples were taken during three research cruises between August 1977 and July 1978 (Tables 19.1 and 19.2):

- The water column is considerably homogenous due to an intense vertical mix. Only slight stratification was observed in three small coastal areas during the rainy season (Bahía Mulata, coastal zone near Santa Lucía and Bahía Guadiana; see Fig. 19.2).
- The horizontal variation in the temperature and salinity was very moderate, showing a weak gradient perpendicular to the coast. These variations reached a maximum in the previously mentioned coastal areas.
- The concentration of nutrients in the platform varied little, both vertically and horizontally. In general the values were low and similar to those in the adjacent oceanic region. Only in the coastal areas influenced by runoff were higher values observed in the rainy season.
- The platform waters are well oxygenated. The main fluctuations in the oxygen content are due to diurnal changes as a consequence of biological activity, especially of sea grasses.

The oceanic area adjacent to the western part of the region in question registered mean temperature in surface waters (mixed layer that extends to a depth of 50 m according to García 1981a) varying between approximately 29.7ºC (July) and 24.8ºC (February), as deduced from graphs presented in García (1981b). Siam and García (1981) state that the initial depth of the thermocline varies seasonally in this region. It is more superficial in summer (35 m in July) and deeper in winter (105 m in January).

The surface circulation system in the adjacent oceanic region is related to three main currents:

- The Yucatán Current, which flows to the north along the strait of the same name. It is common to observe a countercurrent to the south near Cabo de San Antonio, on the far western end of Cuba (Rossov 1967; García *et al*. 1991);
- The loop current, which forms a wide system of anticyclone circulation. Its lower border adjoins the western part of northwestern Cuba (Rossov 1967; Gómez 1979). This area is known for a positive anomaly in the elevation of the sea level which is almost permanent in the synoptic maps prepared with data from the TOPEX/Poseidon system (CCAR 2003). This anomaly is associated to an anticyclonic circulation that generates a subsidence zone in the oceanic region adjacent to the Cuban platform, which had already been identified by Rossov and Santana (1966).

Table 19.1. Mean, minimum and maximum values for temperature, salinity and dissolved oxygen in the northwestern platform and the adjacent oceanic region (layer of 0 to 50 m). From Lluis-Riera (1983).

	Temperature (°C)		Salinity (ppt)		Oxygen (mg/L)		Saturation (%)	
	Mean	Range	Mean	Range	Mean	Range	Mean	Range
Cruise CM-1 (August 1977)								
Surface	28.9	28.4-29.9	35.8	35.3-36.3	4.3	4.1-4.4	99	95-104
Bottom	28.8	28.1-29.5	35.8	35.3-36.4	4.1	3.7-5.2	102	92-110
Oceanic	28.6	n/a	36.2	n/a	4.4	n/a	102	n/a
Cruise CM-2 (March 1978)								
Surface	23.8	21.6-25.8	36.2	35.3-36.5	4.7	4.5-4.8	104	94-111
Bottom	23.6	21.6-25.3	36.3	35.3-36.5	4.7	4.6-4.8	105	93-113
Oceanic	25.2	n/a	36.3	n/a	4.6	n/a	100	n/a
Cruise CM-3 (July 1978)								
Surface	29.7	29.0-31.0	35.6	34.0-36.3	4.3	4.2-4.4	100	94-111
Bottom	29.6	28.8-30.9	35.8	35.2-36.2	4.3	4.2-4.3	101	92-113
Oceanic	28.8	n/a	36.2	n/a	4.3	n/a	103	n/a

Table 19.2. Mean, minimum and maximum values for the main nutrients in the northwestern platform and the adjacent oceanic region (layer of 0 to 50 m). From Lluis-Riera (1983).

	Silicates (µg Si/L)		Phosphates (µg P/L)		Nitrates (µg N/L)		Nitrites (µg N/L)	
	Mean	Range	Mean	Range	Mean	Range	Mean	Range
Cruise CM-1 (August 1977)								
Surface	9	4.7-24.6	0.24	0.00-0.63	0.66	0.20-1.06	0.08	0.00-0.16
Bottom	10	3.2-34.0	0.26	0.00-0.63	0.74	0.16-1.02	0.08	0.00-0.16
Oceanic	n/a	n/a	0.1	n/a	0.74	n/a	0.08	n/a
Cruise CM-2 (March 1978)								
Surface	5	2.7-7.2	0.05	0.00-0.16	n/a	n/a	0.01	0.00-0.06
Bottom	5	3.2-8.2	0.02	0.00-0.24	n/a	n/a	0.01	0.00-0.05
Oceanic	5	n/a	0.03	n/a	n/a	n/a	0.01	n/a
Cruise CM-3 (July 1978)								
Surface	7	5.3-23.5	n/a	n/a	n/a	n/a	n/a	n/a
Bottom	7	5.4-15.8	n/a	n/a	n/a	n/a	n/a	n/a
Oceanic	5	n/a	n/a	n/a	n/a	n/a	n/a	n/a

- The Florida Current, which flows eastwards near the eastern part of the northwestern region. Between this current and the coast, a countercurrent is frequently observed to the west (Gómez 1979).

Several Cuban authors registered a general eastward water flow at the northwestern region, with the presence of a westward countercurrent closer to the coast (Gómez 1979; Siam 1988; Victoria and Penié 1998).

There are no detailed studies on circulation in the platform zone, but it can be assumed that the action of the wind and tidal currents play a fundamental role in the dynamics of the waters and the intense vertical mix, an aspect that has been proven for other areas of the Cuban insular shelf (Emilsson and Tápanes 1971). The available information indicates a significant exchange of platform waters with the adjacent oceanic region (Blázquez 1981). The tides are of irregular diurnal type in the central part and of irregular semidiurnal type in the far western (Gulf of Guanahacabibes) and eastern portions of the region. The tidal range is very small, between 25 and 50 cm (Rodríguez and Rodríguez 1983).

BIOLOGICAL COMPONENTS AND PROCESSES

The phytoplankton in the northwestern region is characterized by low productivity, due to the absence of outcrops or significant fluvial discharges that can have an effective influence on the whole platform. Popowski *et al*. (1982) suggest that the high specific diversity index and the low concentration of organisms (between 3.07 and 23.32 x 10^6 cells/m^3), indicate stable conditions of the water column and low concentration of nutrients. Fabré (1985) states that these values are the lowest of the whole Cuban shelf. Diatoms and dinoflagellates were the predominant groups and were of small size (3-40 µm), typical of oligotrophic tropical regions. Kondratieva and Sosa (1967) estimated the primary productivity in shallow water of the platform (3-5 m) and obtained values between 11 and 244 mg C/m^3/day, with an average of 78 mg C/m^3/day. The same authors found that the productivity in the deep zone (100 m) near the edge of the platform oscillated between 153 and 1129 mg C/m^3/day, with averages between 428 and 927 mg C/m^3/day. These higher values could be related to the existence of a tidal front associated with the border of the platform, although such phenomenon has not been documented.

The primary productivity values calculated in the water column by Kabanova and López (1973, in Claro *et al*. 2001) were higher and exhibited a gradient from the coastal zone towards the ocean, with values ranging from 200 (near the shore) to 1-19 mg C/m^3/day (close to the edge of the platform).

Marikova and Campos (1967) found that the abundance of zooplankton (dominated by small copepods) decreased from the coast to oceanic waters at the edge of the platform. In the coastal regions, values between 1,680 and 1,860 organisms/m^3 were obtained, whereas in the ocean the values ranged from 40 to 150 organisms/m^3. According to Fabré (1985), the concentration of zooplankton in this region is the lowest of the whole Cuban shelf, oscillating between 57 and 120,766 organisms/m^3. Copepods were the predominant group, represented mainly by *Paracalanus parvus*, *Paracalanus aculeatus*, *Acartia* spp., *Clausocalanus furcatus* and *Clausocalanus arcuicornis*. Research on ichthyoplankton in the northwestern region registered a low concentration of fish larvae (Orozco 1983), which was considered a confirmation of the relatively low productivity of the pelagic subsystem of this region.

The sea beds in the region can be classified in two main types: a) Sea floors with non-consolidated sediments, which can be devoid of vegetation or form marine prairies dominated by *Thalassia testudinum*; and b) rocky bottoms where coral reefs abound.

The main source of primary productivity in the soft bottoms is macrophytobenthos. Seventy seven percent of the wet biomass of this component consists of phanerogams and 22% of green algae, mainly of the genus *Halimeda* (Buesa 1974b). Among the phanerogams (75% of the wet weight) the so called turtle grass (known locally as “seiba”), *Thalassia testudinum*, is by far the most common, forming extensive seagrass beds (locally called “seibadales”). Buesa (1974b) estimated the mean density of *Thalassia* leaves in the northwestern zone to be 152 g/m^2 and the total biomass (including the buried parts) to be 241 g/m^2. The rate of photosynthesis was 4 to 5 ml O_2/mg dry weight (Buesa 1974c), with an average annual photosynthesis/respiration quotient of 2.1 (Buesa 1974a) and a duplication time of 57-86 days estimated for all the seagrass beds in the region (Buesa 1974c). These figures indicate a very high productivity, typical of this seagrass formation, and that its vast majority is not consumed fresh and is incorporated into the food chain in the form of detritus (Day *et al*. 1989).

The fauna of the soft bottoms of the northwestern platform has been described by Murina *et al*. (1969). Samples were collected with grab samplers and trawling nets. The average values of biomass and number of individuals varied according to the researched biotope. They were highest in muddy sediments covered with *Thalassia testudinum* (69.14 g/m^2 and 616 specimens/m^2) and lowest in sandy sediments (14.74 g/m^2 and 354 specimens/m^2). According to the authors, the comparison with other areas of the world indicates that these values are very high, which concurs with the high primary productivity rate previously mentioned. The dominant groups, due to their biomass, were sponges and molluscs (36.9 and 34.7% of the total, respectively), whereas polychaetes and crustaceans dominated by number of individuals (40.3 and 24.2% of the total, respectively).

The benthos from rocky bottoms or associated to coral reef has been studied only in certain zones of the northwestern platform and there is no research covering the whole region. In a 10 km long section of the rocky sublittoral zone to the west of the entrance of the Bahía de la La Habana (Fig. 19.3), where the insular shelf is very narrow, modest forereef development was found. These reefs are most developed in the submerged reef flats at depths between 10 and 15 m. In this area the scleractinian corals, sponges and gorgonians tend to be dominant, varying in relative importance according to the environmental conditions, strongly influenced by discharges from the Puerto Habanero and the Río Almendares, which are heavily polluted (Guardia and González-Sansón 2000 a, b; Guardia *et al*. 2001). The coastal reef of Playa Herradura, located 5 km east of the entrance to the Bahía Cabañas (Fig. 19.3) was studied in detail. It was possible to identify well defined zonation, with areas covered by gorgonians whose specific composition varies with depth, an area dominated by *Acropora palmata*, an area where small reef patches exist, and a differentiated area forming a wall with a different faunistic composition from the previous areas (Guardia and González-Sansón 1997a, b, c). An inventory of the most common coral reef species was made in the surroundings of Cayo Levisa (Guardia, pers. comm.) (Fig. 19.2). A comparative analysis of the main groups of invertebrate at the three areas mentioned above gives a clear idea of the variability of this biodiversity component in the region (Table 19.3).

Similar studies have been carried out at the same places to characterize the structure of the ichthyofauna of the reefs (Aguilar *et al*. 1997; Aguilar and González-Sansón 2000, 2002; González-Sansón *et al*. 1997a, b; González-Sansón and Aguilar 2000, 2002; Aguilar *et al*.

Table 19.3. Comparison of three reef areas in the northwestern region of Cuba, considering scleractinian corals, sponges and gorgonians as indicators (Guardia and González 1997a, b, c, 2000a, b; Guardia *et al*. 2001; Guardia, pers. comm.).

Component	Havana Coastal Zone	La Herradura	Cayo Levisa
General Indicators			
No. of sponge species	50	15	37
Density of sponges (col/m^2)	5.2	1.1	4.2
No. of gorgonian species	25	23	15[a]
Density of gorgonians (col/m^2)	0.9	2.9	5.3
No. of coral species	26	29	37
Diversity of corals[b]	2.5	3.3	2.9
Density of corals (col/m^2)	3.6	10.4	9
Coral cover (%)	4.4	15.9	25
Mean size of corals (cm)	12.7	33.3	43.2
Coral species			
Agaricia agaricites	5.9	22.9	24
Porites astroides	14.4	7.4	10.6
Siderastrea siderea	12	no	9
Montastraea annularis	1.6	18.8	13.9
Siderastrea radians	31.1	14.9[c]	1.4
Porites porites	0.3	9.1	4.5
Montastraea cavernosa	4.7	3.9	1.8
Millepora alcicornis	3.4	2.9[d]	4.1
Millepora complanata	3.1	no	3.3
Dicochoenia stokeisi	5.4	0.1	0.4
Diploria strigosa	0.8	1.1	3.2
Eusmilia fastigiata	2.8	1.2	0.8
Meandrina meandrites	2.4	0.5	0.6

[a] In this evaluation of the identification of some specimens was done only to the genus level. This implies that there are more species.
[b] Shannon diversity index (using ln).
[c] Includes *Siderastrea siderea.*
[d] Includes *Millepora complanata.*

2004). A common aspect in all cases is the almost complete absence of big snappers (Lutjanidae), groupers (Serranidae), pompanos (Carangidae), parrotfishes (Scaridae) and other species. The general opinion both among scientists and fishermen is that the absence of these species is due to excessive fishing, as 20 years ago it was common to observe large individuals of those groups in the studied reefs. Therefore, the current ichthyofauna can be considered modified with a tendency for dominance of small species. From the comparative analysis of the structure of this modified ichthyofauna it is concluded that there are noticeable changes in the studied reefs (Table 19.4). These are likely induced by natural and anthropogenic factors that need to be elucidated in the future.

The composition of the oceanic ichthyofauna in waters near the platform can be partly inferred from the composition of the catch resulting from long line fisheries in the eastern part of the region (section between the Bahía Cabañas and Bahía de la La Habana), and from sport fishing (Guitart 1975; Guitart *et al*. 1981). The most frequent species are the swordfish (*Xiphias gladius*), blue marlin (*Makaira nigricans*), white marlin (*Tetrapturus albidus*), Atlantic sailfish (*Istiophorus americanus*) and several species of shark (*Carcharhinus longimanus*, *Carcharhinus falciformis*, *Carcharhinus obscurus*, *Hypoprion sygnatus*, and *Isurus oxyrinchus*, among others). According to our own observations, also common are the dolphinfish (*Coryphaena hippurus*), some species of tuna (Scombridae), wahoo (*Acanthocybium solandri*) and longnose lancetfish (*Alepisaurus ferox*). It can also be assumed that an even greater number of small species, that are not the object of fishing activities, must form part of this ichthyofauna.

MARINE ECOSYSTEMS

As in the vast majority of insular shelves in the Antillean marine biogeographical province, the most characteristic ecosystem of the northwestern region of Cuba is the one structured around coral reefs. In close association to them are the aquatic ecosystems associated with mangroves and the sandy or sandy-muddy bottoms where sea grasses grow. A strong interaction between these three ecosystems is currently recognized and the mangrove-seagrass-reef complex is seen as the key element for the marine ecological analysis of the Caribbean region (Ogden 1987; Wells 1995; CARICOMP 1997).

Marine ecosystems of the northwestern region must exhibit significant interactions that have been well documented in other similar regions of the Caribbean (UNESCO 1983). The mangroves play an essential role in the retention of fresh water flow and sediments, creating conditions for the maintenance of clean waters in the coastal area, thus facilitating the growth of sea grasses and corals. Sea grass beds reduce the speed of the current and allow sediment to precipitate, also playing a role in cleaning the water. The reefs, in their turn, form an effective barrier in many areas, dissipating a large amount of the wave energy, thus creating calm leeward zones and allowing the accumulation of fine sediment, which offer an ideal substrate for the growth of sea grasses and mangroves. Due to erosion processes, corals are also a source of carbonated sediments that contribute to the stabilization of seagrass beds.

Mangroves retain a large part of the nutrients that come from runoff, thus helping reduce the processes of nutrient enhancement and eutrophication of terrigenous origin. Nevertheless, there is a net flow of nutrients from the shore to the seagrass beds, which increases their productivity when the load is not excessive. The entrance of inorganic nutrients from oceanic water is minimal, for which reason corals usually do not suffer eutrophication. Many animals that take refuge in the mangroves and in the coral reefs during the day seek for food in the

Table 19.4. Most abundant fish species in three reefs in the northwestern region of Cuba, according to results obtained through visual census. Species which are among the 10 most abundant of each reef are included. Abundance data represent the percentage of individuals relative to the total number of individuals of all the species in each location. From Aguilar *et al.* (1997); Aguilar and González (2000, 2002); unpublished data from G. González.

	Coast of the City of Havana	La Herradura	Cayo Levisa
Abudefduf saxatilis	2.0	3.9	1.6
Acanthurus bahianus	10.3	4.8	1.0
Acanthurus coeruleus	3.2	7.0	1.0
Caranx ruber	1.6	5.7	0.0
Chromis cyanea	4.0	2.1	14.2
Chromis multilineata	2.7	0.7	0.9
Clepticus parrae	1.1	0.0	3.9
Granma loreto	0.4	1.2	8.6
Haemulon flavolineatum	4.3	3.4	0.3
Haemulon plumieri	2.1	0.3	1.0
Halichoeres bivittatus	7.0	10.7	1.8
Mulloidichthys martinicus	1.4	5.3	0.2
Pempheris schomburgki	0.3	5.4	0.0
Halichoeres garnoti	2.1	0.7	4.3
Scarus taeniopterus-iserti	0.4	3.1	15.1
Scaridae (juveniles)	1.3	5.0	2.7
Sparisoma aurofrenatum	2.1	3.9	4.3
Stegastes leucostictus	0.8	0.8	2.6
Stegastes partitus	17.5	1.5	9.2
Thalassoma bifasciatum	26.2	23.4	12.7
Total	90.8	88.8	85.4

seagrass beds at night (lobsters, many commercially important fishes). These are daily migrations. On the other hand, a group of species that inhabits the seagrass beds and shallow reefs concentrates near the edge of the platform to spawn, generally at points with projections into the ocean (crowns). These are seasonal migrations. Many of the animals that inhabit the reef continuously or take refuge in it have their nursery areas in mangroves (among the roots) or in seagrass beds. These are migrations throughout the life cycle.

There are areas with well developed reefs in practically the whole northwestern area, but the most extensive zone is located in the Banco Sancho Pardo, in the western part of the region (Fig. 19.2). It continues as a reef system throughout the edge of the platform and is known locally as Arrecife Colorados. Although Pavlidis and Avello (1975) state that this can be considered as a barrier reef (and the only true one of its kind in the whole Cuban archipelago), it seems more appropriate to consider it as a coastal bank reef, or bank-barrier reef. In this zone the layout of coastal marine ecosystem fully coincides with the model discussed previously (Fig. 19.4). The physical and biological interactions between the ecosystems previously described are likely to be characteristic of the region.

HUMAN ACTIVITY

Fishing is the main human activity that has a broad effect on the living resources of the northwestern region of Cuba. Only5% of the country's total commercial fisheries catch is from this part of the Cuban shelf, and its yield per unit of area, which is one of the lowest, has been calculated at 920 kg/km^2 (Claro *et al*. 2001). The greater part of this catch consists of fish (Table 19.5), although small amounts of lobster and molluscs are caught.

Most fish species with higher commercial value (snapper, grouper, tuna) have exhibited a decreasing trend in recent years, while species with a lower value (smaller and at lower trophic levels) show the opposite trend (mojarras, pompanos, other fish). This situation coincides with the characterization of Cuban fisheries in general recently made by Baisre (2000). This author found well defined trends in the decrease of trophic level and maximum average size of species caught on the Cuban shelf. A tendency to decrease has also been observed for lobsters since 1985-1986, when historical maximum catches surpassed the maximum sustainable catch potential (373 t) calculated for the region (Puga *et al*. 1992).

The trends in commercial activity and direct observations carried out by visual census (Table 19.5) indicate that there is excessive exploitation of most of the species with high value (groupers, snappers, large parrotfish, large pompanos, among others). There are no statistics on sport or subsistence fisheries practiced by the region's inhabitants, but it is reasonable to assume that it must be intense and, unfortunately, very effective, because it includes underwater fishing and the use of clandestine gillnets (which are prohibited by law).

The decrease in the catch of highly migratory species (swordfish, marlin, sailfish and ocean sharks) seems to respond to a general phenomenon of overfishing of these species that transcends national waters (Baum *et al*. 2003). All the species involved are caught across thousands of kilometers in international waters or in other countries and the regulation of their fisheries is very difficult without some kind of international collaboration. In accordance with the world wide trend, sea turtle fisheries have been totally suspended.

Another important aspect of human impact is pollution originating from land. In the case of the northwestern region, this problem is limited to small areas of the coast where, nevertheless, it can be severe. The most notorious case is that of Bahía de la La Habana, which shelters the most important port in the country, receives the impact of a very large city and is surrounded by diversified industrial development (Areces and Toledo 1985; González 1991; Beltrán *et al*. 1998). The impact of the water from the bay on the coastal zone has been documented in several studies of marine fauna (Herrera and Alcolado 1983; Herrera 1984; Alcolado and Herrera-Moreno 1987; Herrera and Martínez-Estalella 1987; Aguilar *et al*. 2004, among others). Three other bays (Mariel, Cabañas and Honda), very similar to Bahía de la La Habana in origin and morphology, are located in the easternmost stretch of the northwestern region (Fig. 19.3). The level of contamination in these water bodies is far less and decreases towards the west, as the density of human population next to them and associated intensity of port and related industrial development is reduced. Several rivers in the region are also polluted, mainly those that run through the city of Havana and adjacent areas (Almendares, Quibú, Jaimanitas, among others). The impact of the Río Almendares on the marine fauna of the coastal area has been documented

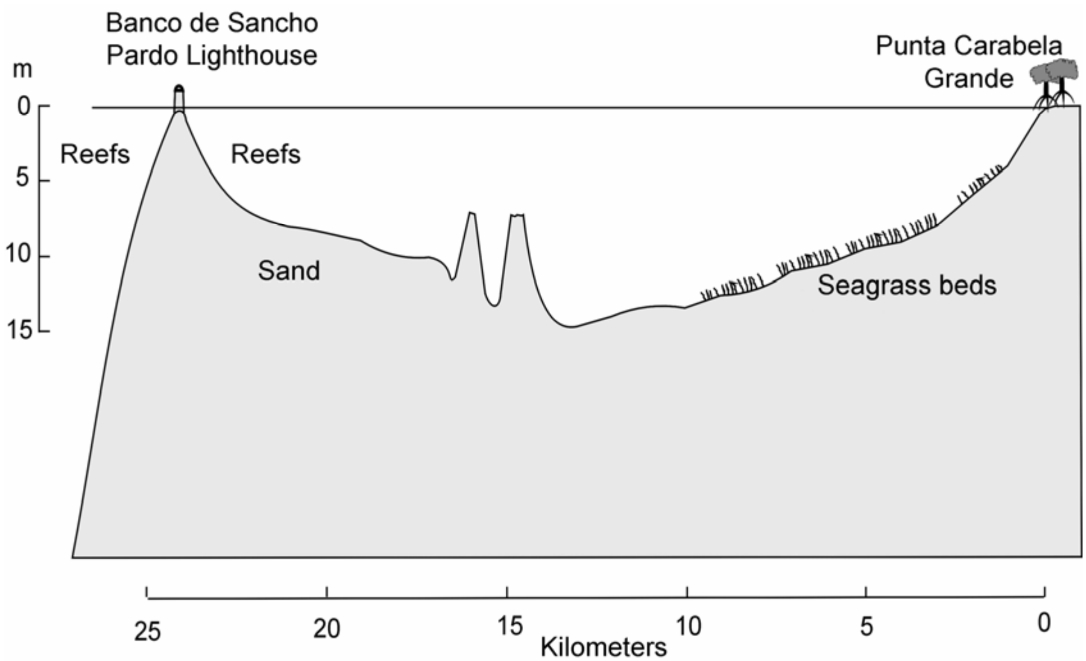

Figure 19.4. Coastal profile corresponding to the western zone of the Gulf of Guanahacabibes. The profile follows line AA' shown in Figure 19.2.

in a series of recent papers (Guardia *et al*. 2001; Aguilar and González-Sansón 2002; González-Sansón and Aguilar 2002). Other rivers in the region also show some degree of pollution, but there is no published data to determine the amount and type of contaminants.

It is important to highlight that in all estuarine systems and the coastal zones under their influence, there is the effect of increased sedimentation and a tendency to eutrophication. These are natural processes that can be exacerbated by human activity, mainly by deforestation and agriculture. With the current level of knowledge, it is not possible to suggest an idea, even partial, of how these factors affect marine ecosystems in the region, or separate their effect from the influence of pollution in the most critical areas. Nevertheless, the predominant idea is that coral reefs, mangroves and seagrass beds are generally in good condition of conservation, although there is excessive exploitation of commercially important fish. This idea is based on the fact that most of the coastal zone is not densely populated, agricultural activity is not very intense and there is no industrial or tourism development that could severely impact large areas. On the other hand, there is the criterion that platform waters (long, narrow and conveniently orientated) are renewed with great efficiency through their interaction with the ocean.

The government of the Republic of Cuba recently announced its willingness to negotiate contracts for the exploration of oil and gas in deep waters of the exclusive economic zone of Cuba in the Gulf of Mexico. This zone borders with the region of interest, and the possible commencement of petroleum exploration and extraction activities in the near future represents a further element to promote coastal marine ecosystems research, in foresight of a possible accident and the need to have baseline data.

Table 19.5. Main commercial catch species in the northwestern region of Cuba. The numbers show representative values in a chronological series of more than 30 years (1962 – 1994). From Claro *et al*. (2001); Baisre (2000).

Common Name	Scientific Name	T /Year	Catch Tendency
Lane Snapper	*Lutjanus synagris*	250	Decreasing
Mutton Snapper	*Lutjanus analis*	125	Stable
Gray and Cubera Snapper	*Lutjanus griseus* and *L. cyanopterus*	30	Stable
Yellowtail Snapper	*Ocyurus chrysurus*	125	Stable
Nassau Grouper	*Epinephelus striatus*	100	Decreasing
Grunts	*Haemulon* spp.	200	Stable
Mojarras	*Eugerres* spp. and *Gerres cinereus*	≅ 5	Increasing
Mullets	*Mugil* spp.	≅ 2	Stable
Pompanos	Carangidae	35	Increasing
Skipjack and Blackfin Tuna	*Katsuwonus pelamis* and *Thunnus atlanticus*	500	Decreasing
Mackerels	*Scomberomorus* spp.	8	Stable
Swordfish, Marlins, Sailfish,	*Xiphias gladius, Makaira* spp., *Tetrapturus albidus*, *Istiophorus* spp.	150	Decreasing
Atlantic Thread Herring	*Opisthonema oglinum*	20	Stable
Sharks	*Carcharhinus* spp., *Hypoprion signatus*, *Isurus* spp., among others	500	Decreasing
Other Fish		400	Increasing
Lobster	*Panulirus argus*	250	Decreasing
Mollusks	*Crassostrea* sp., *Strombus gigas, Cassis* sp.	400	Decreasing
Sea Turtles	*Chelonia mydas, Caretta caretta,Eretmochelys imbricata*	300	Suspended
Region Total		3400	

PERSPECTIVES

The existing information on marine ecosystems of the northwestern Cuban platform is very general and is mainly focused on determining spatial variation on a scale of tens of kilometers, although it includes some studies aimed at the determination of spatial variation at smaller scales. The temporal variation has been researched in a limited way, considering mainly seasonal variations. Particularly noticeable is the lack of research analyzing inter-annual variation in the structure or function of marine ecosystems. Furthermore, an important part of the most extensive papers is fairly old (mostly published over 15 years ago).

Due to the reasons stated above it is necessary to promote the development of a comprehensive project with the objective of evaluating the current general condition of marine biological diversity in the northwestern coastal zone of Cuba. Such project should aim at the establishment of the distribution of the main habitats, threats due to human impact, and recommended actions to preserve the biological diversity and the rational use of the ecosystems and of some economically important or threatened species.

A project of this nature must properly balance research at different spatial and temporal scales. This implies the combination of techniques based on remote sensing and the application of geographical information systems to prepare synoptic maps of habitats at regional level, with detailed small scale research of selected sections of the main ecosystems (mangrove and estuarine systems, seagrass beds and coral reefs). This level will lead to noticeable improvement of the biological diversity inventory, and to research on basic processes such as primary productivity and its fate in the food web, the ecology of larvae and juveniles associated with recruitment processes, the processes concerning coral growth and particularly calcification rate, among others.

In a project of this nature research aimed at the establishment of the effect of land pollution on marine and estuarine ichthyofauna, scleractinian corals and seaweeds must be given high priority, with the performance of analyses at various levels of organization (individual, population and community).

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