Chapter 42

THE CARIBBEAN COAST OF COLOMBIA

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The Colombian Caribbean contains several tropical marine ecosystems (coral reefs, sea grass and calcareous algal beds). In addition it supports others in the northern area which are subjected to upwelling, where seasonal anomalies in the water temperature create special structural and functional characteristics of the biotic communities.

In oceanic areas, coralline and volcanic islands form the archipelago of San Andrés and Providencia which contains very large and diverse coral reef formations. Major environmental problems in the Colombian Caribbean relate to urban development (sewage and solid wastes disposal), unplanned tourism, port development and road construction without proper studies and mitigating measures. Colombia has many environmental regulations which are hard to implement due to conflicting social, cultural and economic conditions. The national government and regional agencies are currently developing policies and plans for coastal management in which natural as well as socio-economic and socio-cultural factors are being integrated.

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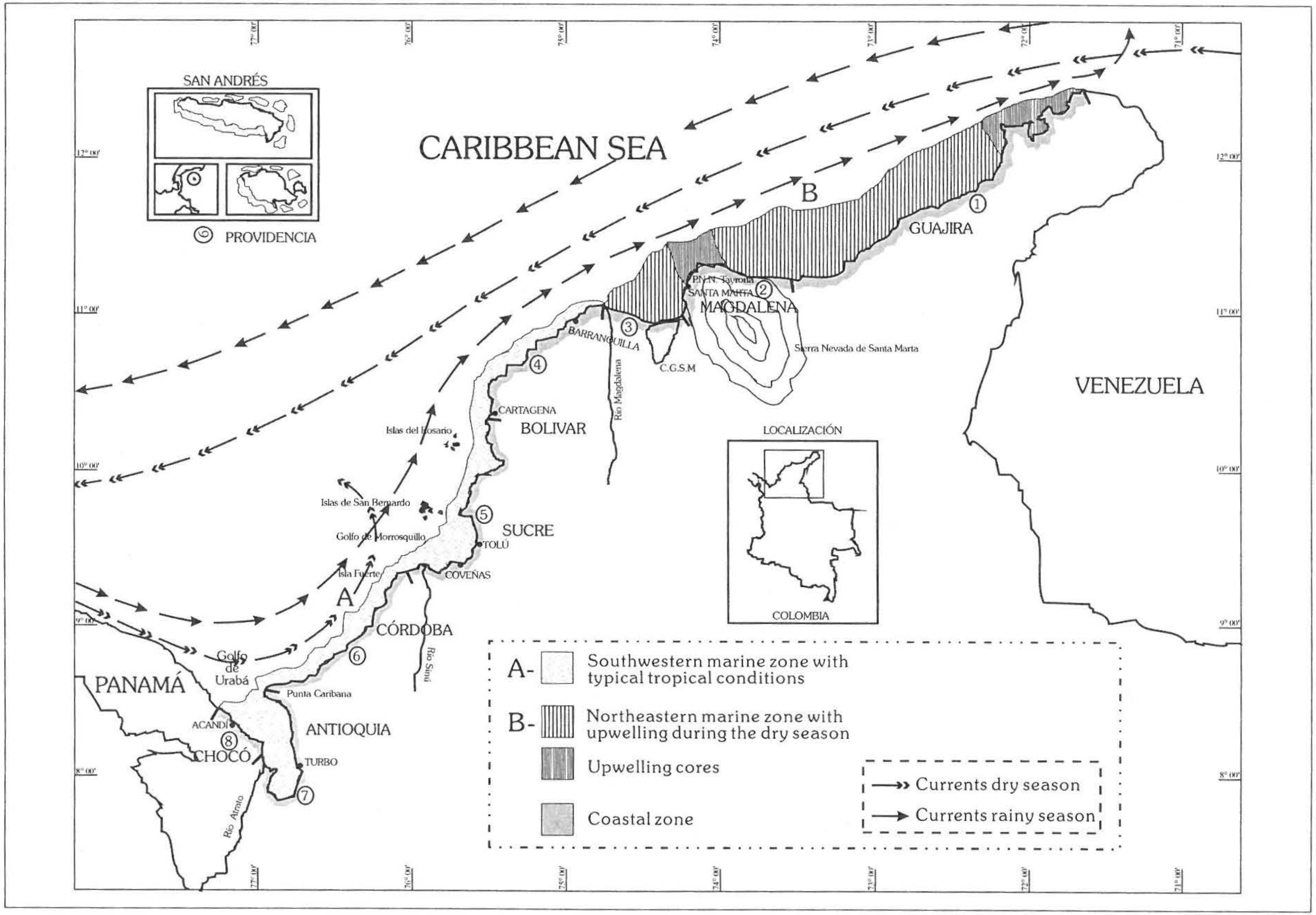

Fig. 1. The Colombian Caribbean with main oceanographic and coastal features, major currents and coastal provinces.

THE DEFINED REGION

The Colombian Caribbean marine area covers approximately 540,876 km² of the southern Caribbean Sea, along a coastline of 1600 km, from Cabo Tiburón, bordering Panama, to the border with Venezuela in the Guajira Península (Fig. 1). Included in this area is the archipelago of San Andrés and Providencia, a set of oceanic islands, atolls and coralline banks aligned north–northeast along the Nicaraguan Rise between 80°–82°W and 12°–14.5°N (Díaz et al., 1996). Although closer to Central America than to South America, these have been part of Colombia since 1822. A wide variety of tropical marine and coastal ecosystems are found along the Colombian coast, such as coralline and rocky reefs, seagrass and algal beds, mangroves, estuaries and coastal lagoons.

The Colombian Caribbean marine area can be divided into two main oceanographic categories (Alvarez-León, 1993) (Table 1). There is a Southwest zone from Golfo de Urabá, bordering Panama, to the mouth of the Magdalena River in the Department of Atlántico. This includes the marine areas of the archipelago of San Andrés and Providencia, and has conditions which are typical of tropical seas. Secondly there is a Northeast zone from a few km east of the mouth of the Magdalena River, in the Department of Magdalena, to the tip of the Guajira Peninsula, with seasonal oceanographic conditions similar to those of subtropical waters. This difference is due to ocean–atmosphere interactions when east tradewinds predominate; these provide the necessary energy to generate such anomalies as upwelling in some parts of the northeastern Colombian Caribbean.

SEASONALITY, CURRENTS AND NATURAL ENVIRONMENTAL VARIABLES

The climate of the Caribbean coast of Colombia is characterized by a bimodal wet–dry seasonality. A strong, dry season from December to April, is followed, in some areas, by a short rainy season in May and June. In July and August dry conditions predominate and from September to November there is maximum precipitation throughout the region. Between Santa Marta and the northernmost limits of the Guajira department, the climate is very dry with a precipitation of 500–1000 mm/yr. From the mouth of the Magdalena River to the Golfo de Urabá, precipitation ranges between 1000 and 1500 mm/yr while on the southernmost part of this Gulf precipitation is around 2000–2500 mm/yr. Relative humidity oscillates between 80 and 98% with an average value of 88% (Alvarez-León, 1989; HIMAT 1992). The duration and intensity of the dry season in the Colombian Caribbean is largely determined by the predominance and strength of the northeast tradewinds, while during the rainy season, winds from the southwest blow along most of the coast (Bula-Meyer, 1990a).

Average temperatures for Colombian Caribbean waters range between 28 and 30°C. Tidal ranges are only 0.3–0.5 m (Alvarez-León, 1989; Giraldo, 1994). Currents are governed mainly by strong east tradewinds which generate the Caribbean Current which has a western direction, or by southwest-west winds which generate the weak Colombian Countercurrent that flows east from the Golfo de Urabá (Fig. 1) (Bula-Meyer, 1990a; Donoso, 1990; Giraldo, 1994). During dry seasons, when tradewinds from the northeast are blowing at their maximum speed, the Caribbean Current may reach as far west as Golfo de Morrosquillo, restricting the action of the Colombian Countercurrent to the southwestern section of the Colombian Caribbean. When northeast tradewinds decrease their speed during the rainy seasons, the Colombian Countercurrent may reach as far east as Riohacha in the Guajira Department.

Continental fresh water flows into the Colombian Caribbean mainly from three major rivers: Magdalena, Atrato and Sinú. The Magdalena River, which is the largest river in Colombia with a length of 1,500 km, drains a basin of approximately 257,438 km² along a considerable part of the Colombian Andes. Daily measurements between 1940 and 1993 indicate an annual water discharge of 7106 $m^3 s^{-1}$ and a sediment transport of 138.92×10^6 t yr^{-1} (Restrepo and

Table 1

Characteristics of the Colombian Caribbean, Southwest and Northeast of the Magdalena River mouth.

Characteristic	Southwest zone	Northeast zone
Continental platform	Wide	Narrow
Coastal topography	Flat with low elevations	Abrupt with elevations up to 5775 m a.s.l.
Average precipitation	Around 800 mm during the dry season and 1200 mm during the wet season	Less than 200 mm during the dry season and around 500 mm during the wet season
River discharge	Magdalena, Atrato and Sinú (year-round)	Small, seasonal rivers
Upwelling and/or outwelling	Outwelling mainly during rainy season	Upwelling during dry season
Climate	Semi-arid and semi-humid	Dry-arid
Surface water temperature	Warm, tropical (>28°C), little seasonal variation	Cooler (°C), drastic seasonal changes
Average sea-water salinity	≤35 ppt	≥36 ppt
Coral reefs and seagrass beds	Well developed, down to 50 m depth	Restricted and little developed, down to 20–30 m depth

Kjerfve, 2000). The Atrato River, the second largest river in Colombia, drains a basin of 35,700 km^2, discharges 2740 $m^3 s^{-1}$ of water into the Caribbean Sea and transports approximately 11.26×10^6 t yr^{-1} of sediment. The Sinú River empties into the Golfo de Morrosquillo and drains 10,180 km^2. Measurements from 1963 to 1993 indicate an annual water discharge of 373 $m^3 s^{-1}$ and a sediment transport of 6×10^6 t yr^{-1}. Restrepo and Kjerfve (2000) estimate annual water and sediment discharges from Colombian rivers into the Caribbean to be 333.77 $km^3 yr^{-1}$ and 163.17×10^6 t yr^{-1}, respectively.

In the archipelago of San Andrés and Providencia, northeast and east–northeast tradewinds are predominant most of the year, with average speeds ranging between 4 and 7 m s^{-1} (Díaz et al., 1996). Strong wave energy generated by these tradewinds is an important factor that largely controls the geomorphological characteristics of the archipelago as well as its sedimentological regime and biological communities. During the second half of the year, storms with winds of up to 20 m s^{-1} from the West and Northwest can occur sporadically (Díaz et al., 1996). The archipelago is located in the hurricane belt of the Caribbean and thus is periodically affected by them, with considerable damage both to the coral reefs and to the infrastructure of the islands.

Upwelling System

A large part of the Northeastern Colombian Caribbean (north of the Magdalena River mouth) (Table 1) is characterized by a coastal upwelling of deep (150–200 m) 'sub-tropical underwater' mainly during the long and short dry seasons (Perlroth, 1968; Bula-Meyer, 1977; Fajardo, 1979), when northeast tradewinds blow at average speeds of 10 m s^{-1}. This water mass has a relatively higher nutrient concentration (9–12 times richer in NO_3), lower temperature (22–25°C) and higher salinity (36.5 ppt) than normal Caribbean surface waters (Bula-Meyer, 1985). The relatively low level of inorganic nutrients, as compared to other upwellings in Perú or California is due to specific conditions of the Subtropical Underwater which upwells from areas already impoverished in these nutrients (Corredor, 1977, 1979). Phytoplankton productivity along this coastal upwelling has been estimated and although values are much lower than those of Perú or California, they are significantly higher than those found for normal Caribbean waters (Corredor, 1979).

Upwelling is the cause of special environmental conditions that characterise the coastal waters along Magdalena and Guajira departments, where two main cores have been identified, one across from the northern Guajira Peninsula and the second across Cabo de la Aguja and Tayrona National Park (Wust, 1964; Gordon, 1967; Bula-Meyer, 1985). The last of these has been described mainly by the physical–chemical conditions of surface waters and their effect on the macroalgal communities of the area (Bula-Meyer, 1985). The latter are vigorous and rich in species diversity. Upwelling, together with strong water agitation and abundant rocky substrata down to 10–25 m deep, causes several anomalies to the typical Caribbean flora during the dry seasons. These include blooms of benthic macroalgae, an increase in species number, growth 2–4 times greater than that for the same species in other Caribbean areas, atypical zonation of several species, an absence of certain characteristic genera and species of the Caribbean (*Penicillus, Turbinaria, Cymopolia*) and the presence of certain subtropical and warm temperate genera and species (*Plocamium, Porphyra, Acrosorium, Ectocarpus confervoides, Dictyopteris hoytii*) (Bula-Meyer, 1977, 1989–1990, 1985).

Several other correlations between upwelling and biota have been identified (Antonius, 1972; Werding and Erhardt, 1976; Guillot and Márquez, 1975; Meyer and Macurda, 1976; Caycedo, 1977; Alvarez-León et al., 1995). The existence of only small, coastal fringing reef in the internal parts of bays and inlets, and the lack of true coral reefs near Santa Marta and Guajira have been attributed in part to the cold temperature generated by the upwelling.

During rainy seasons, coastal upwelling recedes, due to a weakening of the northeast tradewinds. The Colombian Countercurrent can then reach Tayrona National Park carrying substantial amounts of suspended sediments and nutrients from the Magdalena River. This generates phytoplankton blooms, water turbidity and decreases in salinity by 2–4 ppt relative to upwelling values (Bula-Meyer, 1985). Paradoxically, the biomass of most macroalgal populations decreases dramatically, probably due to temperature increase as hypothesized by Bula-Meyer (1989–1990).

SHALLOW WATER MARINE ECOSYSTEMS AND COASTAL HABITATS

The Colombian Caribbean Sea contains most types of marine ecosystems and habitats of the Western Tropical Atlantic. These include, coral reefs, seagrass beds, subtidal algal beds, mangrove wetlands, estuaries, coastal lagoons, sandy and muddy subtidal and intertidal flats and rocky shores. The region (both marine and terrestrial) includes eight National Parks and five other protected areas, sanctuaries or forest reserves covering approximately 2000 km^2 and including all of the above-mentioned marine ecosystems as well as different terrestrial ones (Alvarez-León, 1989; Sánchez-Páez and Alvarez-León, 1997).

Coastal Morphology

Based on CORPES-CA (1992) and Molina et al. (1998), the coastal and marine areas of the Colombian Caribbean can be categorized as having the following sectors or provinces (Fig. 1):

(1) *Guajira Peninsula*: from the mouth of the Palomino river to the northern end of the Guajira Department, the coastal zone is mainly desert. The northern section of coast is very rocky, while the middle and southern sectors are

made of continental and marine clastic deposits. The absence of topographical barriers allows for strong wind and wave action on the coastal edge. Hurricane tails and periodic strong waves also contribute to erosion of this coast. It is a very wide continental platform with extensive macroalgal beds (Schnetter, 1981) with some endemic marine fauna (Díaz, 1990).

(2) *Sierra Nevada de Santa Marta*: from the mouth of the Palomino River to the northeast of Ciénaga city the coast is made of igneous and metamorphic rocks with a hilly and mountainous topography, some of which extends into the sea forming small bays and inlets with sandy beaches, seagrass beds and narrow fringing coral reefs. The continental platform is very narrow, due to which accretional sedimentary processes are absent. There is low vulnerability to wave action and erosional processes due to strong lithological consistency.

(3) *Magdalena River Delta*: from Ciénaga city to Bocas de Ceniza–mouth of the Magdalena River there is a low coastal zone, subject to floods and made of terrigenous silt, clay and sands. The large sand bar "Isla de Salamanca" contains a variety of environments such as mangroves, salt and flood plains, coastal lagoons, sand dunes and beaches. It is very vulnerable to wave and wind action, and is subject to erosional processes. The continental platform and slope is traversed by submarine canyons probably built by the old mouth of the Magdalena River.

(4) *Central Caribbean*: from Bocas de Ceniza–mouth of the Magdalena River to Cartagena, tertiary sedimentary rock hills alternate with fluvial quaternary deposits. There is considerable sediment movement from the mouth of the Magdalena River. The continental platform, made of terrigenous sands and sandy silts, ranges in width from 5 to 30 km. The littoral zone is dominated by sandy beaches subjected to strong wave action and interrupted by rocky cliffs and sand bars across the entrances of coastal lagoons such as Ciénaga de la Virgen. Mud diapirism is common.

(5) *Cartagena–Punta de Piedra and Isla Fuerte*: this is a coast of tertiary sedimentary rocks mixed with different quaternary deposits. Two important deltas are located in this sector: Canal del Dique is a river-dominated delta protected from wave and tidal action by the bay of Barbacoas. The Tinajones Delta (Sinú river) is formed both by wave and fluvial energy. In this sector, large accretion processes are due to fast development of deltas. The continental platform is covered by terrigenous sediments and coral reefs, the latter being found around the archipelagos of Islas del Rosario, Islas de San Bernardo and Isla Fuerte.

(6) *Punta de Piedra (Isla Fuerte)–Punta Caribana*: this area is lithologically constituted by lodolites and turbidites. Erosion is critical in this area and affects several human settlements. The continental platform is wide here and is made of terrigenous sediments. Mud diapirism is common both on the platform and on the continent.

(7) *Urabá Gulf*: the landscape of this region is defined mainly by alluvial plains and mangrove forests. The gulf shows the largest sedimentary accretion found on this Caribbean coast and is related to the rapid progradation of the Atrato River through its deltaic system.

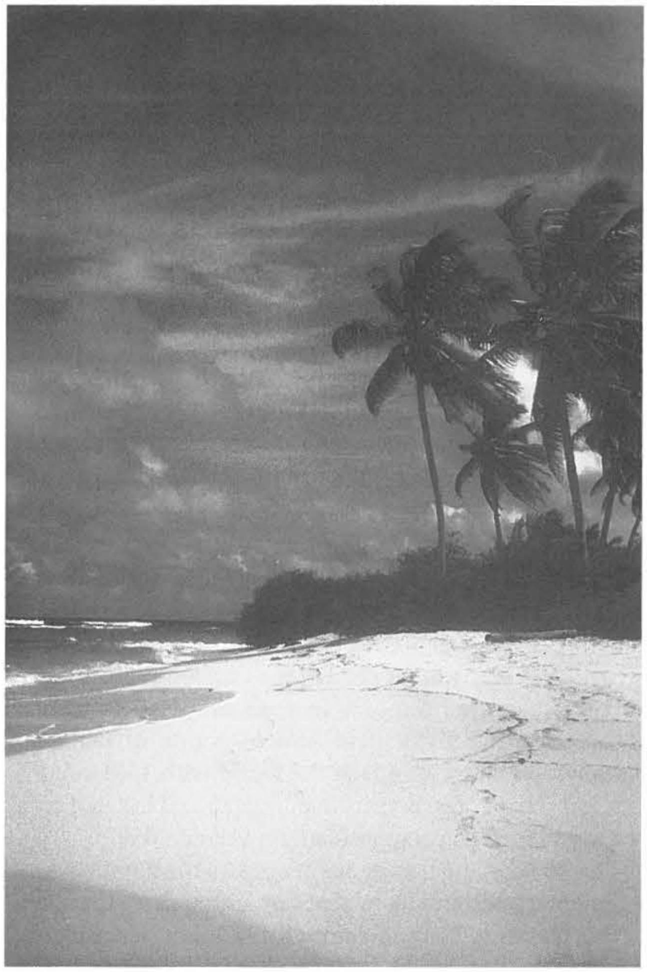

Fig. 2. Bolivar Cay in the oceanic archipelago.

(8) *Darien*: this is a mountainous zone made mainly by tertiary volcanic rocks organized into discontinuous cliffs, separated by alluvial valleys. There is very low coastal erosion. The continental platform is made of terrigenous silts and bioclastic sands with coral formations along the rocky littoral zone.

(9) *Island areas*: islands include the oceanic islands San Andrés and Providencia, with cays and banks, the whole forming one extended archipelago (Figs. 1 and 2). The origins of the islands and banks are associated with volcanic activity and exuberant coral reef development. Reefs are the dominant factor in the present marine environment of this area, forming wide barriers and rings on reduced platforms around the islands. The complex processes of growth, erosion, sedimentation and alteration of current and wave patterns of coralline formations, have shaped the submarine relief and promoted the presence of other associated environments such as reef lagoons, seagrass beds and sand flats with calcareous algal beds.

Coral Reefs

The largest and most important coral reef formations are located in the oceanic area of the Colombian Caribbean around the islands and cays of archipelago of San Andrés and Providencia, more than 700 km offshore, north of the Colombian continental coast and to the east of the Nicaraguan platform (Fig. 1). Coral formations include two barrier reefs offshore from the two major islands, San Andrés and Providencia, as well as patch and fringing reefs, atolls and banks (Díaz et al., 1996). The coralline system around these islands is one of the largest in the Atlantic (approximately 5000 km^2 including coral reefs, seagrass beds and sedimentary bottoms) and the reefs support approximately 45 species of scleractinian corals, 163 macroalgal species, 118 species of sponges and 40 gorgonaceans (Diaz et al., 1996). Recent studies (Díaz et al., 1995; Díaz et al., 1996; Garzón-Ferreira and Kielman, 1993; Garzón-Ferreira et al., 1996; Garzón-Ferreira, 1997) indicate a considerable and general degradation of coral reefs in this area, similar to that occurring in many other parts of the Caribbean Sea. Degradation is observed not only in reefs subjected to intense anthropogenic activity (San Andrés is one of the most densely populated islands in the world with 1548 inhabitants km^{-2}) but is also occurring in remote and isolated reefs of the archipelago complex (Garzón-Ferreira, 1997).

Due to substantial river discharge and the dominance of sedimentary bottoms, coral reefs are scarce along the continental platform (Garzón-Ferreira, 1997). Less than 10% of this continental fringe has coralline development. The largest and most developed coral formations are found in the southwest (Table 1) around the archipelago of Islas del Rosario (southwest of Cartagena), Islas de San Bernardo (across Golfo de Morrosquillo) and Isla Fuerte (Fig. 3). In Golfo de Urabá, fringing reefs are limited to the northwestern coast close to the Panamá border, due to fresh water and sediment outflow from the Atrato river. In general, the southwestern zone of the continental Caribbean is influenced by periodic outflows of freshwater, nutrients and sediments through the Atrato, Sinú and Magdalena river mouths, as well as by increasing tourism and other anthropogenic actions which affect the health of coral ecosystems. In the northeastern zone (Table 1) of the continental Caribbean coast, coral formations are found mainly along the Santa Marta and Tayrona National Park coastline. Here, cold upwelling waters, lower water transparency and hard substrata which is generally limited to approximately 25 m depth, restrict coral formations to small, shallow fringing reefs (Garzón-Ferreira and Cano, 1991). These fringing reefs also suffer from anthropogenic activities in the coastal zone such as sewage discharge, tourism and blast fishing, as well as freshwater, sediment and nutrient riverine outflow during the rainy seasons. Coral formations along the Guajira platform are limited to small patch and fringing reefs in restricted locations (Solano, 1994).

Almost all symptoms and factors relating to coral reef degradation which have been reported in the literature, have been observed during the last 20 years in the Colombian Caribbean (Garzón-Ferreira, 1997). Live coral coverage has decreased to an average level of 20–30% of available hard substrata. Massive coral mortality has occurred, as in other Caribbean areas, during the late 1970s and 1980s. During the 1990s, some degradation continued to occur, although massive episodic mortalities have not been reported except for the die-off of *Gorgonia ventalina* about a decade ago (Garzón-Ferreira and Zea, 1992; Garzón-Ferreira and Kielman, 1993; Nagelkerken et al., 1997a,b).

Coral reef health monitoring in Colombia began in 1992 when the marine research centre INVEMAR joined the CARICOMP international program and implemented a permanent monitoring site in the continental Caribbean coast. Monitoring sites have been extended now to two other localities, one in the area of Islas del Rosario and the other one in the oceanic reefs of the San Andrés and Providencia archipelago (J. Garzón, unpublished report).

Seagrass Beds

Although not very well studied, seagrass beds are found throughout large portions of the Colombian Caribbean, from the Guajira Península in the north, to the Golfo de Urabá in the southwestern limits, as well as around islands and cays in the oceanic archipelago of San Andrés and Providencia. The most conspicuous beds are located in Bahía Portete and Cabo de la Vela (Guajira department), bays and inlets of Tayrona National Park and Santa Marta area (Magdalena department), around Islas del Rosario in the Cartagena area, Islas de San Bernardo in the Golfo de Morrosquillo, Golfo de Urabá and areas around the islands and cays of the archipelago de San Andrés y Providencia. They are absent in areas influenced by strong freshwater discharges from large rivers (Magdalena, Sinú and Atrato). *Thalassia testudinum* is the most abundant and frequent species, found generally to a depth of 10 m. Other common species are *Syringodium filiforme, Halodule wrightii, Halophila decipiens, and Halophila baillones* (Laverde, 1994).

Important resources associated with seagrass beds (turtles, conchs, sea stars) have been depleted by man. Several beds have been damaged due to activities associated with urban, industrial or tourism development such as dredging or landfill in the Santa Marta area while others, far from urban centres, are well preserved (as in Tayrona National Park, Rosario islands, Guajira Peninsula and San Andrés and Providencia Archipiélago).

Macroalgae

This coast is rich in macroalgae, with approximately 450 species out of about 600 reported in the tropical and subtropical American Atlantic (Bula-Meyer, 1990b). This high diversity can be attributed in part, to old environmental

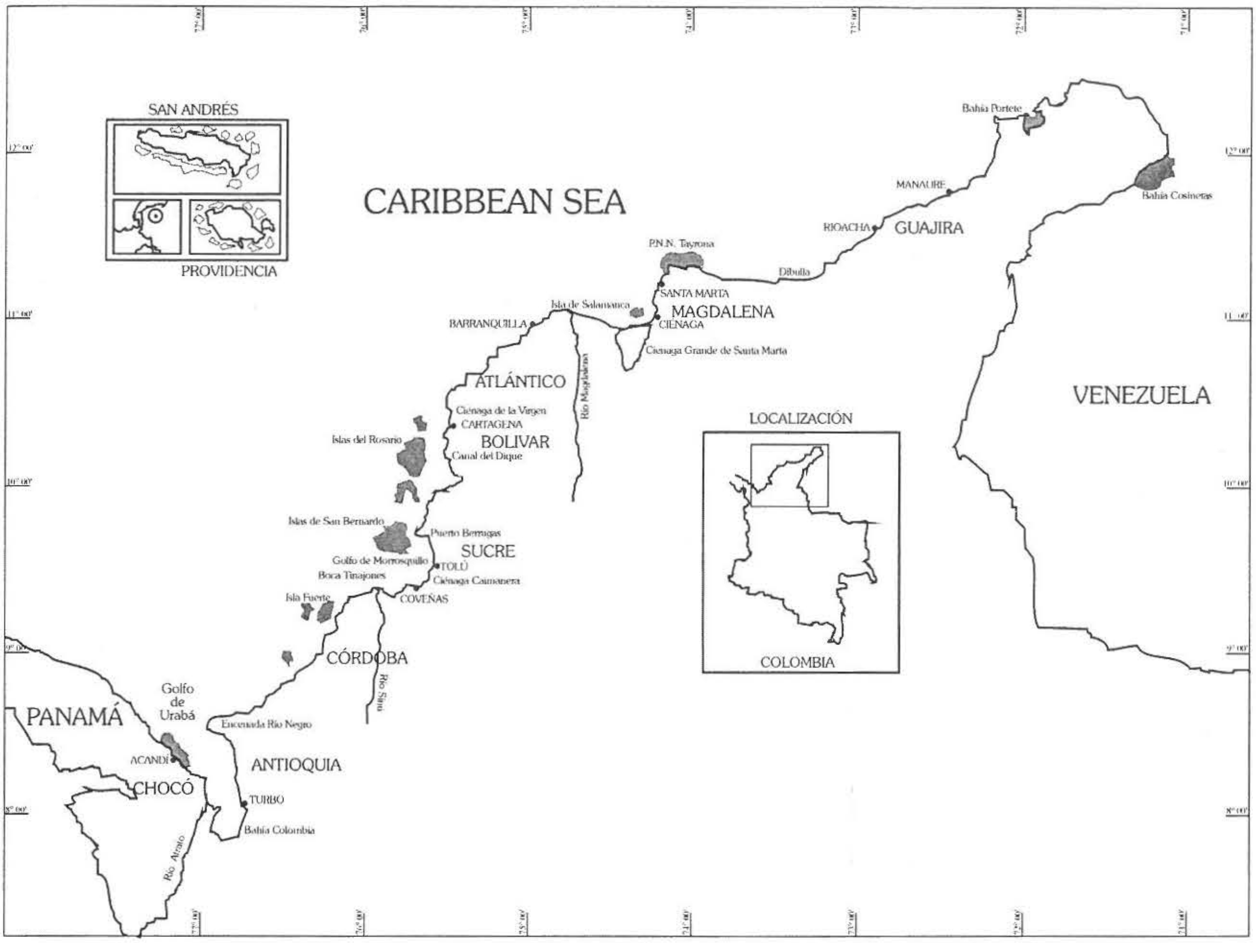

Fig. 3. Location of main coral and seagrass ecosystems.

diversity and stability (Bula-Meyer, 1990). The greatest species richness is found in the Santa Marta and Tayrona National Park area. The latter presents several outstanding factors relating to macroalgae, such as the presence of an endemic genus of brown alga, *Cladophyllum* (Bula-Meyer, 1980), and very large sizes in certain genera such as *Sargassum* sp. which can reach heights of 3–4 m in beds of several thousand square metres. Islas del Rosario, Islas de San Bernardo, Guajira Peninsula and the oceanic islands San Andrés and Providencia also show rich macroalgal flora.

Mangroves

Approximately 1530 km^2 of the Colombian Caribbean coast are covered by mangrove forests (Sánchez-Páez et al., 1997) composed mainly of *Rhizophora mangle, Avicennia germinans* and *Laguncularia racemosa*. In some areas, *Conocarpus erecta* and *Pelliciera rhizophorae* are also present. Generally, tree-height does not exceed 25 m due to predominantly arid conditions. The largest mangrove wetlands are found in the deltas of the Magdalena (including Canal del Dique), Sinú and Atrato rivers (Fig. 4). Smaller mangrove wetlands are found in the islands of San Bernardo and Rosario as well as in Ciénaga de la Virgen (close to Cartagena), Tayrona National Park, Bahía Portete (in the Guajira Peninsula) and Old Providence Island. Rehabilitation of mangroves is an important activity here.

OFFSHORE SYSTEMS

Importance of Fisheries

In the southwestern sector, river discharge supplies considerable nutrient enrichment into the pelagic environment, although turbidity associated with riverine waters prevents high photosynthesis of phytoplankton (CORPES-CA, 1992). The discharge of the Magdalena river is the most important continental source for fertilization of surface waters of the Colombian Caribbean, affecting an area larger than the Exclusive Economic Zone (CORPES-CA, 1992). The mixture of outwelled nutrients with marine waters causes the formation of "fronts" with higher pelagic productivity in which planctivorous organisms concentrate. There is not much information on the pelagic resources of the southern Colombian Caribbean although some records exist of the presence and artisanal catches of pelagic species, specifically *Tarpon atlanticus*. However, recently this population has been severely depleted due to destruction or

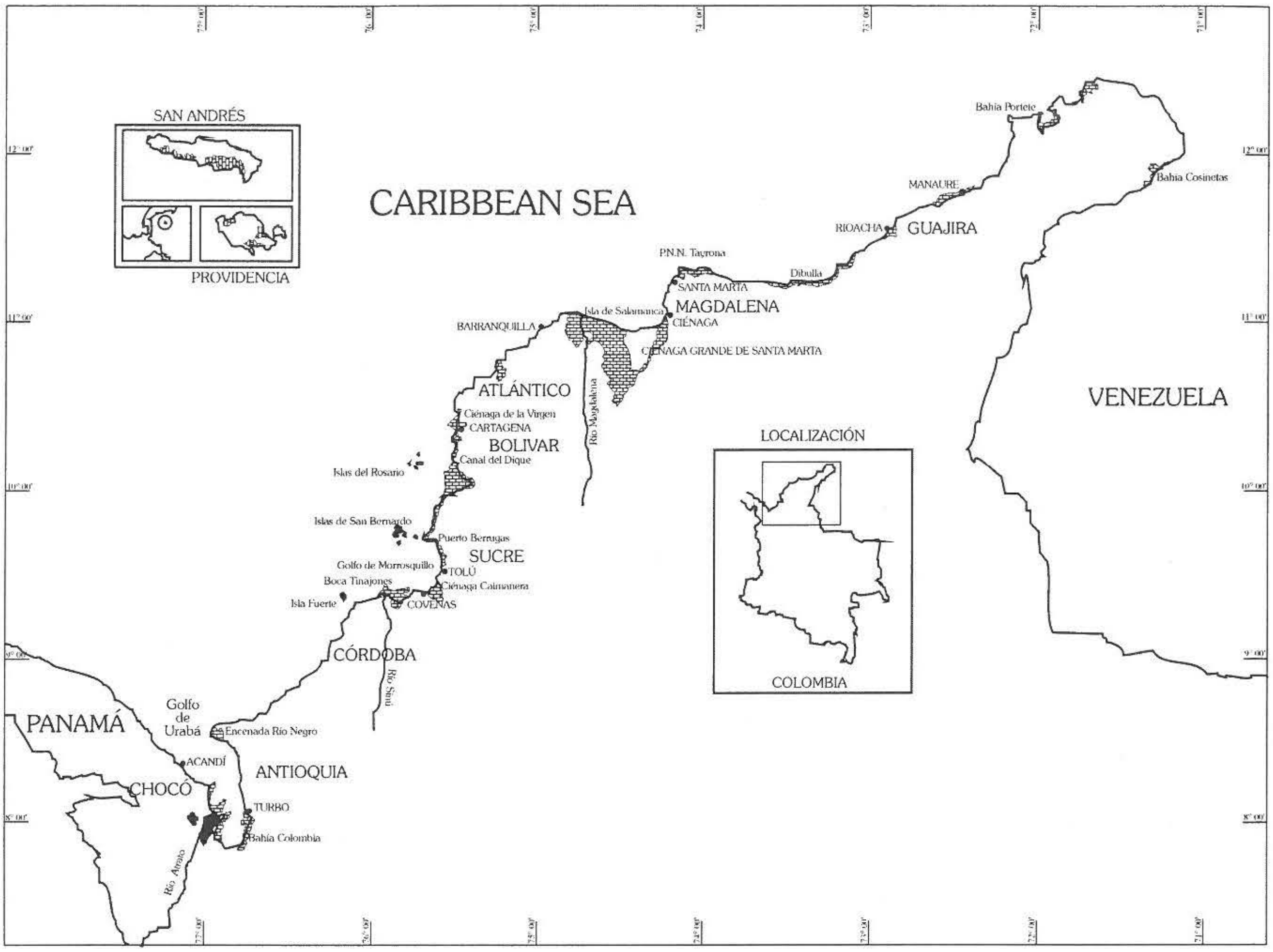

Fig. 4. Location of mangrove wetlands and main estuarine systems.

deterioration of coastal lagoons which were nursery areas for this species. Also common along this southern pelagic zone are sierras, carites and macabí (*Scomberomorus maculatus, S. ragalis, Caranx hippos, C. latus, C.crysos and Elops saurus*) (CORPES-CA, 1992). These species are not subjected to large-scale fisheries but are mostly captured by local, artisanal fishermen. Among small pelagics, *Opisthonema oglinum*, is abundant and widely distributed. Demersal resources are represented mainly by shrimps of the genus *Penaeus*, on which an important fishing industry is based.

In the northeastern sector, fish resources are mostly related to upwelling as described above. Small pelagics of the family Clupeidae are thought to be of potential importance for fisheries, mainly *Opisthonema oglinum, Sardinella anchovia and Harengula clupeola*. Associated with these planctivorous species are some relatively abundant predators, such as *Thunnus albacares, T. atlanticus, Auxis thazard, Scomber colias, S. japonicus, Decapterus macarellus, D. punctatus, Euthynnus alleteratus, Coryphaena hippurus* and *Elegatis bipinnulata*. Squids, such as *Loligo plei, L. pealei* and *Illex* sp. are another potential resource for the fisheries in this area although almost no research has been done on their populations (CORPES-CA, 1992; Alvarez-León et al., 1995). Demersal resources mainly include shrimps of the genus *Penaeus* (*P. duorarum, P. brasiliensis, P. notialis* and *P. subtilis*), snappers and pagoras, mainly *Lutjanus synagris* and *Micropogonias furnieri*, with maximum catches from Cabo de la Vela in the Guajira Peninsula (Alvarez-León and Lesser-Mehr, 1986).

Exploratory and commercial fishing cruises show larger catches per unit (both in weight and size of the individuals) in this northern area compared to the southwestern zone.

In general, industrial fisheries use towing vessels of the Florida type, with escape mechanisms for marine turtles. The most exploited resources since the 1970s are shrimps (*Penaeus notialis, P. brasiliensis, P. schmitti* and *Xiphopenaeus kroyeri*) from the shallow continental platform, although since the 1980s catches have decreased considerably. Shrimps are packed for export under strict quality control in processing plants in Cartagena. Demersal fishes are caught mainly as a by-product (ranfaña) of the shrimp fishing activity although a few vessels specialize in fish catches, mainly snappers, groupers, corvinas and sharks. Lately, tuna (*Thunnus atlanticus, T. thynnus, Euthynnus alleteratus*), fished with long lines and purse seines, has become a very important product for export to the United States,

Mangroves in the Magdalena River Delta

The Magdalena river delta comprises a very large, estuarine–lagoonal system (1280 km^2) known as Ciénaga Grande de Santa Marta. It is the largest of its kind in the Caribbean area and historically is the main source of fish and shellfish for the north coast of Colombia. Extensive mangrove forests covered 520 km^2 of this deltaic area up to the late 1960s. Three stilt villages are located in the two main lagoons of the system (Fig. 1). Anthropogenic activities during the last 40 years, mainly alterations to the hydrological regime through freshwater diversion, construction of roads, dikes and berms, resulted in salinisation of mangrove soils to salinities higher than 100 ppt for more than six months a year (Botero, 1990).

As a consequence of soil hypersalinisation, massive forest degradation started in the late 1960s and, up to the present day, almost 70% of the original forest is dead (Gónima et al., 1996). Besides mangrove mortality, a reduction in the diversity and abundance of fish, bird and invertebrate fauna has been reported, as well as contamination of water, sediments and organisms with pesticides, heavy metals and pathogenic bacteria (Botero and Mancera-Pineda, 1996). A progressive and significant increment in water salinity, seston concentration and eutrophication has also been documented to 1994 (Botero and Mancera-Pineda, 1996; Mancera-Pineda and Vidal, 1994)). During the last six years (1994–1999) the Colombian government has been implementing a rehabilitation project for the area, mainly through diversion of fresh water back into the system, management of forest and fisheries resources and social development programmes. Fresh water from the Magdalena river is flowing back into the system (approximately 163 m^3/s) and mangrove regeneration is clearly visible (Botero and Salzwedel, 1999). Several institutions involved in research and environmental management are currently monitoring the mangrove rehabilitation in terms of forest structure, nutrient exchanges, fish and shellfish populations and biodiversity. The Ministry of the Environment has been supporting and enhancing several other projects in which diverse planting methods are being devised for restoration of small-scale degraded areas. Hypocotyls, seedlings, shoots and stems, from natural forests and from experimental green houses, are obtained and planted with the active participation of the local native communities.

Fig. 1. Stilt village in the mangrove–lagoonal system Ciénaga Grande de Santa Marta.

European Union and Japan. Other abundant species caught with tuna *are Coryphaena hippurus, Tetrapterus albidus, Makaria nigricans, Xiphias gladius* (sword fish), *Scomberomorus cavalla* (sawfish) and several shark species such as *Galeocerdo cuvieri, Prionace galuca, Carcharodon carcharias* and *Isurus oxyrhychus.*

POPULATIONS AFFECTING THE AREA

According to the latest census, the Colombian Caribbean population reached 7,088,990 in 1993, which is 19.75% of the total Colombian population. Coastal inhabitants number approximately 2,800,000. The largest and most important population centres are the cities of Barranquilla, Cartagena and Santa Marta, where most tourism, industrial and port activities take place. The population on San Andrés and Providencia Archipiélago is approximately 50,000, San Andrés Island having one of the highest population densities (1850 inhab/km^2) in the Caribbean basin.

Fishing, tourism, ports and navigation (recreational and commercial) are the main activities in the marine areas, but since 1985 shrimp aquaculture has been developing steadily. Through several large rivers, the Caribbean coastal and marine areas receive many of the run-off substances and environmental impacts occurring inland, including from the Andean region which has a large human population and intensive urban and industrial activities. The Magdalena River alone discharges annually approximately 138 million tons of sediment into the Caribbean basin together with considerable amounts of nutrients, fertilizers and pesticides.

RURAL FACTORS

Artisanal Fishing

Artisanal fishing is an important activity sustaining inhabitants of small towns and villages located around the most productive ecosystems of the coast. Recent statistical information of fish catches indicates a decrease in fish resources mainly due to overfishing and habitat degradation (Sánchez-Páez et. al., 1997). Most fish products are destined for national or local (family) and tourism consumption and are sold in the cities of Cartagena, Barranquilla and Santa Marta. Mangroves and coastal lagoons are fished mainly for oysters (*Crassostrea rhizophorae*), mullets (*Mugil incilis, M. liza*), mojarras (*Eugerres plumieri, Gerres cinereus, Diapterus rhombeus*), catfish (*Arius proops., Cathorops spixii*), juvenile

Sierra Nevada de Santa Marta

Although not a marine ecosystem, Sierra Nevada de Santa Marta (SNSM), the highest coastal mountain in the world with a height of 5775 m a.s.l., exerts an important influence on the coastal zone of the Colombian Caribbean, especially around the area of Santa Marta, Tayrona National Park, Ciénaga Grande de Santa Marta and part of the Guajira Península. SNSM is very rich and diverse in terrestrial and freshwater ecosystems and is considered a Biosphere Reserve. At least 15 rivers originate in the ice caps of this mountain, draining different types of highlands, forests and agricultural lands and finally flowing into the Caribbean Sea or the estuarine lagoon Ciénaga Grande de Santa Marta. Due to colonization and related activities in the Sierra, these rivers carry increasing amounts of sediments, pesticides and organic matter which eventually reach the marine or estuarine zones. The very abrupt coastal topography of Tayrona Park and Santa Marta area is a direct consequence of the presence of this coastal mountain (Hernández-Camacho et al., 1998).

tarpons (*Tarpon atlanticus*) and snooks (*Centropomus undecimalis, C. ensiferus*), crabs (*Callinectes boucurti, C. sapidus*) and shrimps (*Penaeus* spp. and *Xiphopeneus kroyeri*). Red snappers (family Lutjanidae), groupers (family Serranidae), lobsters (*Panulirus argus*) and queen conch (*Strombus gigas*) are important resources associated with coral reefs, rocky bottoms and seagrass beds around the reefs of Islas del Rosario and Islas de San Bernardo, on the platform of the Guajira Peninsula (which is well known for its lobster catches) and from the oceanic islands (Alvarez-León and Lesser-Mehr, 1986; Gutièrrez and Valderrama, 1994).

A variety of artisanal fishing methods are used ranging from line hooks, gill nets, dragnets, casting nets and traps, to more harmful ones such as blast fishing, bolicheo and zangarreo. In the latter, areas are surrounded with gill nets and the water is hit with poles or agitated with an outboard engine to frighten fish or generate anoxic conditions due to removal of anoxic bottom sediments. This is done in coastal lagoons and mangrove areas. These methods obviously have consequences both for the environment and the associated living resources. Although blast fishing, bolicheo and zangarreo are illegal fishing practices, local authorities are unable to control them.

Aquaculture

Shrimp aquaculture started here in 1985, and today shrimp ponds with *Penaeus vannamei* and *P. stylirostris* cover a total area of approximately 1900 ha (19 km^2) in the southwest. No mangrove areas have been affected by this as farms have been located on sand flats and on high grounds or terrestrial lands. A total annual production of 6000 tons is exported to the United States, Europe and Japan. The productivity of Colombian shrimp mariculture is relatively high, approximately 2000 kg/ha/yr (Aguilera, 1999). In the last four years, shrimp mariculture has made important scientific and technological advances related to disease prevention and control. Through family selection procedures, the industry has now specific virus-resistant groups from which all larvae used by farmers to seed their ponds is now being produced. This means that Colombia is now self-sufficient regarding shrimp larvae production and can thus avoid import from other countries or wild catches, both of which are known sources of viral diseases to cultured shrimp.

Fish mariculture is still at the research and laboratory level with a few projects presently aimed at inducing reproduction in red snapper (*Lutjanus analis*) or on feeding and growth rate experiments with wild-caught snapper and grouper juveniles. Bivalve (oysters and scallops) mariculture has been developed at a research scale, with good prospects for artisanal or industrial applications, especially with *Crassostrea rhizophorae*, based on seed collection in the wild (H. Rodríguez, unpublished information).

Land Uses

According to IGAC (Instituto Geográfico Agustín Codazzi) 18% of the land along the Colombian Caribbean has agricultural potential, but various limitations mean that only 4% is economically suitable. Around 38% of the land is capable of forestry, but most of it should be dedicated just to conservation. Although only 32% of the land is fit for rearing cattle, the reality is that almost 72% of the land in the Caribbean region of Colombia is used primarily for this activity (CORPES-CA, 1992) with obvious environmental consequences to soil, forest and fresh water. Large palm oil, banana and other fruit plantations in the foothills of the Sierra Nevada de Santa Marta contribute to fertilizer and pesticide runoff into the coastal zone, especially into the Ciénaga Grande de Santa Marta (Plata et al., 1993). Increasing human settlement on this mountain, combined with agricultural activities and tree felling, promotes erosion around river beds, thus increasing sediment loads arriving at the coastal zone. Although legislation and measures are being implemented, to control anthropogenic activities in the middle and highlands, there is still much to be done in order to rehabilitate forests and watersheds on this large and important coastal mountain.

COASTAL EROSION

Table 2 gives quantitative information on the degree of erosion and accretion in the littoral zones. Of the 1600 km of Colombian Caribbean coastline, 12% shows accretion, 16% strong erosion and 72% is stable or variable. Highest accretion is linked to areas where deltas, sand spurs and large beaches are being formed. The greatest erosional processes (in Guajira, Isla de Salamanca, Punta Piedra-Punta Caribana

Table 2
Degree of erosion or accretion in the littoral zone of the Colombian Caribbean

Province	Erosion		Accretion	
	km	%	km	%
I. Guajira Peninsula	156	56	22	11
II. Sierra Nevada de Santa Marta	14	5	7	3
III. Magdalena River Delta	28	10	0	0
IV. Central Caribbean	11	4	24	12
V. Cartagena–Punta de Piedra (Isla Fuerte)	18	6	55	26
VI. Punta de Piedra (Isla Fuerte)–Punta Caribana	17	6	17	8
VII. Urabá Gulf	29	11	82	40
VIII. Darien	5	2	0	0

and Urabá Gulf) with possible consequences to industrial, urban or tourist areas, are mainly related to natural factors such as wave and wind energy, subsidence and/or sea-level rise, or to structures such as jetties, wave breaks or sites of sand and gravel extraction along beaches and river beds.

EFFECTS FROM URBAN AND INDUSTRIAL ACTIVITIES

Tourism

The Caribbean coast of Colombia is presently the main tourist area in the country. Although some ecotourism has been developing in recent years, the truth is that a large part of the coastal and marine habitat degradation can be attributed to disorganised and uncontrolled tourism activities. Harmful effects can be observed mainly in beach and coral reef areas close to main population centres where garbage accumulation, coral extraction and destruction, sediment and sewage discharges have had a significant effect. Governmental agencies in charge of environmental regulation are increasingly trying to protect the existing National Parks and Reserves as well as to increase their area, especially highly productive and diverse systems such as mangroves, coral reefs and coastal lagoons.

Port Activities

Significant traffic goes through ports on this coast. In the last ten to fifteen years, coal exports from mines in the Guajira Península and inland have significantly increased in number and size. Unfortunately, port construction is being done without adequate planning and without taking into account other uses of the coastal and marine zone. Coal export activities do not coexist well with tourism, fishing and urbanization, and have a negative impact on the tourism industry as a result of coal dust emissions in the air, water and beaches, as well as increasing cargo shipping close to tourist areas.

Crude oil is exported through a large marine facility in Golfo de Morrosquillo. Until 1998, crude oil was pumped to a large static ship tanker located in the middle of the Gulf from where oil would be distributed to ships. The static tanker was recently removed from the Gulf and oil is now pumped directly to ships entering and leaving the area periodically. So far, only small oil spills (100–200 gallons) have occurred as a consequence of these operations.

Urban Development

Several areas of this coast have poor sanitary conditions due to discharges of raw domestic sewage into the sea. No sewage treatment plants are available in the main urban centres. An estimated 26,300 tons/yr of sewage enters the Colombian Caribbean from urban and municipal areas. In addition, the sea receives, via several large rivers, many products from inland towns and industries, mainly in the Andean region with its large human population and intensive industries. The Magdalena River alone discharges annually approximately 138 million tons of sediment into the Caribbean basin, together with considerable amounts of nutrients, fertilizers, pesticides and heavy metals.

PROTECTIVE MEASURES

There are many regulations regarding natural resources and environments but only recently has the government started to develop specific policies and plans for integrated coastal zone management in which natural as well as social, economic and cultural conditions are taken into account. Probably the most noteworthy case is that of the rehabilitation programme of Ciénaga Grande de Santa Marta (PROCIENAGA, 1995) in which the national and local government have invested considerable amounts of financial resources and effort. It already shows positive signs of mangrove recovery. The programme has also led to preliminary fisheries management and control while convincing the native fishermen that the only way to guarantee a sustainable resource is to implement management measures and strategies. The National Parks Authority, together with the regional environmental agencies, are increasingly controlling impacts, especially in coral reef and mangrove areas through stricter enforcement of regulations. Several of the most polluting industries located around the Bay of Cartagena have been required either to decrease their pollutant load into the Bay or to close down.

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