STATUS OF THE CORAL REEFS OF THE DOMINICAN REPUBLIC
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1. INTRODUCTION

The Dominican Republic acknowledges that its coral reef resources are important, and their basic value lies in the natural protection they offer and the maintenance of Dominican beaches, which are the basis for the tourism industry. The island of Hispaniola is the second largest island in the Caribbean (78,000 km^2). It is located at 17º 40' and 19º 56' N latitude and 68º 20' and 70.01º W longitude, in the north central boundary of the Caribbean Sea. It is separated from Cuba to the north-northwest by the Windward Passage (4,000 m), from Jamaica to the west-southwest by the Jamaica Passage, (3,000 m), and from Puerto Rico to the east by the shallow Mona Passage (350-400 m). Oceanic currents and winds are governed primarily by the easterly trade winds.

Hispaniola is politically divided into two countries: Haiti to the west and the Dominican Republic to the east (Map 1). The Dominican Republic has a land area of 48,484 km^2, and a varied coastline of 1,389 km., 27% (376.7 km) of which are mangroves, and 11% (166 km) coral reefs. The main coastal features found along the coast are emerged reef terraces and cliffs, especially on the southeastern portion of the island. The continental shelf has a mean width of 7.5 km, and covers an area of 8,130 km^2. There are two submerged offshore banks: La Navidad and La Plata, 70 and 150 km^2 respectively, located north of Cabo Samaná, in the Atlantic Ocean (North Coast). These banks are important winter breeding and mating territories for humpback whales. Many wrecks from colonial times (1500's) can also be found here.

The Dominican Republic occupies a fairly large land mass. There are large rivers and streams washing extensive watersheds, and usually there are no coral formations directly downstream from them. The Caribbean coast is basically made up of carbonate reef terraces allowing shallow fringing reefs to develop. On the northeastern region there are usually mountainous terraines close to shore, associated with higher pluviometry which in turn cause short torrential streams that drain into the adjacent sea, loading it with sediments, and limiting reef growth. This occurs for approximately 1/3 of the coastline. Along the rest of the coast reef growth is of the fringing or barrier type. These usually occur in association with the dry regions of the country where waters are clear. Nevertheless, even in these dry regions there are three places that have natural sediment inputs and restrict reef settlement (Punta Martín García in Barahona, Punta Salinas in Peravia, and El Morro in Montecristi).

On the southern coast, on its sheltered portions where land projects into the sea, fringing and patch reefs can be found, becoming adequate and important breeding grounds for conch (*Strombus spp),* lobster (*Panulirus spp)* and a myriad of other species. Much of these breeding grounds are located in protected areas, such as Parque Nacional del Este (Eastern), Parque Nacional Submarino La Caleta (Central), and Parque Nacional Jaragua (Western). These protected areas are being exploited for its tourism and fisheries resources in varying degrees. The rest of the southern coastline is basically composed of uplifted Pleistocene to Recent reef terraces, where mayor cities are established (Geraldes, 1980). All along this coast one finds low relief, highly

eroded reef growth, basically due to high-energy conditions. In places where the marine platform widens (average width is less than 700 m), and the depth is below 40 m a well-developed reef structure with breaker zone is found. A beach is usually found in these places, and as a result the tourism industry has occupied the beachfront. In the southwestern region, depositional processes basically form the coastline, where basaltic and inorganic sands and stones configure the coastline. In these areas, reef formation is reduced to small patches due to the increased turbidity (highly mobile substrata) since rivers and stream mouths are common features. The rest of the coast is composed of high escarpments and nearby deep seas.

Important reefs tracks can also be found on the north coast -Montecristi barrier reef-, and on the eastern coast -Macao-B·varo-Punta Cana barrier reef. This last reef system is located at the Mona Passage, and these reefs are therefore bathed by two mayor oceanic conditions: the Atlantic Ocean and the Caribbean Sea, creating unique conditions that represent in one locality these two biogeographical provinces.

All in all, wherever reefs are found, there are beautiful beaches as well, and the tourism industry is well established on or near them (in the case of protected areas). This tourism industry can be quantified as approximately 45,000 rooms in the coasts of the Dominican Republic. The fact that reefs are important ecosystems for the maintenance of beach conditions and the rise in the economical importance of tourism for the country has given rise to an interest in conserving them. Today, reefs are recognized as very important, strategic, economical, social and political resources, and thus the recent attitude of the country in benefit for their protection.

2. STATUS OF CORAL REEF BENTHOS AND FISHES

Status of the reefs prior to 1998 with emphasis on the status of corals, other coral reef benthos (percent cover of corals, incidence of coral diseases, natural threats to corals etc.) and reef fish populations PLUS a summary of the impacts of the 1998 bleaching event (if any impacts) and current status of the reefs.

The oldest publication describing a coral reef for the country was by Sir W. Halcrow and Partner's (1976) on a study for Boca Chica (southern coast). Geister (1980), and Schubert and Cowart (1980) wrote about the paleontology of the reef terraces on the southern coast of the Dominican Republic. Documenting about the pollution effects on coral reef was done by Galzin and Renaud-Mortand (1983). Barnwell's (1980) described reef conditions after hurricanes impacts. Dominican contributors on reef studies are: Bonnelly de Calventi (1974), published a taxonomic coral list. Carlos González-Nuñez (1974), described reef locations on the country. In 1973 F.X. Geraldes, began his research on coral reefs working in the Museo Nacional de Historia Natural, Centro de Investigaciones de Biología Marina, Universidad de Santo Domingo. These works included descriptions of reef types, species and locations and published, (Geraldes,1976, 1978). Rathe (1981) produced the first systematic study of sponges in coral reefs. Geraldes (1983) also studied the effects of hurricanes on Dominican reefs. More recent studies include: reef characterizations, ecological assessments, and species lists (Geraldes, 1994a, 1996a, 1996b, 1996c; Geraldes et al., 1997; Geraldes and Vega, 1995a, 1995b; Vega, 1994a, 1994b; Vega et al., 1994, 1997; Chiappone et al., in press), geological reef studies (Greer and Swart, 1999), as well as reef conservation efforts made by creating volunteer networks for reef monitoring (Cintrón et al., 1994; Geraldes,1994b).

All of this information has served to document the progressive degradation of the Dominican coral reefs and other coastal environments. This degradation is mainly due to increased deforestation, modification of irrigation practices, increasing siltation, and increased nutrient input from agricultural runoff. There has also been a noticeable increase in human use of coastal resources due to population expansion, with a subsequent increase of waste disposal in coastal waters, inducing changes in water quality. There has also been an increment in the discharge of

nutrients via waste effluents of polluted water (sanitary and industrial systems). Finally, there has been a direct impact on reefs due to intense reef fishing pressure during the 1980's. During this last decade (1990's), the reefs have been mainly impacted by beachfront uses for tourism industry. This economical activity has grown without control and lack of clear environmental regulations, or actions that are not fully compatible with sound environmental practices. All this has created severe effects on the nearby coastal and reef ecosystems. Recently there has been an increase in the number of divers on some reefs, with the concomitant damage of certain reef tracks, mainly in the north as well as in the eastern shores. Natural events have also affected coral reefs. These include 3 mayor hurricanes (David and Frederick in 1979, and Georges in 1998), the *Acropora sp.* and *Diadema sp* dieoffs of the late 1970's and early 1980's, and the recent gorgonian diseases, all of which have diminished the reef structure. Bioerosion, space competition by algae, lack of grazing (overfishing of scarids, acanthurids and other herbivores), and the almost complete removal of large predators (sharks, groupers, snappers, etc) by fishing have all upset the reef ecosystems.

In some areas the growth in the tourism industry has helped reduce the fishing pressure upon reefs. Many fishermen have retired from fishing and hired to work in the hotels due to the decreased revenues from fishing (due to the decrease in fisheries resources from overfishing) and the attractive salaries paid in comparison by the tourism industry. Another action that has decreased the fishing pressure on coral reefs, in this case stewarded by the Dominican Fisheries Department and NGO's, has been the promotion of the use of fish aggregating devices (FAD's). This has induced the fishermen to use the pelagic fisheries resource, and thus has helped to reduce the fishing pressure on the coastal reef fisheries.

In 1992, an ongoing effort was begun to scientifically assess the reefs in the Dominican Republic (Geraldes F., 1994b) since a work financed by WWF/US revealed that the situation of the reefs was rapidly deteriorating. Later work by Geraldes (1994c) for the National Planing Office of the Dominican Government (ONAPLAN), confirmed the degradation of a coastal track with strategic importance for the tourism industry, a situation that represented the rest of the coast of the country. This motivated a legal decree that had the intention of protecting the reefs and the coast from degradation by its overuse and abuse. This legal act grew to become what is today the National Institute for Environmental Protection (INPRA) . The INPRA has the mandate to implement proper modern and sound environmental procedures for all activities in the entire nation's territory.

Although natural threats to corals and coral diseases per se have not been directly studied in the Dominican Republic, there has been much information gathered since 1992. Most of it on coral reef characterization, including diversity and species coverage by corals, sponges, octocorals, and algae, as well as fish species abundance and diversity. Below is a small summary of the findings to date, for the different reef regions of the Dominican Republic starting from the northwestern region and moving clockwise to the southwestern coast.

Recent studies done in the **Montecristi barrier reef** (Geraldes, 1996a, 1996b, 1996c; Geraldes et al., 1997), in the northwest coast, have produced updated information about this area, a community and substrate map (1:40,000) of the coastal region, and the first biodiversity list for the region's marine and coastal habitats. The biodiversity sampled here includes 22 taxonomic classes, 285 families, 525 genera and 742 species. The highest species richness is found in the hard bottom communities, which is related to substrate rugosity and complexity. Of these hard bottom community types, coral patches, high relief spur and grooves, and reef keys represent the higher refuges for biodiversity. Coral coverage is dependent on the stretch of reef and its relative

position regarding the Rio Yaque del Norte estuary. In the outer portion of the reef the % coverage can be as high as 50%, although the average is 35%.

In the central northern coast of the country rocky shores built by uplifted reef terraces (Pleistocene-Recent) are common coastal features, and in its nearby waters fringing reefs are found in the coast of **Luperón** These reefs usually begin at 3 m., and are configured by a series of rounded coral forms and soft corals, denoting high energy systems, where large waves and strong surge forces are normally found most of the year. Reef structure is dominated by a hard bottom, with low relief and high gorgonian cover up to 10 m deep. Coral cover is approximtely 12%, with algae dominating (67%) over hard and smooth substrates. Very little reef rugosity or relief (1.04%) is characteristic up to 30 m. From then on usually and abruptly the bottom drops to greater depths, sometimes to the edge of the continental platform to >50 m.

Another feature of the northen shores of the Dominican Republic are the sedimentary coastal region of calcareous origin. These coastal tracks are washed by numerous torrential streams that originate sedimentary plumes and rip currents. These conditions allow for a patchy coral growth with low cover by live corals and dominated by encrusting, turf, and fleshy algae. At18 m deep a hard bottom community grows on top of a sandstone substrate. In areas where coastal features provide appropiate shelters, the coast was originally fringed by healthy mangroves and marshes (now turn into tourist hotels and resorts), which acted as sediment barriers that previously allowed the formation of patch reefs; that formed small mounts and pillars that rose vertically from a 15-m bottom to the surface. Some times a narrow fringing reef of *Acropora palmata* and *Porites* sp. could also developed. These structures protected the coast and created a large stretch of beach, which is now being utilized by the tourism industry.

Today most of these sedimentary basins are somewhat degraded due to environmental misuse by the resorts and golf courses, towns, villages, etc. supporting some 20,000 rooms. Pollution and nutrient runoff have seriously affected the nearby reefs and coastal regions. Recent sutdies for specific portions show that there is an 80% coral mortality and that 92% of the bottom and reef substrate is covered by algae, especially *Gracilaria* spp., *Dyctiota* spp., *Turbinaria* spp. and *Codium* spp. The structure of these patch reefs follows a similar pattern: they are surrounded by sand and smooth hard bottom where octocorals with sparse growth of *Acropora palmata, Millepora alcicornis, Diploria clivosa,* and *Dendrogyra cylindrus* begins in the 4-m contour; deeper, at the 10 m contour, the diversity and cover by coral species increases, covering 28% of the substrate. It is suspected that the removal of the natural nutrient barrier and the increase in the nutrient output has caused the algae cover to be 43%. In terms of species diversity the absence of large predatory fish species is noticeable. The sponges occupy 6.4% and they are mainly of the encrusting and burrowing types.

In the same northen shore there is a unique reef formation linked to the geology of the **Samana Peninsula** that is formed by relic Atlantic Reefs from the Pleistocene. Today reefs are growing on top of emerging carbonate outcrops on the northern shore of the Samaná peninsula, **Las Terrenas-Portillo** . Here sparse medium sized coral colonies, mainly of *Diploria* sp. and *Meandrina* are found, as well as octocorals; and a thick carpet of fleshy and turf alga covers this basic substrate. The species richness is not high and is comprised of 11 species of algae, 9 sponges, 9 octocorals and 2 hard corals. Near shore the reefs here are fringing, and are found very close to shore, as patches that tend to enclose small imperfect lagoons. Inside these lagoons, and very close to shore in shallow waters reef patches can be found, with coral remains of *Acropora palmata, Montastraea annularis* complex*, Millepora* spp., and *Diploria* spp*.* Most of these patches are fully covered by fleshy and turf algae (Geraldes and Vega, 1995b). Further out to sea approximately 5 miles offshore, there are numerous shoals (15 m deep) that rise from the surrounding oceanic waters. These are eroded carbonate terraces, either by bioerosional

processes or by exposure to weathering during past geological times. The species of corals found in these shoals are few and in low coverage (11.7%). More dominant is turf algae (44%), fleshy algae (20%), and encrusting sponges (18%) (Geraldes and Vega, 1995b). The lack of large predators and the scarcity of large herbivores as well as sea urchins are affecting coral recruitment on these reefs allowing the opportunity for more active erosional processes to occur.

In some other places in Samaná, the coastal features turn intrusive bodies (marbles), forming very high clifts (400 m), with subsequent deep seas nearby (>150m), offering spectacular wall dives. In these places corals grow from the surface to 50 m deep in a 30° inclining wall. The coral forms are of the encrusting and massive type, and coral cover is approximately 40%. Tube sponges follow with a 28% coverage (Geraldes and Vega, 1995b). Large fish are frequently found here, and during winter, humpback whales can also be easily encountered here as well as in the Portillo and Terrenas reef sites.

The coastal region of the northeastern shore of the Dominican Republic is very humid. Numerous rivers and streams are found here, the largest being the Yuna River system, which discharges west inside of Samaná Bay. Together with the Los Haitises and the Sabana de la Mar watersheds, they form the largest estuarine system of the Caribbean islands. The waters in the entire region are generally murky due to the high loads of sediments, limiting coral growth. Near the town of Miches, at Punta Hicacos, a small fringing reef has developed. To the west there are small patch reefs. Extending towards the center of the bay to the north, there are offshore shoals, which are dangerous for navigation and where important 16th century wrecks are found (Tolosa and Concepción).

The Silver Banks reefs are conformed by columns or pillars to the south and protected by a reef crest. The mean coral cover in the Silver Bank is 40%. There is a low density of sponges (2.0%). Turf algae covers 51% of the sampled substrate. The rugosity of this reef is relatively high (1.3%) due to the magnitude of the coral columns or pillars, some of which reach the surface of the water. The fishes of the Silver Banks have not been statistically analyzed, but it seems like the populations have been decreasing at a steady rate (CEBSE, pers. comm.).

In the eastern shore of the Dominican Republic, facing the Mona Passage, is the **Bávaro-El Macao-Punta Cana Barrier Reef System.** This portion of the island has a configuration resembling a bold arrowhead. **Bávaro** faces northeast into the Atlantic, **El Macao** is to the east (Mona Passage), and **Punta Cana** to the southeast (the Caribbean). The coastline is sandy, followed by mangroves, coastal lagoons, and swamps; and drains into the sea through numerous outlets or underground springs. The watershed is a coastal plain in the Bávaro region. At El Macao and Punta Cana, reef terraces are usually found close to shore mainly at Cabo Engaño and near the airport. The reefs of Bávaro, El Macao and Punta Cana extend for 70 km. There are marked structural differences among them. While Bávaro and El Macao face northeasterly winds and high swells, Punta Cana faces southeasterly winds and waves. Thus Bávaro and El Macao present a high energy reef complex with hard bottoms and low relief profiles, while Punta Cana presents the characteristics of a low relief reef.

In the Bavaro reefs, the coral species commonly found in this area *are Porites porites, Porites astreoides, Siderastrea radians, Millepora complanata, Acropora cervicornis, Diploria* spp., *Colpophyllia natans*, and *Montastraea annularis* complex*. Acropora palmata* skeletons covered with algae in association with *Millepora* sp. dominate the windward side of the breaker zone, which is narrow and steep. At 4 m, there are large dead stands of *A. palmata* as well as large boulders of *Montastraea annularis* complex, and *Diploria* sp. At 13 m there is an irregular and wide sand channel ending at a rise of 8 m and forming shoals of smooth sandstone, mostly covered by turf

algae. These shoals are uneven, with crevices 2-5 m deep. Between them shallow sand pockets appear and interconnect to others found in a gentle slope towards the 10 m contour. The reef base then flattens and low-relief spurs (1.5 m high) with sand and rubble-filled grooves follows, extending for 800 m or more, to some 18 m. The coral cover for this portion of the reef is 16%.

El Macao reef, located in the north central portion of the Mona Passage, close to Cabo Engaño, has Atlantic reef characteristics. Its appearance is similar to the one described for El Portillo in Samaná. The smooth and solid limestone rises from the sandy surroundings up to 10 m, forming a high relief reef. There are no spur and groove formations here. These rocky formations are more like reef relics from the late Quaternary period. The substrate where the reef has established itself is covered with algae (23%, of which 1.3% are encrusting and boring algae). The basal reef rocks of this reef have become brittle through bio-erosional processes, causing sediments and sand to originate and creating temporary sediment plumes that affect coral recruitment and growth. This explains the low coral coverage (5.54%), most of which are small colonies no larger than 20 cm in diameter.

Punta Cana reef is located at the southern portion facing the Mona Passage, after a deep portion of patch reefs around Cabo Engaño. The Punta Cana reef grows closer to shore, characteristic of the fringing reef type, and is oriented towards the southeast. This zone is frequently hit by hurricanes. The Punta Cana sandy beaches are interspersed with low coral cliffs, which turn into high escarpments towards the south where the reefs end and there are deep nearshore waters. The reef lagoon region is shallow with rubble and sparse seagrasses. Several freshwater springs discharge underwater, thus influencing the type of biological diversity found here. The breaker zone at 5 m is narrow and composed of very large compacted skeletons of *Acropora palmata* and where algal cover is high and few live corals are present. Following the breaker zone, there is a sand and rubble area with large boulders comprising the base of this frontal structure. The spur and groove area is of low profile and highly eroded. The 50 m contour line is very close and there are some areas where it is possible to find seamounts that are used as dive destinations.

The reefs of **Parque Nacional del Este** are generally low relief systems found either as fringing, small deep (20-30 m deep) patches, or banks. Most of them are in the leeward side protected by a land mass of Pleistocene and Recent reef terraces. Southeasterly trade winds are dominant. The reef on the leeward side can be divided into two distinct areas: along the southern coast of Saona Island (located on the South of Parque Nacional del Este) which is influenced by oceanic currents (Metcalf et al., 1977); and along the western side of the Catuano Passage (more protected). The bottoms of the Saona reefs are consolidated hard bottoms and the benthic communities are dominated by octocorals and sponges. Hard corals are abundant only at specific places where they concentrate forming small and disperse coral patches. Here the sea energy, waves, and current are strong and in part are responsible for sculpturing these reefs. The reefs west of Catuano are basically of sandy bottoms with patch reefs. Large amounts of sediments and organic sands are transported from the Catuano Passage and deposited along this coastline towards the west, with large seagrass meadows covering most of the very nearshore areas. Corals grow mostly in patches form 12 to 30 m deep. Further to the west, away from the influences of the Catuano Passage, coral patches increase in frequency and grow as deep-water fringing reefs, these being the most common reef structures of the southern coast of the Dominican Republic.

Parque Nacional del Este (PNE), is the most studied marine site in the Dominican Republic (Vega, 1994a, 1994b ; Vega et al., 1994 ; Vega et al., 1997). Six categories of hard bottom substrate have been identified for this area : low relief spur and groove formations, reef flats, transitional reef communities, patch reefs, low relief rocky shoals, and rocky coasts. The basal substrate for these formations is consolidated carbonate reef as well as sediments and rubble.

Fringing Reefs

The bottom rises abruptly at the edge of the channel. In the deep portions high relief spur and grooves with large and rounded coral forms are common, while in shallower areas a hard bottom almost without sand deposits serves as substrate for a large octocoral prairie. On the 10 m contour, a wide frontal section of large skeletons of *Acropora palmata* sometimes reaches the surface. Also there are patches of *Montastraea* sp. and *Millepora complanata* form mainly on the leeward side of the breaker zone , sometimes forming small island made of coral debris and deposits.

The back reef is formed by *Porites* sp. as the dominant species. At 0.5 m depth, in the 3 m contour coral diversity increases. Algae (27 species) covers 50% of the area, sponges (16 species) occupy 5% of the area, octocoral (7 species) growth is sparse, and corals (14 species) cover 25% of the benthos. *Porites porites furcata* is the dominant species. This setting forms a frontal low wall that ends in a narrow sand-gravel bottom colonized by a dense seagrass bed of *Thalassia testudinum.*

The reef crest, that geographically faces the westbound currents, it is common filled with large amounts of solid waste from the heavy traffic of the Mona Passage and other offshore territories to the East. Dominating the top of the crest in 0.2 m of water is the short leaf type of *Thalassia*. There are also some live colonies of *Acropora palmata, A. cervicornis, Millepora complanata, Diploria strigosa, Manicina areolata,* and *Siderastra radians.* Underneath, unconsolidated large pieces of *Acropora palmata* lay like non-cemented tiles. At the 2 m depth, a patchy seagrass bed establishes itself on top of large pieces (>25 cm diameter) of a gravel substrate. In this zone, 8 species of algae covers 50% of the bottom. Sponges and octocorals are rare: 5 species of sponges, and 3 species of octocorals. Hard corals are represented by 10 species, growing sparsely with small colonies.

In the least exposed regions of Isla Saona (facing due South), small fringing reef scan be found. The reef crest is close to shore (30 to 150 m), separated by a shallow sandy channel with seagrasses. Sporadic coral congregations turns the narrow reef flat and converts itself into a *Acropora-Montastraea* zone, forming the breaker. Seaward follows a hard carbonate platform, where gorgonians and coral grow at similar depth and configuration of other Saonan sites.

Low Relief Spur and Groove Communities

The low relief spur and groove communities are mainly found at the western and leeward side of PNE and south of Saona Island. They are far from the coast at 15 to 30 m deep. Sponges are dominant, as well as octocorals and algae. Corals colonies are medium-sized and scarce.

The reef system is a continuation of a patch reef near the coast in 3 to 8 m of water dominated by live *Acropora palmata* and *Montastraea annularis* complex. After this patch reef, a broad sand channel follows, and it is at its end where the spur and grooves begin, with an orientation facing East towards the incoming ocean and winds. Coral cover is low (7.5%), octocorals are the dominant benthic forms (17% coverage), and algae occupies 25% of the bottom. The algae are dominant with 15 species, conforming patches of *Halimeda opuntia* and *H. tuna* . Twenty nine species of sponges have been documented with *Agelas, Xestospongia,* and *Verongula* constituting the most common genuses. Octocorals are abundant with 10 species, *Pseudopterogorgia acerosa* and *P. americana* being the most commonly seen species. Twenty five species of hard corals have been observed, with relative low coverage. The most common species are medium sized colonies of *Diploria labyrinthiformis, Siderastrea siderea,* and *Montastraea cavernosa.*

In some areas there is a dominant hard bottom, with sparse sand-clay sediments at 15 m. forming this eroded spur and groove formations with a gentle slopes towards a 2 m cut reminiscent of ancient shores, and into a sand channel where seagrasses grow. The dominant benthic fauna are

the octocorals with an 18% coverage and 16 species, *Briareum, Eunicea,* and *Pseudopterogorgia* being the most common genuses present. Sponge coverage is 11%, with a diverse sponge composition (36 species), *Agelas, Verongula,* and *Xestospongia* being the most common. The corals account for 8% of the bottom coverage with 26 species (the highest species count for the whole PNE). Algal cover is significant, 24%, and is represented by 15 species. This location has been chosen as the CARICOMP reef monitoring station for the country.

In deeper areas at 20 m, the loose substrate is formed by sand, clay and rubble. Benthic biodiversity dominance is basically that of algae with 14 species and covering 25% of the substrate. Sponge diversity is high as well, with 34 species and covering in some cases up to 50% of surveyed areas. The most common genuses present are again *Agelas, Verongula*, and *Xestospongia.* Coral coverage is low 5% and only 18 species have been documented.

In the northen portion of this protected coastline, and where the sand beaches end, and a low lying rocky shore (Recent) starts, the offshore reefs are represented by well defined spur and groove system, with relief up to 2 m high. The reef orientation is east- west, perpendicular to shore. The coverage by corals is 34%, with 25 species; sponges 11% with 37 species; and algae 35% with 16 species.

Hard Bottom Carbonate Reef Flat Communities

Another type of reef formation inside the protected area of Parque Nacional del Este is described as hard bottom flat carbonate substrate reefs. These are of low relief and are associated with high energy seas and currents. They are most common in the eastern portion of the park, facing the incoming surge and waves from the open seas. In terms of diversity, they are dominated by turf and brown algae, and/or a co-dominance of algae (36 species) and corals. The most conspicuous genera are *Dictyota, Turbinaria, Stypopodium*, and *Halimeda*. Coral colonies grow sparsely forming large individuals. Octocorals are few in number, represented by *Gorgonia ventalina, Pseudoplexaura porosa,* and *Plexaura flexuosa*: all species adapted to high-energy conditions. Seven sponge species are present, encrusting and boring forms (*Chondrilla nucula*, and *Cliona langae*) dominating. The corals are more diverse with 12 species, the most common being *Acropora palmata, Diploria clivosa, Porites astreoides,* and *Porites porites*.

Transitional Reef Communities

To the northwest of the central portion and in the southern coast of Saona Island, and somewhat protected by an outing of the southern coast of Saona Island, in 7 m of water, a low relief reef flat occurs, colonized by algae, corals and octocorals. It may be considered a transitional reef with accumulations of sediments and rubble. There are 24 species of algae, with *Halimeda, Dictyota,* and *Amphiroa* dominating, with a cover between 25 to 50%. There are 22 octocorals species with *Eunicea, Plexaura, Plexaurella,* and *Pseudopterogorgia* being the most abundant, and encompassing 25% of the bottom coverage. Hard corals are present with 23 species growing scattered along the flat bottom and covering 5% of it.

Patch Reef Communities

These are located in protected waters on the western portion of the leeward side of the park, or inside the Catuano Passage, protected by the fringing reef and reef crest of Catalinita Island.

The reef structure is dome shaped with a 30 m diameter, sometimes can be collapsed in its middle portion. where *Porites* rubble accumulates. In their exposed portions, large coral heads are found with a tendency to link to the back reef by a rubble and deposition bed. Algae is the dominant form here with 50% coverage by 21 species, *Halimeda opuntia*, *Caulerpa racemosa*, *Titanoderma* sp., *Stypopodium zonale*, *Amphiroa tribulus*, and *Dictyota* sp., being common. Sponges are scattered

with a 5% coverage, with 20 species present, denoting *Cliona langae, Iotrochota birotulata* as the most obvious ones. Octocorals are very sparse with 7 species and only in the periphery of the patch structure. Corals represent >5% coverage with 11 species present. *Porites porites, Montastraea annularis* complex*,* and *M. cavernosa* are the most common ones.

In other oceanic conditions (more open waters), but always protected by some coastal structure, starting at 6 m deep, a series of coral patches can be found separated by sediments and rubble. The physical relief is medium to low in a hard substrate where corals congregate to form outcrops of growth with large heads intercepted by sand channels that surround them. In some cases *Acropora cervicornis* is found here initiating the settling process and patch formation. Algae are represented by 21 species, dominated by *Dyctiota* sp. Octocoral fauna is common with *Eunicea, Plexaurella, Pseudoplexaurella, Pseudopterogorgia,* and *Pterogorgia* being the most commonly seen. Also common are the hard corals with 23 species. The presence of large (>2 m diam) colonies of *Acropora palmata* that serve as base structure for other species to settle (such as *Agaricia tenuifolia*, and less common and rare *Millepora squarrosa)* is striking. Great numbers of *Montastraea*, *Colpophyllia*, and *Dendrogyra* were also found in these coral patches.

Hard Bottom Carbonate Platform Communities

A tidal channel (4 m deep) frequently washed by strong currents generated by tides and winds, models this type of benthic community. Due to the strong currents, the dominant biota found are algae and octocorals, and in less quantity sponges and corals. Algal cover is above 50%, with 29 species present, the most common being *Hypnea cervicornis, Acanthophora spicifera, Jania rubens,* and *Laurencia intrincata.* Of these, *H. cervicornis* represents more than 25%. *Halimeda opuntia, H. tuna, Coelothryx irregularis, Amphiroa brasiliana,* and *Galaxaura oblongata* also are common. It is notable that the red algae are dominant in this location.. Sponges are sparse around this reef site, occupying 5% of the bottom with 28 species. It is interesting to note that some of them can reach sizes up to 1.2 m, and the most commonly found species here are *Amphimedon compressa, Pandaros acanthifolium,* and *Callyospongia vaginalis*. Octocorals are the most conspicuous visual group at this reef, with some individuals reaching up to 2 m high. They are well represented by 23 species, the largest number of species found in the park Nevertheless their basal attachment or foot only covers 5% of the bottom. The common species are: *Pseudopterogorgia acerosa, Eunicea clavigera,* and *E. calyculata*, representing 60% of the total. Corals cover 1% of the bottom, with 14 species of small size (<100 cm^2) growing basically in concentrations surrounded by rubble. The dominant species found are: *Millepora alcicornis, Porites asteroides, Dichocoenia stokesii,* and *Diploria labyrinthiformis*, which represents 90% of the population.

On the southeastern coast of the Dominican Republic, there is a small oceanic island called **Catalina**. Near it there are two reef sites: one is a leeward reef and the other is a wall. The leeward reef lies after a seagrass bed, following a slope to 5 m deep, where a spur and groove system begins, and ends at 14 m. This area has been turned into a cruise ship and tourist port, with resultingly large impacting of the reefs found here. Open water anchoring structures were deployed to tie the large vessels. Assessment studies have found a reduction of more than 80% in the overall benthic cover due to the physical effects from these structures. Here coral cover has been reduced from 12% to 4%; similar values have been found for sponge and octocoral cover; algal cover increased from 15 to 27%. The solid reef platform has been transformed into rubble substrate. In general terms, this reef site is one of the most affected and damaged in the country. In nearby undisturbed areas, the average coral cover is 8%, with 31 species ; octocorals cover 3%, with 14 species ; sponges cover 8%, with 33 species ; and algae cover 21%, with 19 species. (Geraldes, 1994b).

There is also a wall, located on the northen portion of the island, in the Catalina Channel. It is close to shore after a narrow (20 m) and shallow (2-3 m) zone. At 2-5 m depth a dense and healthy coral conglomerate is found, where *Acropora palmata, Montastraea* complex, *Diploria* spp., *Madracis decactis, Porites* spp*., M. miriabilis,* many sponges such as *Xestospongia* spp*.,* and *Cliona* spp*,* and octocorals cover most of the bottom. The wall starts abruptly at the eastward margin and vertically goes to > 40 m, ending at a sandy bottom. On the wall *Halimeda* spp. and plate forms of *Agaricia* spp., as well as *Porites annularis,* and *Montastraea* spp., are common. In the deeper areas, anthipatharian and octocorals are also common in crevices and along the vertical hangings.

The **southern coast, from Parque Nacional del Este and due west until the Rio Haina on its central portion**, is formed by medium to high escarpments of uplifted Pleistocene-Recent reef terraces, sometimes interrupted by rivers mouths, short tracks of beaches, small bights and underground streams outflows. On these coasts the coral reef features are basically the same as the one described for the reef terraces of the north coast. Usually these coastal features are associated with a narrow continental platform. Where shallow shores are found, a complex reef structure usualy fringing and barrier reefs form, and one also finds beaches and mangrove swamps. Today these specific regions are being transformed into tourist centers and small towns. The areas where there are large river mouths that provide safe natural ports, have been utilized since the 15th century for human settlements. The mouth of the Ozama River, where the nation's capital stands, today with almost 2 million inhabitants, is a good example.

The coastal features of the fringing reefs along this track of coastline basically consist of low lying organic sands, in association with underground streams and runoff outflows. In these areas the water depth diminished, basically by the dilution, erosion and bioerosion of the calcium carbonate of the reef terraces. This created proper grounds and conditions for corals to become estaablished. The reef front and breaker zones of these reef regions are close to shore and separated by a shallow channel, where seagrassess and other benthic organisms flourish. Another feature of these reefs are their location and the influence they receive from large upstream rivers. From the rivers they receive large sediment loads, as well as agricultural byproducts and city wastes, that deposit themselves on the shallow portions of the reef. All these have had effects on the reefs, altering their condition and reducing their structurization, mainly of the breaker zone (composed of *Acropora palmata, Diploria strigosa, Montastraea annularis* complex*, Millepora complanata, Porites porites* and *Porites asteroides).* Today, most are dead colonies covered by turf algae: they are not cemented together but placed *in situ.*, detritus and garbage usually covering them. Encrusting and boring sponges such as *Anthosigmella varians* and *Cliona langae* thrive here. This situation has affected the energy dissipation function on these reefs, and beach erosion is therefore an economic issue of concern for the region and its tourist industry. Nevertheless, on the deep portions of these reefs, away from the altering coastal processes above mentioned, from 12 m depth on, a high relief spur and groove system begins with relatively healthy coral growth covering 33% of the bottom. This is one of the few places in the country where coral cover surpasses algal cover (26%). (cover by octocorals is 8% and by sponges it's 2%). Some stress is nontheless evident, by the presence of white band disease in some corals.

In this coastal track one also finds a special reef structure consisting of a unique reef front formed by a *Porites-Montastraea* association, without acroporids. It grows towards the shoreline and connects with it by a very shallow and often exposed (at low tides) sand accumulation, where *Syringodium* dominates. Eight species of algae, 10 species of octocorals, 7 species of sponges and 21 corals represent the most common benthic organisms here found. This region is being severely impacted by dredging and by the deployment of jetties to sustain the development of tourism.

In this same track of coastline, in the town of **Boca Chica** inside of Andres Bay, a reef worth mentioning is found. The structure consists of a small barrier reef, including mangrove islands. This reef has the longest history as a study site of the country. Here several underground springs emerge from the Rio Brujuelas. The reef of Boca Chica is an eroded spur and groove formation, with a clearly defined zonation pattern with regards to depth: sandy beach, back reef lagoon, reef crest, breaker zone, lower palmata zone, spur and grooves, sand channel, buttress zone and drop-off. The benthic composition has a coral coverage of 20%, while sponges cover 5% and algae 56% of the bottom. The major groups of benthic organisms found here are represented by: 12 species of algae, 6 species of octocorals, 22 sponges, and 30 corals. *Agaricia* sp., and *Montastraea annularis* complex are the most common species found. Algae such as *Laurencia* sp., and encrusting sponges (*Cliona* sp. and *Anthosigmella varians)* are common as well.

In the shallows, at the breaker zone (4-6 m deep), large colonies of *Acropora palmata, Montastraea annularis* complex surrounded by *Porites asteroides, Porites divaricata, P. porites, Millepora complanata,* and *Gorgonia flavellum,* are still present. Nevertheless, the seascape seems catastrophic. Pieces of corals lie all-round and degradation is obvious by physical as well bioerosional processes. *Diadema antillarum* and tunicates, boring sponges, and large amounts of turf algae cover all available space of bottom surface. Among all this, small colonies of *A. palmata* appear. At the breaker zone, the *Acropora* barrier is dead but still in place and functional. Encrusting algae (*Porolithon pachydermun)* and zoanthids fill the surface area of this zone. The reef crest and following flats follow, as large depositories of reef debris. The intense erosional process serve to produce sand for the Boca Chica beach. In deeper waters (about 30 m), plate forms of *Agaricia* sp*., Montastraea annularis* complex*, Colpophylia natans, Meandrina meandrites, Mussa angulosa* and *Mycetophyllia* sp., accompany a massive growth of *Halimeda* sp. and *Amphiroa* sp.. Reaching lesser depths, at 20 m, *Erythopodium* sp. appear as well as the encrusting sponges *Cliona langae* and *Ectyoplasia ferox.* Some large *Xetospongia muta* are also found. Corals are not the dominant feature in this seascape, but there are striking colonies of *Acropora cervicornis, Dendrogyra cylindrus, Porites asteroides, Porites furcata, Millepora alcicornis,* and *Agaricia* sp.

More to the West of Boca Chica, and protected from the winds and currents in a cove one finds the **Parque Nacional Submarino La Caleta**, an 18 km^2 small marine and recreational park. The reefs begins at 18 m, with low and medium relief spurs and grooves. The benthic organisms reported for this area are 32 species of corals, (*Agaricia agaricites, Diploria strigosa, Leptoseris cucullata, Madracis decactis, Meandrina meandrites, Millepora alcicornis, Montastraea cavernosa, Porites astreoides, Siderastrea siderea,* and *Stylaster roseus,* among others), 20 species of octocorals (*Gorgonia flabellum*, is the most common, followed by *Erythropodium caribaeorum* and *Pseudopterogorgia bipinnata*, as well as *Plexaura homomalla* and *Pseudopterogorgia americana),* 50 species of sponges (*Amphimedon compressa, Aplysina cauliformis, Ircinia strobilina,* and *Pseudoceratina crassa* are found at almost all depths, followed by *Agelas conifer, Callyospongia vaginalis, Ectyoplasia ferox, Iotrochota birotulata,* y *Xetospongia muta)*, and 45 species of algae. The benthic coverage is as follows: algae 41%, sponges 13%, octocorals 13%, and corals 28% (Geraldes, 1994a ; Geraldes and Vega, 1995a).

In the south central portion of the Dominican Republic, a large open bay is found between Punta Caucedo to the east (La Caleta) and Punta Najayo to the west; this is where the **Najayo-Palenque** Reef is located. The site sits after the Ozama - Haina- Nigua river complex. These three rivers also are the natural boundary for Santo Domingo, capital city of the country. The coastline here is made up of reef terraces up to the Nizao river further to the west. The Nizao and the Ozama-Haina-Nigua river complex are separated and don't form an estuary; this is also due to the great ocean depth found nearshore (>300 m). The water discharged by these rivers is polluted, and enriched with sediments from the cities of Santo Domingo and San Cristóbal as well as from

the surrounding sugar cane plantations/processing plants and farms found nearby. The coastal currents flow westward towards the Najayo-Palenque Reef. These reefs are typical of high energy seas conditions, with low profiles dominated by a hard, current swept bottom, and sparse octocoral growth. It is assumed that the substrate is not uniform due to tectonics or erosional processes caused by catastrophic events that have altered it, leaving boulders and uplifted tile-like structures where corals attach in the leeward area.

From here to the west the coastal features change to loose sediments of terrigenous origin. Climatic conditions also turn this region into a desert-type environment. In some places, large areas are covered by sand dunes (25km), where bio-cementation processes are ocurring, and sandstones are found close to shore, serving as appropriate substrata for corals and other life forms to establish themselves. This area is known as **Salinas and El Derrumbao**. This shallow, seagrass-dominated feature terminates some 30 m from shore, where there is an abrupt drop towards a submarine fault (> 1,500 m deep). The wall is formed by cemented sand rectangular blocks measuring 3 - 5 m by 2 m. *Madracis* sp., *Porites porites, P. divaricata, Montastraea annularis* complex, *M. cavernosa, Colpophylia natas,* as well as *Siderastrea siderea* are common species found in the first 10 m. Then at this depth a overhang occurs and cryptic species abound. Several large sponges such as *Cliona* sp., *Ectyoplasia ferox,* and *Xetospongia muta* can be found as well. After the overhang, the wall turns into sand with a high angle of slope which is usually covered with fine sediments that are easily stirred by divers.

Continuing west, the reefs are scattered and only present where the depth is suitable for supporting reef life. Most of the seas here become very deep (> 20m) close to shore, and/or have inappropiate substrates (sand, gravels, loose soil, etc.) for the establishment of coral. In the few areas where the conditions are appropiate, however, reefs can be found. Such is the case of **Puerto Viejo, Azua**.

The Puerto Viejo reef forms a small barrier with an 8 km^2 lagoon, and with a breaker zone containing a few mangrove keys. Due to its sheltering effect, it has been used as a natural port since the 1500's. Nearshore, tidal flats with *Halodule* and *Syringodium* are common. Corals are found in the sand depressions or erosional pits. Common coral species are *Manicina aerolata, Porites porites, P. divaricata, Siderastrea radians* and *Diploria strigosa*. In the lagoon, which has a depth of 14 m, *Thalassia testudinum* is dominant. Corals grow in patches and *Diploria spp.* and *Siderea spp.* dominate. Others, such as *Acropora cervicornis, Millepora complanata, Porites asteroides, Agaricia agaricites, A. furcata,* and the rare *Acropora prolifera* are sparsely found. Strong tidal currents flow and influence the circulation of this lagoon, enhancing coral growth, specially in the back reef, where *Acropora cervicornis, Porites asteroides, P. divaricata, Diploria strigosa, Siderastrea siderea, Manicina areolata, Siderastrea radians,* and *Millepora alcicornis* are the common species.

The reef flat is dominated by zoanthids growing on top of coral debris. Corals like *Porites asteroides, Diploria clivosa,* and very large colonies of *Acropora palmata* are dominant in the breaker zone. In deeper waters (10 m) a hard bottom carbonate platform is found, with sand pockets. Large tree-like colonies of *Acropora palmata,* as well as large boulders of *Colpophyllia natas,* are found here creating intricate structures where other reef creatures seek refuge and nourishment. These coral patches tend to grow closer together in deeper water. At 13 m deep they usually merge to conform low-relief spur and groove formations.

The coastal features from Puerto Viejo, Azua to Cabo Beata (to the southwest), is predominantly of deep seas and turbid waters, that prevents reefs from forming. In **Barahona**,

however, a fringing–barrier system is found, with a configuration similar to the reef at Boca Chica already described above.

At this southwestern point, the island of Hispaniola changes its geological characteristics. Abyssal depths are found within meters from shore, following the Beata Ridge that is responsible for the uplifted terrains nearshore. These conditions are predominant for a long coastal track (87 km) where only one site – **Oviedo** - is shallow enough and protected to allow a small fringing reef . Here, the coastline abruptly turns north at Cabo Beata, and a protected and shallow portion begins where reefs and sheltered conditions are favorable for nurseries of lobster, conchs, and other important fisheries. This region is a protected area with national park status called **Parque Nacional Jaragua**.

The terrestrial region of and surrounding the park is very dry, with cacti and desert-like vegetation dominating on land, growing on an uplifted Eocene-Pleistocene terraces (Geraldes, 1980). There are no rivers or surface runoffs. On its windward side, strong seas, medium sized cliffs, and high energy pebble and pocket beaches with fringing reefs are found. On its leeward coast, protected by high cliffs, sheltered, long and white sandy beaches are common, followed by consolidated hard carbonate, where coral cover and density is high.

There is not a well developed fringing or bank reef in most of the zone. Flats where seagrasses thrive are dominant. At the island of Beata, at its northeastern end, coral reefs are located offshore forming bank reefs (Borrell, 1981; Vega, B., 1981). On the leeward side there are seagrass beds, followed by a hard carbonate bottom with sparse coral, sponge, and octocoral growth, and with a high cover of algae. The most abundant corals are *Porites, Undaria (Agaricia), Diploria, Siderastrea siderea* and *Montastraea cavernosa*. 20 km. away from the mainland is Alto Velo, an oceanic island of volcanic origin. It has bare slopes that drop steeply into the ocean depths. In the shallows, on the leeward side, and inside crevices, cryptic reef creatures grow sparsely, mostly of crustose and flattenend forms (Borrell, 1981; Vega, B., 1981). Another interesting site of this region is **Los Frailes Shoals**, located 12 miles southwest of Cabo Rojo. These rock outcrops receive clean oceanic waters which allow the establishment of a diverse and interesting community. There are boulders and submerged walls 10 m high covered by *Tubastrea aurea.,* large *Montastraea, Diploria* and *Colpophyllia* colonies, as well as sponges on the other side . In the Beata canal lies a platform that reaches a depth of 18 m.. This is covered with algae, hydrozoans, gorgonians and *Cliona* sponges, as well as some *Acropora palmata* colonies (Weil, 1997).

North of this region is **Bahía de Las Aguilas.** Here, a reef begins at 18 m on a wide platform covered by seagrasses. The reef then drops to 45 m until reaches a sandy bottom. There is a high cover by plate-like *Montastraea, Agaricia,* and *Undaria,* and large *Colpophyllia* colonies can be found. The blue-green algae *Schyzothrix* is also abundant between 13 and 18 m. Octocorals are scarce and scattered along the slopes. Sponges are abundant and diverse. *Millepora* is common in the shallow areas, where *Acropora cervicornis* patches are common. Signs of white band disease are present. *Montastraea franksi* and *Agaricia lamarcki* are the dominant coral species in the deep area of the reef (Weil, 1997). The reef has a higher coral diversity and coverage, with *Montastraea, Porites, Undaria (Agaricia)* and *Agaricia* are dominant. Rare species such as *Mycethophyllia reesi* are uncharacteristically abundant (Weil,1997). Further north of this location at Cabo Rojo, the continental shelf forms a submarine canyon.

The above description encompasses Dominican Republic's most important reef zones, while the information corresponds to work done since 1995 until today. There have not been any reported major impacts on any of these reef sites since.

No studies were done directly dealing with the bleaching event of 1998, although observations in Parque Nacional del Este and Parque Nacional La Caleta show that the bleaching event was scattered, and only occurred in some corals and less than 5% of the coral population.

It is also important to mention events that have reportedly impacted the reefs of the country. The first one was the Acroporid die-offs during the early 1980's, followed by the long-spined urchin (*Diadema antillarum*) die-out of 1983–1984. Both had important catastrophic consecuences for the coral reef: a notable reduction on the grazing of algae was clearly evident and soon this caused the algae capable of smothering corals to proliferate in some areas, particularly where over-fishing had already removed large-sized herbivorous fishes. In addition, the bioereosional processes increased with the avalilability of coral squeleta from *A. palmata* in the trophic zones. Recent evidence suggests that gorgonian and other coral diseases are present in certain reef areas. There is presently an effort to assess and monitor this situation through the CARICOMP network.

3. STATUS OF CORAL REEF FISHERIES

According to the Department of Fisheries of the Dominican Republic, the current landing composition of the catch is generally composed of 287 species of fishes, 9 species of crustaceans, and 10 species of molluscs. Of these landings, fishes compose the largest percentage, with an average of 80% for the period 1980-1990. Conch and lobster compose 15 –17%. The rest of the catch consists of other species of molluscs and crustaceans (crabs, cephalopods, etc.). Conch has increased in value in the international markets ($4.00/lb), thus increasing the fishing pressure for this species along the Dominican reefs, mainly for export purposes as well as for local comsumption. The fishing methods generally used are traps, pots, hook and line, trawl lines, gill nets, and spearguns, using both free diving and hooka equipments. There are no recent reports of fishing with explosives. The use of poisons to capture aquarium or edible fishes has greatly declined.

Overall the fisheries activity in the Dominican Republic has decreased within the last decade, which has helped, to some extent to increase the reef's potential extractive populations. Reef fish populations are increasing in some areas where market pressures have reduced the numbers of active fishers. However, this has not decreased the actual fishing pressure on some target species such as queen conch, spiny lobster, groupers, snappers, and grunts associated with high market values. Queen conch and spiny lobster fisheries are being depleted due to overexplotation in nurseries. Aquarium trade reef fishes, black corals, hermit crabs, and 'live rock' are also somewhat harvested in the Montecristi reefs and in the north shores, as well as in the coast of Parque Jaragua, although information about specific amounts, the nature of the collection (methods used, etc.), export figures, etc. have not been analyzed. There are specific laws against collecting hard corals or destroying reefs. Illegal collection of loggerhead, hawksbill, and green sea turtles is on the decline. It is correct to consider that the manatee (*Trichechus manatus*) and the jewfish (*Epinephelus itajara*) are commercially extinct in the country, although they are sold if caught. Recent promotion about the conservation of manatees (brought about by the rescue of an orphaned manatee by the National Aquarium) and sea turtles has helped to increase the general knowledge and conservartion awareness of these animals. There is also evidence that the populations of queen conch (*Strombus gigas*) and/or spiny lobster (*Panulirus argus*) are greatly reduced in some areas, basically due to the intense fishing pressure that has occurred at the nurseries (Parque Nacional de Montecristi, Parque Nacional del Este and Parque Nacional Jaragua).

The fisheries techniques and gear used in the Dominican Republic are still generally rudimentary (artisanal), but the use of hookas is on the rise in most of the commercial fisheries done in the island, becoming more and more popular for catching conch and large reef fishes at deeper depths.

Alternatives to fishing on coral reefs has basically been achieved by the use of fish aggregating devices (FAD), and recently there has been a surge in the promotion of FAD. Fishing near FAD's has become popular and in the areas where this gear has been put into use there has been a notable increase in catches of pelagics species (dolphin or mahi mahi, marlin, etc.), who's high market value has turned fishermen's interest towards this type of explotation. This has favored a decline in the fishing pressure of near-coastal and reef fisheries in the country.

4. ANTHROPOGENIC THREATS TO CORAL REEF BIODIVERSITY

The increase in population is probably the factor that has had the most impact on coral reefs. Today there is an average human coastal population density of up to 2,200 per km^2 near major cities like Santo Domingo, Puerto Plata, and San Pedro de Macoris. Although the remainder is not so heavily populated, it is nevertheless suffering from major anthropogenic threats, be they direct or indirect.

Some watersheds in many parts of the country have been deforested since the 1700's, so it is now impossible to estimate how freshwater and terrestrial soils naturally impacted coastal reefs. Destruction and degradation of coral reefs now appears near most human settlements due to the increase in negative environmental impacts to the aquatic and coastal environments. There is also clear evidence that some of these impacts are caused by human activities such as agriculture, tourism, animal husbandry, and industrial development. In general, land-based fertilizers, pesticides, other forms of chemical pollution (e.g. hydrocarbons, heavy metals), domestic and industrial trash, wastes from the mining industries, etc. all are reaching via runoff the river mouths, estuaries and adjacent marine ecosystems like coral reefs (Puerto Plata, Sosua, Las Terrenas, Miches, Juan Dolio-Guayacanes, Boca Chica, La Caleta, Palenque). Coastal development has led to the destruction of wetlands and mangroves for landfills, coastal construction, and dredging. Ports and shipping activities, recreational boats and marinas, some localized and rare reef-based coral mining, can also be found in Montecristi, Luperon, Puerto Plata, Sosua, Las Terrenas, Macao, Bavaro, Punta Cana, Bayahibe, Guayacanes-Juan Dolio, Boca Chica, La Caleta, Palenque, Barahona. Physical damage from boat groundings are characteristic impacts near large ports and cities, as well as in some small islands used by cruise liners in the tourism industry.

Overfishing is also heavily affecting Dominican reefs. Overharvesting of commercially important species such as *Strombus gigas, S. pugilis*, *Panulirus* sp., and fishes of the Serranidae, Lutjanidae, and Scaridae familes, is a problem. Lately, there has been an increase in the harvesting of other reef creatures such as black corals, hermit crabs, ornamental reef fishes, starfish, sea urchins and live rocks for the souvenir industry.

Most of these activities are prohibited or regulated by Dominican laws, but there is a lack of political and financial support to achieve the proper enforcement and personnel training. In order to minimize the negative effects on reefs non-government organizations have contributed with conservation actions.

Some reef sites near tourist areas present different levels of stress. This is in part due to increased visitation, contamination, anchor and propeller damage, as well as removal of target species used to supply small restaurants and cafeterias on the beach fronts (large predators, lobster and chonch, as well as juvenile snappers). In some areas, and with the purpose of reconditioning the beach for human use (bathing), hoteliers and contractors have removed the seagrasses, urchins, and rocks from the shallows; most of the time by hand, but in cases using bulldozers. These actions have created (among other things) nearshore turbidity currents by

exposing loose sediments, that have affected the back reefs and breaker zones. In consequence, the tourism industry suffered negative criticism and has lost clients that demand a more nature-friendly oriented policy. This has motivated a recent movement by this sector searching to become known as environmental friendly, by assessing their actions and complying with proper management recommendations for their beach front properties.

Recently, a new threat has risen, mostly from the services industries (mainly transport and energy). These industries have grown rapidly in recent years, and are trying to utilize the shelter that reefs naturally offer. New large trans-shipping ports have been planned in coastal areas that have reefs, which would mean the destruction of entire reefs through dredging in order to construct the ports. Large power plants with inappropiate designs have also been proposed near reef areas (Boca Chica reef). The Instituto de Proteccion Ambiental (INPRA) and the goverment are requiring these projects detailed EIA and Environmental Statements. The general public are also in strong opposition and are demanding that these projects be constructed elsewhere where tourims (and thus the reefs) would not be threatened.

5. CURRENT AND POTENTIAL CLIMATE CHANGE IMPACTS

Bleaching events in the Dominican Republic are somewhat rare and usually associated with stress conditions due to water quality problems created by inapropiate resource management, pollution, deforestation and alike. Bleaching events are also more likely to occur when sea-surface temperatures increases by as little as about 1^{o}C above the long-term average for about a week in summer. The largest event coincided with the1998 ENSO coral bleaching.

6. CURRENT MPAS AND MONITORING AND CONSERVATION MANAGEMENT CAPACITY

There are six MPA's in the country, and all have been somewhat described in the preceding question 2. Starting at the northwest is Montecristi National Park, with a barrier reef, mangroves, a river delta and estuary, coral keys, seagrass beds, etc. It is the largest and least impacted MPA in the country. Over fishing of large predators is a major concern here. Offshore, approximately 95 miles north of the city of Puerto Plata lies the National Humpback Whale Sanctuary. This 15,000 square miles MPA includes the Silver and Navidad Banks (where atolls/bank reefs are found) and extends until the Samana Peninsula to its south. On the northeastern coast is Los Haitises National Park on the Samaná Bay. This park's marine habitats are basically composed of mangroves (the largest area in the country), and estuaries (mud flats and seagrasses). On its portion away from the riverine influences, there are small patch and algal reefs. On the southeastern portion of the island is Parque Nacional del Este, the most studied protected area of the country, which constitutes important breeding grounds for *Strombus sp., Panulirus sp.* and other species. Close to it but further west is Isla Catalina, an oceanic island, basically used for recreational purposes. Its reefs have been affected by anchor damage form cruise liners. Further west is Parque Nacional Submarino La Caleta, the first MPA in the country. This park has served as a training center for native marine scientists, and has been used as a model to represent the reef environments on the dioramas of the Natural History Museum and the exhibits of the National Aquarium. Today, this small marine park is basically used for diving. Finally, on the southwestern portion of the country and near the frontier with Haiti, there is Parque Nacional Jaragua. This MPA is very important as a nursery for *Panulirus sp.* as well as for other species.

In the MPAs of the Dominican Republic fishing activity is intense, and in most cases overfishing of nearby reefs and coastal resources has already occurred. Most of these MPA's have in common that they shelter the largest reef tracks as well as the most important nursery areas of the Dominican Republic. This, together with the fact that there is very little control and improper management of

these areas, induces fishermen to fish and extract important juveniles as well as mature populations, at their nurseries or at their breeding grounds.

In some MPA's the tourism services have increased (Parque Nacional del Este), in which case there has been a change of trade by some fishermen that have become boat captains for tourists instead.

The lack of qualified personnel capable to administer marine areas at the Subsecrearía de Areas Protegidas y Biodiversidad of the Secreatía de Estado de Medio Ambiente y Recursos Naturales, as well as the lack of an adecuate and effective fisheries extension program and services, of enforcing officers at the Subsecretaría de Estado de Recursos Costeros Marinos and it's Fisheries Department, and of appropiate penalties for violation of existing laws, as well as a general confusion as to which institution should apply these laws, all create a real problem in the administration of these MPA's regarding the fisheries issues. Sometimes this situation gets even more difficult, when institutions such as the Dominican Navy and the Drug Enforcement Agency intervene in the decision-making process and allow and give permits for fishermen operations for "patroling services".

The issues associated with tourist and general public visitations to domincan MPA's can be considered major threats, since there is also a lack of appropiate visiting regulations, and if there are, of enforcement capacity by the governamental institutions in charged as well as other regulatory entities in the goverment. NGO's and the tourist industry are presently developing programs on environmental education and awareness, evaluating alternatives based on research in order to try to resolve this issue.

7. GOVERNMENT POLICIES, LAWS AND LEGISLATION

Until September 2000, there were a large number of organizations and institutions that deal with environmental issues in order to administer over 300 environmental decrees, regulations and orders. Some of these institutions are formed by law, while others are conformed just by an executive order or presidential decree. This situation came to an end with the creation of the Secretaría de Estado de Medio Ambiente y Recursos Naturales (Law 64/00). This modern law includes the protection and preservation of the marine resources and adopts all previous legislations that protect reefs and marine biodiversity. It is administer by several undersecretaries. There is one for Marine and Coastal issues, another for the Protected Areas, and other for the Environmental Protection. All of them have staff and bylaws specifically designed to address the pertinent issues of their concern. This legislation is a conceptual law that will enable a modern admininstration, through councils, as well as flexible enough to permit adaptations to changes in the environemental management of the country.

Nevertheless the traditions for multiple agencies dealing with the environmental issues still persists, and its enforcement is particularly poor. Government commitment to international treaties like MARPOL, CITES, and the Convention of Biological Diversity has enhanced compliance with local environmental, fishery and development regulations. Concepts of integrated coastal management are just beginning to be applied. The Global Environmental Fund (GEF) of the World Bank has funded projects to assist the dominicans in evaluating their coastal resources, as well as another project to desing the national environmental policies. Shoreline development is controlled by law, and restricts all constructions to be landward side of beach dunes or 60 m away from high water. Turbidity barriers, or some other method of sediment control, are required and being used at coastal construction sites.

The most important evironmental decrees and regulations that deal with reef issues are:

- Decree No. 1728, issued March 3, 1976; stating that any coral extractions in Dominican territorial waters should have a permit issued by the Department of Fisheries of the Dominican Republic.
- Decree No. 318, issued October 13, 1986; prohibits the extraction and commercialization of stony and black corals in the Dominican territorial waters. Substitutes Decree 1728.
- Decree No. 289, issued in 1987; places under special protection and custody all bodies of water, rivers, lagoons, mangroves, coral reefs and coasts, includes also the grouper, manatee and the cocrodile. Assigns the Dominican Navy these responsabilities.
- Decree No. 112, issued May, 12, 1995; declares as of national interest the effective protection of the beach resources and the coral reefs that are present in the territorial waters. Prohibits the extraction of any type of corals, sponges, gorgonians, sea stars, urchins, molluscs shells or any other part living or not, that is a part of the coral reefs
- Environmental Law 64 –2000, (August 2000); includes all previous legislations and drecees in regards to management, concerving and protecting marine habitats, ecosystems, biodiversity and protected areas.

8. GAPS IN CURRENT MONITORING AND CONSERVATION CAPACITY

At this time only a few of the marine protected areas are adequately monitored or effectively managed. Nonetheless, the Global Environmental Facility (GEF), the Parks in Peril/The Nature Conservancy/USAID project, the World Wildlife Fund, the United Nations Environmental Program (UNEP), and others have supported the development of coral reef monitoring protocols for the island, following the methods developed by CARICOMP. Ecological surveys and biodiversity inventories at four marine parks have also been completed. The remoteness of some of these protected areas has been favorable since they have been relatively unaffected by direct human activities, excep periodic over-fishing. Recent attitude of divers in the country is; that they are helping to protect reef resources from illegal fishing, cleaning up trash, conducting reef monitoring surveys, and educating others about the value of intact reef ecosystems.

In those areas where large population are found and where reefs have been degraded, a large project (110 US$ million) has recently being signed with the World Bank to resolve the sanitary and solid wastes pollution on all of the major tourist centers (6) along the coast of the country. This project will contribute to reduce some of the environmental stressess caused by uncontrolled dumping and sanitary discharges that are affecting reefs nearby these tourists centers. The implementation of this project is still pending on the counterpart budget assignment on the side of the Dominican goverment.

Mooring buoys have been installed by Fundación MAMMA/TNC in Parque Nacional del Este, and in Parque Nacional Submarino La Caleta, and also along some comertial dive sites Also the Center of Marine Sciences of the State University (CIBIMA), and local NGO's are preforming the monitoring of reefs habitats in MPA's as well as in non-protected reefs.

9. CONCLUSIONS AND RECOMMENDATIONS FOR CORAL REEF CONSERVATION

Most of the reefs in the Dominican Republic can be considered to be relatively impacted, basically from the overgrowth of algae on the reef due to the lack of grazing caused by overfishing and in some cases from coastal changes that introduce nutrients to the water. In the MPAs (Montecristi, Parque Nacional del Este, Parque Nacional Jaragua) this is also the case. The problem lays on the lack of managerial capacity and care of these ecosystems, which has led to

this situation. This problem is aggravated in the MPAs closest to Haiti (Montecristi and Jaragua), because peoples tresspass the nation's boundaries and poach the reefs for any eatable organism, leaving empty reef tracks. In places such as Parque Nacional del Este and Parque Nacional Submarino La Caleta juvenile forms of herbivores are still present,although it is usually devoid of large individuals of any kind.

As for reefs outside MPAs, they can be found in a wide variety of states; some are severely impacted by overfishing, siltation, physical removal of corals, dredging, anchor damage, wrecks, pier and port construction, road drainage, city drainage, and pollution in general. This situation is most obvious near urban centers, and recently near tourist developments. The country's coastline is long and sometimes remote, and the goverment must have good managerial and overseeing capacity. In these remote areas, relatively good reef conditions prevail, with the exception of the usual overfishing sypmtoms.

The informal services sector that has recently established itself in the coastal regions of the Dominican Republic has created important impacts on the ecosystem found here. These people usually migrate from inland looking for work in the tourism industry. Normally they form villages overnight, and these lack all sort of sanitary and urban services. The dumping of trash and waste on the seacliffs is a common practice, and these are later found on top of corals and other benthic organism on the reefs nearby. Another impact near these villages of newly established seaside hotels is from beach vendors. Usually individuals begin as an ambulatory salespeople, but when the business flourishes, they install temporary shelters that later become permanent; in a short time, and on a large portion of beach, all sorts of produce and merchandise, are being offered, including sea creatures (stuffed or dried), most of them illegal trade. This situation calls for another type of action that has to include the police and municipal authorities, the tourism ministry, and public health, as well as the environmental authorities

In the Dominican Republic, there exists a general lack of capacity by the part of the government for administering these marine and coastal ecosystems. The government has introduced a new natural resources law into Congress to deal with the issue. There will nevertheless be a need to form personnel at the medium (technicians) and low (inspectors and alike) levels, in all ministries and governmental offices encharged with administrative duties. In the private sector, environmental education, sustainable managerial practices, promotion and propaganda are needed in order to promote a change in attitude and actions with regards to marine and coastal (including reefs) conservation. At the community and fisher levels, there is a need to educate and transmit the interdependency concept of ecosystems, as well as to introduce the responsible fishermen attitude. Also alternative fishing practices, such as the use of Fish Aggregating Devices (FADs) need to be promoted. The perspective and outlook of other coastal inhabitants that are mainly dedicated to tourism and related services is of extreme importance, and has not been analyzed in its proper context in the Dominican Republic.

In order to prevent further reef deterioration in the Dominican Republic, there is a need for:

1. improvement of the organization of environmental administration,
2. training and formation of medium and low technicians as inspectorial bodies,
3. promotion of environmental education on marine and coastal issues,
4. promotion of sustainable environmental business practices among the tourism industry,
5. promotion of responsible fisheries practices,
6. decrease or elimination of untreated sanitary and solid waste discharges in all coastal areas, including large cities, with special interest in lowering pollution discharges from industries,
7. improvement and enlargement of reforestation programs in the upper and medium watersheds,

8. application of the Integrated Coastal Management principle, as well as the recommended practices of the international conventions (CITES, MARPOL, Biological Diversity, etc.),
9. improvement of the technical capacities of the administrative bodies for patrolling and maintenance of their units and equipment.

REFERENCES.

1. Barnwell, F.H. 1980. Impacto del Huracán David (1979) sobre los corales de la cresta del arrecife de Boca Chica, Bahía de Andrés, República Dominicana. Contribuciones del CIBIMA. Santo Domingo, Dominican Republic 15: 1-10p.
2. Bonnelly de Calventi, I. 1974. Corales Pétreos de la República Dominicana. Estudios Biología Pesquera. Colección Ciencia y Tecnología, UASD 1 : 1-3.
3. Borrell, P. 1981. La Isla Beata. In : Investigaciones en las Islas Beata y Alto Velo. Museo del Hombre Dominicano y Marina de Guerra. Editora Amigo del Hogar, República Dominicana. Pp. 111-123.
4. Chiappone, M. (ed.). 2000. Coral Reef Conservation in Marine Protected Areas. A Case Study of Parque Nacional del Este, Dominican Republic. The Nature Conservancy. 119 pp.
5. Cintrón G., J. R. García and F. Geraldes. 1994. Manual de Métodos para la Caracterización y Monitoreo de Arrecifes de Coral. Washington D.C. World Wildlife Fund. 67 p.
6. Galzin, R. and J. Renaud-Mornant. 1983. Le lagon de "la Bahia de Andrés" a Saint Domingue et son eventuel desequilibre (extraction de sediment, pollution). Contribuciones del CIBIMA 37 : 1-19.
7. Geister, J.. 1980. Pleistocene reef terraces and coral environments at Santo Domingo and near Boca Chica, south coast of Dominican Republic. IX Conf. Geol. Carib. 2 : 14 p.
8. Geraldes, F.X. 1976. Ecología y Taxonomía de los Arrecifes de Coral Dominicanos 1 : Costa Sur. Tésis de grado para Licenciado en Biología, Departamento de Biología, Facultad de Ciencias, Universidad Autónoma de Santo Domingo. 124 p.
9. Geraldes, F. X. 1978. Los Arrecifes de Coral de la Costa Sur Dominicana. In: Conservación y Ecodesarrollo. Editora Alga & Omega. 125 p.
10. Geraldes, F.X. 1980. Arrecifes Fósiles de la Costa Sur de la República Dominicana. IX Conf. Geol. Carib. 2 : 6 p.
11. Geraldes, F. X. (ed.). 1994a. Inventario y elaboración del plan de manejo del Parque Nacional Submarino La Caleta. Primer informe parcial. Fundación Dominicana Pro-Investigación y Conservación de los Recursos Marinos, Inc. (MAMMA). Documento de proyecto. PRONATURA/FMAN/PNUD. 150 p.
12. Geraldes, F. X. 1994b. Iniciativa para la conservación de los arrecifes coralinos del Caribe. Informe Final del proyecto CIBIMA/WWF. 150 p.
13. Geraldes, F. X. 1994c. Estudio de los ecosistemas costeros marinos del sector 9 (Boca Chica-San Pedro de Macorís). Informe ONAPLAN/UNEP, 135 p.
14. Geraldes, F. X. 1996a. Los Ecosistemas Costeros Marinos del Litoral de la Provincia de Montecristi. Informe Segundo Semestre, Proyecto CIBIMA-UASD/GEF-PNUD/ONAPLAN. Centro de Investigaciones de Biología Marina, Universidad Autónoma de Santo Domingo.
15. Geraldes, F. X. 1996b. Bitácora del Crucero Montecristi 96. Proyecto CIBIMA-UASD/GEF-PNUD/ONAPLAN. Centro de Investigaciones de Biología Marina, Universidad Autónoma de Santo Domingo.
16. Geraldes, F. X. 1996c. Reporte sobre los sistemas arrecifales del litoral de la provincia de Montecristi. Crucero Montecristi 96. Reporte Proyecto CIBIMA-UASD/GEF-PNUD/ONAPLAN. Centro de Investigaciones de Biología Marina, Universidad Autónoma de Santo Domingo.

17. Geraldes, F. X. and M. Vega. 1995a. Evaluación Ecológica, Pesquera y Socioeconómica. Plan de Manejo del Parque Nacional Submarino La Caleta. Informe Final Proyecto FMAN/PNUD/PRONATURA. Fundación Dominicana Pro-Investigación y Conservación de los Recursos Marinos (MAMMA). 152 p
18. Geraldes F. X. and M. Vega, 1995b. Reporte sobre Evaluaciones Ecológicas en los Ambientes Arrecifales y Zona Costero-Marina de Las Terrenas, El Portillo, Puerto Escondido, y Cabo Cabrón, Península de Samaná, República Dominicana, 24-25 de septiembre del 1995. Fundación Dominicana Pro-Investigación y Conservación de los Recursos Marinos, Inc. 54 p.
19. Geraldes F. X., M. Vega, V. Alvarez, E. Pugibet, L. Almánzar T, Vargas, H. Ramírez, C. Mateo, Y. Rodríguez, R. Torres, A. L. Franco, V. Rivas, and R. Castellanos. 1997. Reconocimiento e inventario de las principales comunidades del litoral de Montecristi. Crucero MC96. Informe de 2do. Semestre. Proyecto *GEF-PNUD/ONAPLAN.* CIBIMA-UASD. 350 p.
20. González Núñez, C. 1974. Operación Madre Perla (1960). Bol. Soc. Dom. Geo. 4 : 13-31.
21. Greer, L. and P. K. Swart. 1999. A tale of three reefs: A field guide to southwestern Dominican Republic. U. of Miami/RSMAS. 47 pp.
22. Halcrow, W. and Partners. 1976. Environmental study of the Boca Chica reef for the develpment of a tourist center for the southern coast of the Dominican Republic. Report for the Banco Central of the Dominican Republic. 200 pp.
23. Metcalf, William G., Marvel C. Stalcup, and Donald K. Atwood. 1977. Mona passage drift bottle study. Bull. Mar. Sci. 27(3) : 586-591.
24. Rathe, L. 1981. Estudio Sistemático de las Esponjas (Porifera) del Litoral de la República Dominicana. Tésis de Grado para Licenciado en Biología, Departamento de Biología, Universidad Autónoma de Santo Domingo.
25. Schubert C. and J. Cowart. 1980. Terrazas Marinas del Pleistoceno a lo largo de la costa suroriental de la República Dominicana. Cronología Preliminar. IX Conf. Geol. Carib.2 : 8 p.
26. Vega, Bernardo. 1981. Aspectos Históricos delas Islas Beata y Alto Velo. In : Investigaciones en las Islas Beata y Alto Velo. Museo del Hombre Dominicano y Marina de Guerra. Editora Amigo del Hogar. Santo Domingo, República Dominicana. Pp.13-16.
27. Vega, M. 1994. Evaluación ecológica rápida del área marina del Parque Nacional del Este, República Dominicana. Informe Final. Acuario Nacional. 100 p.
28. Vega, M., Gabriel A. Delgado, and Kathleen M. Sullivan. 1994. Rapid Ecological Assessment. Parque Nacional del Este, Dominican Republic. 151 p.
29. Vega M., M. Chiappone, G. Delgado, R. Wright, K. Sullivan 1997. Evaluacion Ecologica Integral del Parque Nacional del Este, República Dominicana 2: Recursos Marinos. The Nature Conservancy Media Publishing Ltd, Bahamas. 93 p.
30. Weil, Ernesto. 1997. Coral, Octocoral and Sponge Diversity on Reefs of the Jaragua National Park, Dominican Republic. Manuscript report to Grupo Jaragua. Project Marine Biodiversity of the Dominican Republic GEF-PNUD/ONAPLAN. 9 p.