Habitat Use/Habitat Zoning Study
Isla Caja de Muertos Natural Reserve, Puerto Rico

(Contract No. WC133F04CQ0005 – Task Order No. T0007)

FINAL REPORT

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December 23, 2005

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EXECUTIVE SUMMARY

Isla Caja de Muertos Natural Reserve is one of the most important marine ecosystems of the south coast of Puerto Rico. The presence of mangrove forests, seagrass beds and coral reefs in an offshore location make this ecosystem an important recruitment, nursery and resident habitat for coral reef fishes and invertebrates, many of which are of commercial value. Coexistence of interdependent habitats allows for high system biodiversity, because of the known habitat transitions in the life cycles of many reef fishes and invertebrates. The Isla Caja de Muertos ecosystem also represents an important source of larval export of many marine species that disperse offshore and replenish adjacent areas of the Puertorrican shelf. The island's terrestrial landscape features a tropical dry forest with its typical xerophytic community, including species that are rare and only found in other oceanic islands of the Puertorrican archipelago. Its shoreline habitats are of critical importance as seabird rookeries and sea turtle nesting grounds.

The existence of protected coves and coralline sandy beaches, along with the exceptional richness and beauty of natural resources and available visitor amenities and facilities provided for the public by the Department of Natural and Environmental Resources (DNER) makes Isla Caja de Muertos an area of high recreational value. It is one of the main recreational alternatives of south coast residents and tourists. It is also the main marine recreational area for owners of sailboats and yachts from the Club Náutico de Ponce. Thus, the Isla Caja de Muertos Natural Reserve represents an important stimulus for the boating economy and related industries of the south coast of Puerto Rico.

The recreational potential of the Isla Caja de Muertos Natural Reserve is much greater than what is currently available. However, the development of this reserve as a major ecotourism site in Puerto Rico would be in conflict with its preservation as a natural reserve. Adverse effects of lighting, noise levels, production of garbage and presence of people in the vicinity of sea turtle nesting areas, as well as the direct impact of high numbers of visitors upon the limited resources of space, water and power represent some of the major conflicts. The present use of the Isla Caja de Muertos Natural Reserve by the public is one of low-intensity passive recreation, kept to a maximum

carrying capacity of 200 persons per day. Such level of use of the reserve's facilities and infrastructure is currently reached only during certain weekends and holidays.

As a result of this study, proposed modifications to the present infrastructure and recreational support facilities at Isla Caja de Muertos include: installation of additional mooring and marker buoys; implementation of closed fishing areas and seasonally-closed beach areas; recommended SCUBA and snorkeling areas; designation of areas for passive recreation only; and the refurbishment of DNER recreational/educational support facilities. The latter effort would include restoration of the Visitors Center building's infrastructure and landscaping and production of new educational/scientific exhibits representative of the island ecological systems for public education and awareness.

1.0 INTRODUCTION

1.1 Study Purpose

The detailed identification of benthic habitats and human uses of these habitats within existing natural reserves in Puerto Rico is crucial in developing management strategies for the protection of the coral reef ecosystems within the reserves. Over sixteen of the designated natural reserves in Puerto Rico contain a marine component that includes corals. However, studies of benthic habitat and multiple uses within these reserves have not been conducted in at least six of these areas and studies that have been conducted have been limited to characterizations of the coral reef communities. The Puerto Rico Department of Natural and Environmental Resources (DNER), Division of Natural Reserves and Wildlife Refuges, has the important responsibility of habitat conservation in all of the natural reserves, but the lack of data regarding management needs based on uses within the reserves has delayed management actions.

The purpose of this project is to conduct habitat use and zoning studies in two natural reserves in Puerto Rico. The results of these studies will be used to prioritize areas requiring management measures similar to those being implemented through projects sponsored by NOAA's National Marine Fisheries Service (NMFS) Southeast Regional Office, Habitat Conservation Division, Caribbean Field Office in La Parguera in Lajas, Caño Luis Peña in Culebra, and La Cordillera in Fajardo. These projects included a habitat use/habitat zoning study and the installation of navigational aids, signage, and other markers based on needs identified by the studies. Therefore, the project described in this report is a continuation of ongoing efforts in reserves identified as top priorities by DNER.

Based on a meeting held on November 10, 2004, in Rio Piedras with NMFS, DNER, and The Louis Berger Group, Inc. project team, as well as final confirmation received from DNER on December 6, 2004, the Isla Caja de Muertos Natural Reserve and Guánica State Forest and Biosphere Reserve were selected for study.

This work provides maps of the most important benthic habitats and marine oriented recreational activities in the Isla Caja de Muertos Natural Reserve. A general

characterization of marine communities associated with the main benthic habitats is included, along with an assessment of impacts and/or potential conflicts between recreational activities, commercial fishing, and the ecological health of natural communities in the reserve. Recommendations are also presented for both improvement of the recreational facilities and protection of the marine communities. Previous marine habitat use/habitat zoning studies have been prepared for La Parguera Natural Reserve (García-Sais and Sabater, 2004), Canal Luis Peña Marine Reserve in Culebra (Hernández-Delgado, 2003 a, b, c, d), and Los Arrecifes de la Cordillera Natural Reserve (CSA Group, 2005). These studies have been funded by the NMFS and performed in consultation with the DNER.

1.2 Background

Isla Caja de Muertos was designated as a Natural Reserve in 1980 by the Puerto Rico Planning Board in recognition of its highly valuable resources and the need to protect them. Natural resources within the reserve include: coral reefs, seagrass beds, aquatic bird rookeries, sea turtle nesting areas, sandy and rocky beaches, and terrestrial landscapes, including dry forests, cactus scrub-shrub communities, caves and mangrove wetlands. A comprehensive biological characterization of the main marine and terrestrial ecosystems of the reserve (Suplemento Técnico) was prepared by DNER (Villamil et al., 1980). DNER developed a management plan to protect the island's unique resources and develop recreational and scientific activities compatible with the fragile resources of the reserve (González et al., 1989).

The reserve has been used for many years as the primary marine recreational area for local tourists from the central south coast of Puerto Rico and by international tourists lodging at hotels in the city of Ponce. DNER visitor use facilities at the reserve appear in Plate 1. Some of the recreational activities practiced at the reserve include fishing, swimming, snorkeling, SCUBA diving, hiking, picnicking and boating (Plate 2). Local commercial fishermen target the queen conch (*Strombus gigas*), in seagrass beds of the Reserve, particularly in waters surrounding Cayo Berbería.

Plate 1. DNER facilites at Isla Caja de Muertos Natural Reserve.

Plate 2. Main recreational area at Pelican Beach, Isla Caja de Muertos.

In 1985, the Puerto Rico Ports Authority initiated ferryboat rides to Isla Caja de Muertos during weekends, departing from La Guancha in Ponce. Approximately 19,000 persons visited the island by ferry and 3,000 visited the reserve in private boats during 1989 (González et al., 1989). During weekdays, most of the visitors are local tourists that arrive in private boats, sailboats and yachts from the Club Náutico de Ponce. After 1992, the Ports Authority ceased the tourist transport operation to the Reserve for economic reasons (Robert Matos, DNER, Director of Natural Reserves and Refuges, personal communication). Currently, Mr. Rafael Vega, Island Venture, has been granted a concession by DNER to transport tourists to the reserve, making one or two trips daily, with up to 80 passengers per trip (Plate 3). According to Carlos Cianchini (DNER management official for the Isla Caja de Muertos Natural Reserve, personal communication) the maximum holding capacity of the visitor facilities of the Reserve is 200 people per day. The maximum capacity is determined by the availability of gazebos (15) and bathrooms (4). Approximately 20,000 people visit the reserve during the year.

Plate 3. Ferry boat concession transports visitors between Ponce and the reserve.

Geographic Location

Isla Caja de Muertos Natural Reserve lies 8.5 km south of Ponce in the Caribbean Sea. The reserve consists of Isla Caja de Muertos, Isla Morrillito, Cayo Berbería and surrounding waters (Figure 1). Total surface area of the reserve is 188.4 km^2. The largest terrestrial component, Isla Caja de Muertos is approximately 3 km long and 1 km wide. Cayo Berbería is approximately 1 km long and 0.2 km wide and is located 5.5 km to the northeast of Isla Caja de Muertos and 4.8 km south of Ponce. The natural reserve boundaries are: Northeast 17°57'N/66°26'W; North 17°57'N/66°29'W; Northwest 17°54'N/66°33'W; Southeast 17°53'N/66°26'W; and Southwest 17°51'N/66°33'W.

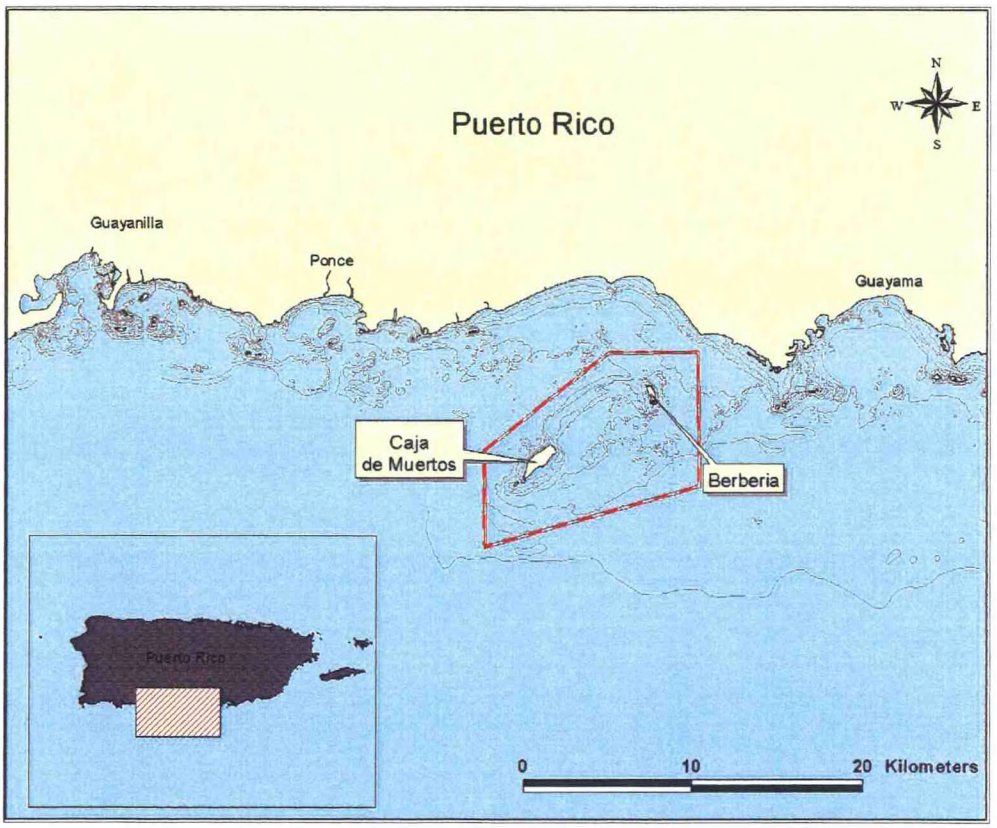

Figure 1. Location map and geographic boundaries of Isla Caja de Muertos Natural Reserve.

Climatology

Climatological information for Isla Caja de Muertos Natural Reserve has been estimated from computer models based on data from Santa Isabel Airport (González et al., 1989). The mean annual air temperature is 25.2 ° C. Rainfall follows a seasonal pattern, with a relatively wet period between May and October, and a relatively dry period from November through April. Mean annual rainfall is 602.7 +/- 175.2 mm. This geographic region is within the ecological zone classified as Subtropical Dry Forest (Ewel and Whitmore, 1973).

Trade winds, associated with high atmospheric pressure zones, represent the dominant climatological system throughout the year. The weather associated with this system is generally warm and dry, with occasional showers late in the afternoon. Prevailing wind direction is from the northeast, with mean velocities fluctuating between 4.6 and 22.4 km/hr. Cold fronts, tropical waves and hurricanes markedly influence the climatological pattern of Isla Caja de Muertos. During the period between November and April, cold fronts originating in the North Atlantic reach south towards the Caribbean lowering air temperature and producing rainfall. The wind is typically from the north and northwest, although fluctuations of wind speed and direction are associated with these weather systems as they pass over the island. Tropical waves are experienced seasonally during the summer and fall in Puerto Rico (May – October). These may bring considerable rainfall and may transform into tropical storms and hurricanes. The hurricane season in Puerto Rico is from June through November.

Hurricanes have had a significant effect upon the marine communities and visitor facilities of Isla Caja de Muertos. During 1979, the passing of Hurricane David caused considerable damage to shallow marine communities of the south coast of Puerto Rico, including those at Isla Caja de Muertos. Hurricane Georges in 1998 caused significant damage to the island's facilities and produced changes in coastal geomorphology, removing coralline sand from beaches and exposing a rocky shoreline in various sections of the reserve.

Geology

The geology of Isla Caja de Muertos was described by Beach (1975) and Beach et al. (1980). Isla Caja de Muertos and Cayo Berbería are composed mainly of sedimentary rocks from the Eocene and Miocene periods. They are part of the Ponce Limestone Formation that covers a large area of southern Puerto Rico. Isla Caja de Muertos is composed of three main rock types: 1) the oldest rocks are volcanoclastic sequences and layers of volcanic sands dating from the Eocene; 2) sand, basaltic conglomerates and tertiary limestones deposited on top of the oldest formation and representing the dominant geologic feature of Isla Caja de Muertos; and 3) unconsolidated Holocene (modern) deposits of gravel and sand that are presently found along the island coastline.

The morphology of Isla Caja de Muertos is the result of an anticline trending east-northeast and three major faults that cross the island (Plate 4). Cayo Berbería is part of the Isla Caja de Muertos platform, a shallow cemented limestone terrace, presumably part of the Ponce Limestone Formation.

Plate 4. Rocky shoreline at Isla Caja de Muertos showing anticline formation.

Economic Importance

Isla Caja de Muertos Natural Reserve is one of the most important marine ecosystems of the south coast of Puerto Rico. The presence of mangrove forests, seagrass beds and coral reefs make this ecosystem an important recruitment, nursery and resident habitat for coral reef fishes and invertebrates, many of which are of commercial value. The coexistence of interdependent habitats allows for high system biodiversity, because of the known habitat transitions in the life cycles of many reef fish and invertebrates. Thus, the Isla Caja de Muertos ecosystem also represents an important source of larvae for a myriad of marine species that disperse and replenish adjacent areas of the Puertorrican shelf.

An artisanal-subsistence fishery is associated with the reef and seagrass habitats of the reserve. Approximately twenty fishermen from Ponce, Juana Diaz, Peñuelas and Santa Isabel fish in Isla Caja de Muertos and Cayo Berbería's waters. The largest fishery targets queen conch, which are collected by diving from small boats or yolas (locally made wooden boats). There is also a small scale finfish fishery, particularly targeting snappers, trunkfish, jacks, and white mullet. During our visits to the reserve, six fish pots were seen with floating markers. Fishermen are also known to fish with hand lines and gillnets within reserve waters (C. Cianchini, personal communication).

Isla Caja de Muertos is an important marine recreational area for local and international tourists, particularly from the central south coast. It is one of the main recreational destinations of boat and yacht owners from the Club Náutico de Ponce. Thus, the existence of the Isla Caja de Muertos resource represents an important stimulus for the tourist-related industries in Puerto Rico. The recreational potential of the Isla Caja de Muertos Natural Reserve is much higher than what is presently available. However, the development of this reserve as a major tourism site in Puerto Rico would be in direct conflict with its preservation as a natural reserve.

Isla Caja de Muertos is also an important educational and scientific research resource. Students from several universities and organizations, such as the Boy Scouts, participate in educational field trips to the reserve. One coral reef system within the Reserve has been included as part of the DNER-NOAA Coral Reef Monitoring Program.

1.3 Biotic Communities

Terrestrial Fauna

General taxonomic surveys of the terrestrial fauna of Isla Caja de Muertos have been performed by DNER scientists. Canals et al. (1980a) reported a total of 34 species of arthropods of which 85 % were insects, 12 % were spiders and 3 % mites and ticks. Most arthropod species present on Isla Caja de Muertos are common to the south coast of Puerto Rico. The relatively short distance between islands has facilitated dispersal and establishment of terrestrial fauna. Colonization is associated with airborne species, such as flying insects, and species that can be transported via floating objects, or introduced accidentally by boats. Arthropods present include spiders, such as tarantulas and the black widow (*Tarantula* sp. and *Latrodectus mactons*, respectively) and the scorpion *Centruroides nitidus*. Ants, represented by 14 species on the island, constitute one of the most specious groups of arthropods and are important in terms of management due to their high abundance and aggressive behavior (González et al., 1989).

Among crustaceans, the hermit crab (*Coenobita clypeatus*) is common throughout the island. Its population is dependent upon the availability of empty gastropod shells. Like other terrestrial crustaceans, hermit crabs must spawn in the sea, and so they make mass migrations to the shoreline every year. The ghost crab, *Ocypode quadrata,* is common on the sandy beaches of the island, where it digs its burrow and forages for small intertidal invertebrates that become exposed through wave action. The rock crab, *Geocarcinus ruricola,* is common on rocky shorelines of the southeast coast of Isla Caja de Muertos and the mangrove crab, *Aratus pisonii,* is abundant in red mangrove trees at Cayo Berbería (González et al., 1989).

Reptiles of the genus *Sphaerodactylus* spp. (geckos) and *Anolis* spp. (lizards) are the most common reptiles on Isla Caja de Muertos. The green iguana (*Iguana iguana*) is an introduced species that is present in the mangrove habitat. The endangered green and hawksbill sea turtles (*Chelonia midas* and *Eretmochelys imbricata*, respectively) forage in the waters around Isla Caja de Muertos, and the hawksbill nests on sandy beaches of the island between May and December.

A total of 42 species of birds have been reported from Isla Caja de Muertos Natural Reserve (González et al., 1989), including the endangered brown pelican (*Pelecanus occidentalis*), the frigatebird (*Fregata magnificens*) and the booby (*Sula leucogaster*), which nests within the rocks of Cayo Morrillitos. The aforementioned species are relatively large predatory birds that feed exclusively on schooling fishes. At least six species of sandpipers and six species of terns have been sighted on the island, as well.

Rats (*Rattus norvegicus*) and domestic cats (*Felis catus*) are introduced mammals that are common in the terrestrial habitats of the reserve. The fruit bat (*Artebius jamaicensis*) and the fishing bat (*Noctilio leporinus*) have also been reported (González et al., 1989).

Terrestrial Flora

Terrestrial vegetation at the Isla Caja de Muertos Natural Reserve (Plate 5) is typical of subtropical dry forests (Holdridge, 1974, Ewel and Whitmore, 1973). Vegetation within the reserve has been described by González et al (1989). Deciduous vegetation prevails, with abundant cacti and plants with small, succulent leaves. Evergreens and wild grass prevail close to the shoreline in sandy areas of the coastal zone, which occupies an area of 6.4 ha. The dominant species are seashore dropseed (*Sporobolus virginicus*), beach morning glory (*Ipomea prescaprae*) and beach bean (*Canavallia maritima*). Rocky areas of the coastal zone are mostly devoid of vegetation, but the herb prostrate spurge (*Chamaesyce postrata*) grows within rock depressions where sand/soil deposits are available. Higher in the supra-littoral zone three shrubs dominate. These are sea grape (*Coccoloba uvifera*), manicheel (*Hippomane manxinella*) and button mangrove (*Conocarpus erecta*).

Plate 5. Deciduous vegetation typical of the subtropical dry forest at Isla Caja de Muertos.

The coastal plain covers an area of 53.4 ha and includes five types of vegetation: thorn woodland (12.5 ha), cacti scrub-shrub (10.9 ha), evergreen shrubs (25.6 ha), salt flat (1.2 ha) and mangrove (3.2 ha). Common species in the thorn woodland include twisted Acacia (*Acacia tortuosa*), white leadtree (*Leucaena lecocephala*), caper tree (*Capparis flexuosa*), guinea grass (*Panicum maximum*), and pitted beardgrass (*Andropogon pertusus*). The dominant cactus species are *Stenocerus hiptux*, prickly pear (*Opuntia dilleni*) and pipe organ cactus (*Pilosocereus royenii*).

A relatively small mangrove wetland (3.2 ha) is located on the south coast of Isla Caja de Muertos, composed mostly of button mangrove and white mangrove (*Laguncularia racemosa*). Sea pickle (*Sesuvium portalacastrum*) and saltwort (*Batis maritime*) grow in two salt flat areas associated with this mangrove system. Evergreen shrubs of the coastal plain include wild grape (*Coccoloba krugii* and *C. mixeoarxhy*), bitter ash (*Rauvolflia nitida*), white frangipani (*Plumeria alba*), shortleaf fig (*Ficus citrifolia*), maidenberry (*Crossopetalum rhacoma*), pepperbush (*Croton humilis*), wild sage (*Lantana involucrate*), indigoberry (*Randia aculeata*) and gumbo-limbo tree (*Busera*

simaruba). These two latter species and poison ash (*Comocladia dodonea*) dominate areas of higher elevation within the coastal plain towards the Lighthouse.

The karst zone is composed of a semi-evergreen forest (33.5 ha), thorn woodland (22.6 ha), cacti (5.5 ha) and rocky sea cliffs (3.2 ha) (González et al. (1989). A similar assemblage of species described for the coastal plain prevail in the semi-evergreen forest of the karst zone, except that indigoberry and gumbo-limbo tree are found in higher abundance along with poison ash. The dominant cactus is *Stenoceros hipux*. *Alchornea latifolia*, white frangipani, poison ash, and *Leptochoopis vigata* grow at the top of the karst. Rocky areas are colonized by xerophytes, such as ballmoss (*Tillanosia recurvata*) and purslane (*Portulaca* spp.). At Cerro Morrillo, vegetation is best developed near the base of the north section with large individuals of catchbirdtree (*Pisonia albida*), fiddlewood (*Xirhewzylum fruticosum*) and other shrubs. With increasing altitude, the canopy of trees decreases in height and plants only grow in depressions where soil deposits are present.

Two types of vegetation are found at Cayo Morrillito; a herbaceous community (3.2 ha), dominated by seashore dropseed and buffelgrass (*Pennisetum ciliare*), and a small evergreen landscape (0.8 ha), dominated by sea grape.

Marine Communities

Marine communities associated with coral reefs, colonized pavement, seagrass beds, mangroves, rocky shorelines, and sandy beaches are present at Isla Caja de Muertos Natural Reserve. The geographic distribution and detailed biological characterization of these habitats and associated communities is presented in the results section of this report.

An initial description of the marine ecosystems, including taxonomic surveys of the marine communities of the reserve, was prepared by the DNER as part of the scientific background studies supporting the natural reserve designation (Villamil et al., 1980). The taxonomic structure and vertical zonation of the coral reefs was described by Goenaga and Cintrón (1979) as part of the general inventory of coral reefs in Puerto Rico by the DNER. Subsequent observations that included quantitative assessments of coral cover from reefs at Isla Caja de Muertos and Cayo Berbería, were prepared by Canals et al. (1980 a, b). Quantitative baseline characterizations of the sessile-benthic, fish and motile megabenthic communities based on permanent transects established at three reef systems in the reserve, including Cayo Berbería, were performed by García-Sais et al. (2001). One of the coral reef systems at Isla Caja de Muertos has been included in the National Coral Reef Monitoring Program for Puerto Rico (García-Sais et al., 2005) (Plate 6). This program is part of NOAA's U.S. Coral Reef Initiative, the purpose of which is to effectively conserve and manage coral reefs and related ecosystems.

Seagrass beds constitute an important marine benthic habitat of the Isla Caja de Muertos Natural Reserve. They serve as recruitment and nursery habitat for many coral reef fishes and invertebrates and provide habitat for a diverse assemblage of resident populations, including the commercially valuable queen conch, *Strombus gigas* (Plate 7). Many adult and juvenile coral reef fishes forage in seagrass beds. Seagrass beds at Isla Caja de Muertos also constitute foraging habitat for the endangered Caribbean manatee, *Trichechus manatus* (Belitsky, 1979, as cited in Gonzalez et al, 1989) and the green sea turtle. The total surface area of seagrasses within the Isla Caja de Muertos Natural Reserve has been previously estimated as 1,100 ha. (González et al., 1989).

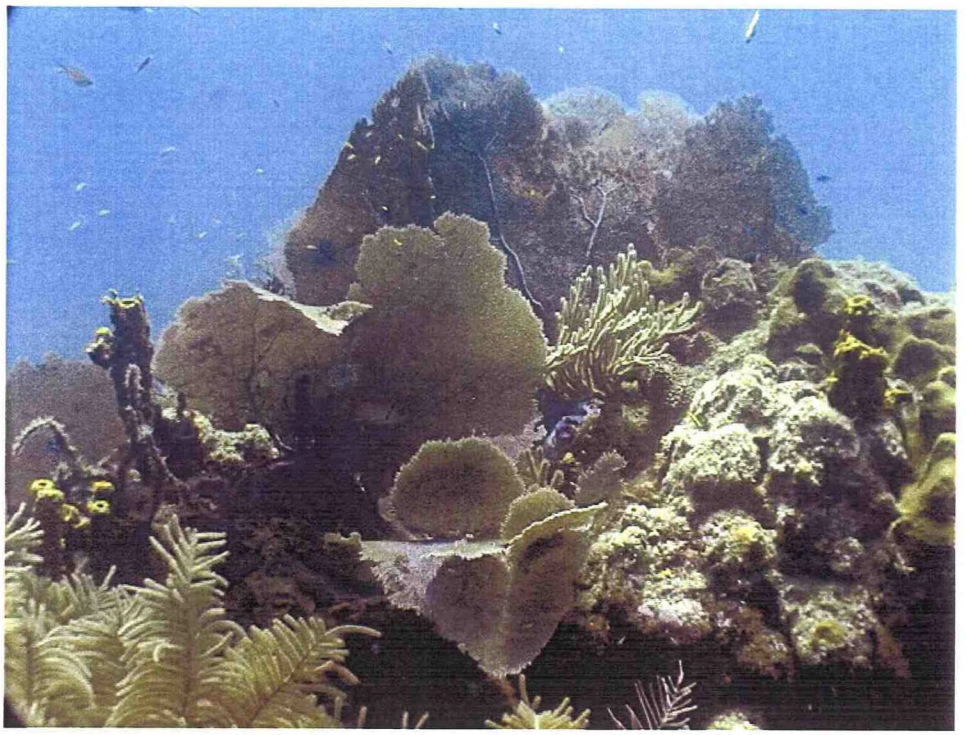

Plate 6. Coral reefs from Isla Caja de Muertos are included in the National Coral Reef Monitoring Program (DNER-NOAA).

Rocky and sandy beaches provide habitat for the intertidal communities of Isla Caja de Muertos. Marine communities are distributed within three distinct zones (González et. al. (1989). The supralittoral zone, at the higher end of the shoreline is only in contact with seawater during periods of very high tides and/or during events of strong wave action. Gastropods of the genus *Littorina* spp. are the most abundant marine organisms in this zone, particularly on rocky shorelines. Ghost crabs and hermit crabs are most common in sandy areas. The vegetation of the supralittoral zone includes herbaceous plants (seashore dropseed, beach morning glory, beach bean, and prostrate spurge) and shrubs (sea grape, manicheel tree, and button mangrove). The mesolittoral zone is submerged during several hours each day during high tide and remains wet throughout the day during periods of strong wave action. On rocky beaches, mollusks such as snails (*Nerita* spp.) and chitons (*Acanthopleura* spp.) are the most common organisms. Denticulate clams (*Donax denticulatus*) and mole crabs (*Emerita portorricensis, Albunea* sp.) are common in the mesolittoral zone of sandy beaches. The infralittoral zone is marked by the lower end of low tide and is always submerged or wet. Mollusks that live

attached to rocks in this zone include the topshell (*Cittarium pica*), white hoofsnail (*Hipponix antiquatus), Cypraea* sp., *Purpura patullo,* and others. Brittle stars (*Ophiotrix*

Plate 7. Commercially valuable queen conch in seagrass habitat.

spp., *Ophiocoma spp.*), are also present on rocky substrate. Sand dollar urchins (*Mellita sexiesperforata*) are common in the infralittoral zone of sandy beaches. Brown and red macroalgae are common on rocky substrate of this zone. The taxonomic composition and distribution of benthic macroalgae on rocky beach habitats of Isla Caja de Muertos was described by Villamil et al. (1980).

Mangrove systems are present at Isla Caja de Muertos and Cayo Berbería. Button mangrove and white mangrove are the main structural components of a relatively small (3.2 ha) mangrove forest on the south coast of Isla Caja de Muertos. This mangrove system includes a pair of salt flats in the interior section that are partially covered by herbaceous species (seashore dropseed, sea pickle, and saltwort). The mangrove system at Cayo Berbería has been classified as a fringing mangrove forest (Villamil et al.,1980). Red mangrove (*Rhizophora mangle*) is the dominant species and is found along the border of the entire island. White mangrove grows intermixed with red mangrove in intermediate sections of the forest. Black mangrove (*Avicennia nitida*)

dominates in the interior basin, where a salt flat and a hypersaline lagoon have formed. Vegetation typical of semi-arid forests, such as sea grape, tropical fimbry (*Fimbristylis cymosa*), small yellow knicker (*Caesalpinia divergens*), seashore dropseed, sea pickle, and saltwort are also present on Cayo Berbería (González et al., 1989).

1.4 Objectives

The objectives of this study were to:

1. Identify and prepare a revised map of marine benthic habitats within the Isla Caja de Muertos Marine Reserve
2. Identify the location, types and intensity of recreational and commercial activities within the reserve
3. Evaluate the present condition of marine benthic habitats and identify potential impacts due to recreational and commercial activities
4. Provide management recommendations to reduce potential impacts from recreational and commercial use and allow for utilization of marine resources with minimal impact to the benthic habitats and associated marine communities of the natural reserve

2.0 METHODS

2.1 Distribution of Benthic Habitats

Mapping of the benthic habitats at the Isla Caja de Muertos Natural Reserve was based on field validation and modifications to NOAA's benthic habitat map for Puerto Rico and the US Virgin Islands (Kendall et al., 2001). Information on the distribution of benthic habitats was also derived from an earlier map prepared by DNER (Villamil et al., 1980) based on aerial photographs. The digitized aerial photograph from NOAA's benthic habitat map for the Isla Caja de Muertos Natural Reserve was entered into Hypack software and opened from a computer interfaced with a GPS onboard the research vessel. This allowed navigation over the digitized photograph in real time. A total of 386

ground truth observations were made in the field and saved as X, Y georeferenced points.

The survey of benthic habitats comprised a total area of 616.9 ha distributed within the 10 meter depth contour around Isla Caja de Muertos (except for the eastern platform which was circumscribed to 0.5 Km from the shoreline), and 241.6 ha. around Cayo Berbería. Field work was conducted from February to May, 2005 (total of 10 days of field survey). This set of observations (points) was superimposed over NOAA's benthic habitat map for Isla Caja de Muertos and was used to modify existing habitat polygons, where necessary. Additionally, bathymetric contours from NOAA electronic navigation charts were added to the maps. In some areas, these contours are incorrect, however this information is still useful in identifying shallow areas where human activity could lead to habitat impacts.

Some of the most important modifications to NOAA's map included:

1) an expansion of the sand cover at Pelican Beach, which is the main anchoring site;
2) relocation and expansion of the total area of the coral patch reef to the north of Isla Caja de Muertos;
3) inclusion of two coral patch reefs located to the north of Isla Caja de Muertos classified as "unknown" on NOAA's map;
4) separation of the backreef lagoon and fringing reef from the all inclusive "linear reef" original classification; and
5) simplification of seagrass cover categories into one including "mixed seagrass and macroalgae" as verified in the field.

For the purpose of this study, marine benthic habitats were classified in the following categories:

- **Colonized hard ground** : hard bottom, not of coral construction, including low and high topographic relief, with partial cover of hydrocorals, stony corals, and other encrusting biota

- **Mixed seagrass and macroalgae** : vegetated bottom dominated by a mixed seagrass and macroalgal assemblage
- **Sand** : abiotic, unconsolidated sediments of primarily coralline biogenic origin
- **Backreef lagoon** : extensive coral reef system located to the northeast of Isla Caja de Muertos, on the leeward (protected) side of the emergent fringing reef
- **Patch reef** : isolated coral reef formations submerged on the Isla Caja de Muertos insular shelf
- **Staghorn coral biotope** : relatively large live coral formations dominated by staghorn coral
- **Fringing reef** : emergent section of the coral reef located to the northeast of Isla Caja de Muertos

2.2 Biological Characterization of Benthic Habitats

Taxonomic characterizations of the dominant biological components of coral reefs, colonized pavements and seagrass beds within Isla Caja de Muertos were performed to supplement and update previous surveys by Goenaga and Cintrón (1979), Canals et al. (1980 a, b), Villamil et al. (1980) and García-Sais et al. (2001). Aspects of benthic habitat "ecological health," such as incidence of infectious diseases in corals, coral bleaching, dead corals and/or mechanical damage to corals and seagrasses were noted. Particular attention was given to the assessment of impacts due to recreational activities, such as propeller scars, fishing lines entangled in corals, garbage, clothing and other materials present within the benthic habitats of Isla Caja de Muertos. Digital underwater photographic documentation of the marine communities associated with coral reefs, colonized pavements and seagrass beds within Isla Caja de Muertos were collected.

2.3 Recreational and Commercial Activities in the Marine Environment

Geographic mapping of recreational activities in the marine environment of Isla Caja de Muertos was accomplished using the same technique as for mapping benthic habitats. Recreational activities, including docking of the ferry boat (the existing dock was not

previously included in existing maps), boat anchoring sites, existing mooring buoys, fishing areas, snorkeling areas, and swimming/bathing areas, were geo-referenced by navigating to the location where the recreational activity was taking place and identifying it as a way point with annotations in a computer (Hypack software). Likewise, the locations of observed commercial fishing activities were recorded. The positions were then superimposed on a digitized and georeferenced map of the island. The proposed locations of recommended actions to mitigate recreational impacts to benthic habitats were also mapped with the same technique. In order to identify and map some of the critical habitats for endangered species in the reserve (such as the nesting beach of the hawksbill turtle and coral reef areas), the Management Official for the Isla Caja de Muertos Reserve, Mr. Carlos Cianchini, was brought aboard to assist in locating these areas on March 18, 2005. Photographs of areas where recreational activities were observed were taken from the boat during the survey and from the air on July 24th and 25th, 2005.

2.4 Management Recommendations

Management recommendations included in this document were developed based on information from previous scientific publications, such as the technical works by Goenaga and Cintrón (1979), Canals et al. (1980 a, b), Villamil et al. (1980), García-Sais et al. (2001), and field observations from this study. Special attention was focused on the existing Management Plan for the Isla Caja de Muertos Natural Reserve document (González et al., 1989) and the recent mitigation plan negotiated between administrators of the Port of the Americas and DNER (CSA Group, 2004). Reserve management vision and specific alternatives were discussed with the Management Official for the Isla Caja de Muertos Reserve, Mr. Carlos Cianchini, and with the Director of Natural Reserves and Refuges of DNER, Mr. Robert Matos. Informal interviews with several local fishermen and visitors at the reserve were made to gain insights about their views of the reserve management status, fishing regulations and recreational activities and supporting facilities.

3.0 RESULTS

3.1 Zoning Map of Benthic Habitats

Isla Caja de Muertos

The geographic distribution of benthic habitats around Isla Caja de Muertos is presented in Figure 2. A low-relief colonized hard ground platform surrounds most of the northeast and southwest section of the island. The total surface area covered by low-relief colonized hard ground habitat around Isla Caja de Muertos was 423 ha, representing 68.6 % of the total benthic habitat within the 10 meter depth contour surveyed around the island (Figure 3). The colonized hard ground platform rises to the surface along the northeast coast, creating a fringing reef that extends to the south in a widened horseshoe shape. A backreef lagoon is formed on the leeward (protected) side of the fringing reef, with large coral promontories growing on the outer deeper sections and mixed seagrasses and macroalgae prevailing on the shallow margins close to the shoreline. The eastern-southeastern side of the island is largely a colonized hard ground platform with a small fringe of sand very close to the shoreline. This section of the coastline is known as Playa Larga, and is the nesting area of the hawksbill turtle. The sandy area of Playa Larga leads southerly towards a section of sea cliffs that surround the southwest end of the island, including Cayo Morrillito. The sea cliffs are important seabird rookery habitat for birds such as the booby and the brown pelican. Underwater, the bottom is high-relief colonized hard ground, consisting of rock slabs with sand channels. High-relief colonized hard ground habitat covers approximately two percent of the total benthic habitat surveyed around Isla Caja de Muertos, or 12.3 ha.

Seagrasses are widely distributed around the western and northern sections of the island and continue along the shallow platform that joins Isla Caja de Muertos with Cayo Berbería. At Isla Caja de Muertos, seagrasses are established within a depth range of 3 – 5 meters, approximately 50 meters from the shoreline, except at the backreef lagoon where seagrasses grow almost to the shoreline. These seagrass beds are composed of both turtle grass (*Thalassia testudinum*) and manatee grass (*Syringodium filiforme*). The total surface area covered by seagrasses at Isla Caja de Muertos is 103.7 ha, or 16.8 % of the total benthic habitat surveyed (see Figures 2 and 3). A narrow fringe of sand,

intermixed with patches of low-relief colonized hard ground is found between the shoreline and the seagrass habitat along the northwest section of the island.

A relatively large coralline sand deposit is found in a protected cove on the southwest section of Isla Caja de Muertos, forming a beautiful sandy beach known as Pelican Beach. This is the main recreational area of the reserve. DNER visitor facilities are located at this beach. There is a large cement dock that allows landing of the ferryboat and other vessels that support DNER's operations on the island.

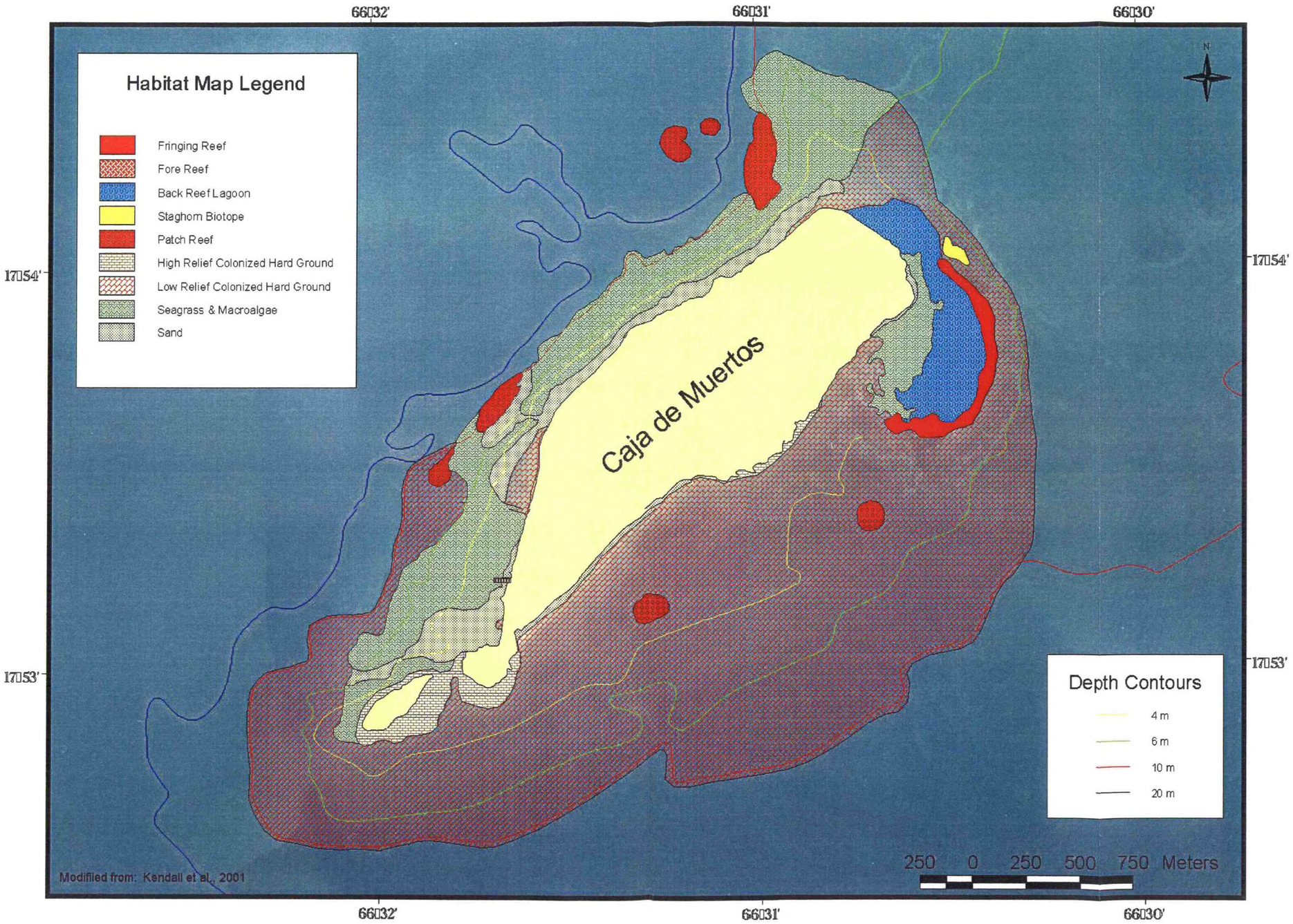

Figure 2. Geographic distribution of benthic habitats at Isla Caja de Muertos. Modified from Kendall et al. (2001). Bathymetric contours are from NOAA Electronic Navigation Charts US5PR42M and US5PR45M, modified based on field observations.

Benthic Habitat Type	Area (m^2)	%
Low Relief Colonized Hard Ground	4,231,146	68.6
Mixed Seagrass & Macroalgae	1,037,373	16.8
Sand	302,059	4.9
Back Reef Lagoon	250,398	4.1
Patch Reef	140,360	2.3
High Relief Colonized Hard Ground	123896	2.0
Fringing Reef	74,912	1.2
Staghorn Coral Biotope	8,425	0.1
Total =	**6,168,569**	**100**

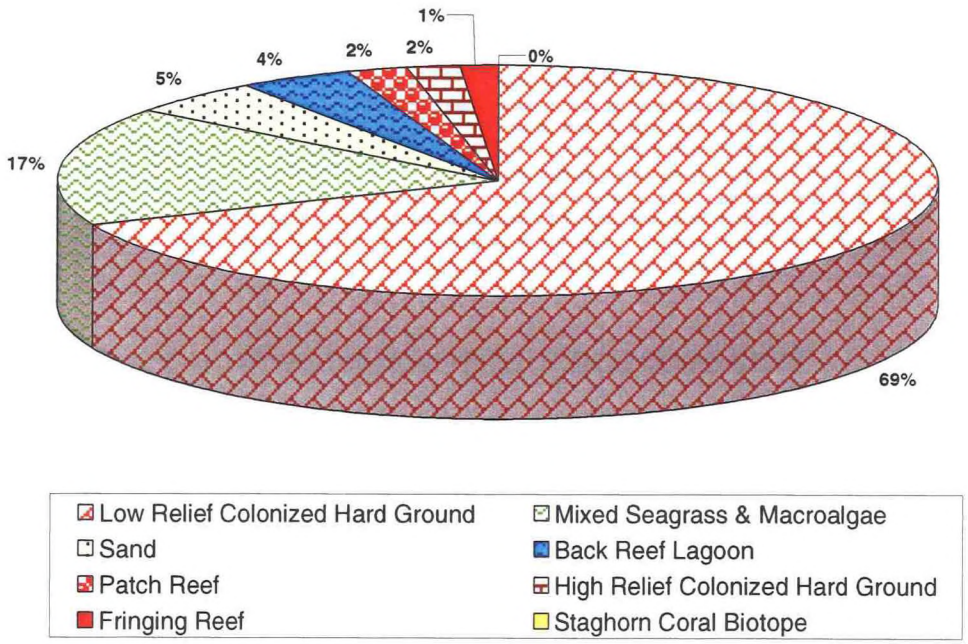

Figure 3. Percent and areal cover of the main benthic habitats of Isla Caja de Muertos.

Coral reefs comprise approximately 47.4 ha, or 7.7 % of the total benthic habitat area around Isla Caja de Muertos and at least 39.2 ha at Cayo Berbería. The largest coral reef system of Isla Caja de Muertos is located at the backreef lagoon on the northeast coastline (Figure 2). This coral reef system extends more than 2.0 km along the coast on the protected (leeward) side of a fringing reef formation. The underwater topographic relief within this backreef lagoon is entirely associated with coral growth, including a massive buildup of staghorn and elkhorn coral (*Acropora cervicornis*, *A. palmata*) on the

northeast section of the lagoon. Coral reefs are also found as submerged patch formations on the northwest, west and eastern sections of the Isla Caja de Muertos shelf.

Cayo Berbería

Cayo Berbería contains a fringing coral reef formation along the east and south coast. An extensive reef flat is found on the south coast that leads offshore to an abrupt forereef slope, where most of the massive coral development has occurred. Coral reefs are also found as patch reef formations on the south and east coasts of Cayo Berbería (Figure 4). Coral reefs occupy an area of at least 39.2 ha, representing 16.2 % of the island's benthic habitat (Figure 5). Areas of colonized pavement, mostly dominated by soft corals and macroalgae are found to the northeast and to the southwest of the island, interfacing with seagrass beds. The total cover by colonized pavement habitats at Cayo Berbería is approximately 13.1 ha, or 5.4 % of the total benthic habitat around the island.

Seagrasses form a continuous habitat that surrounds almost the entire island of Cayo Berbería (Figure 4). An extensive seagrass bed is found along the western and northern sections of the island covering the entire shallow platform that connects Cayo Berbería with Isla Caja de Muertos. Seagrasses are the dominant benthic habitat, representing 78.0 % of the total submerged area of the mangrove island (Figure 5).

The mangrove forest of Cayo Berbería is located at the center of the island, where it occupies a total of 32.5 ha. The mangrove forest is fringed by red mangrove and contains growth of white, black and button mangrove in the interior section. There is a small hypersaline lagoon at the center of the mangrove forest.

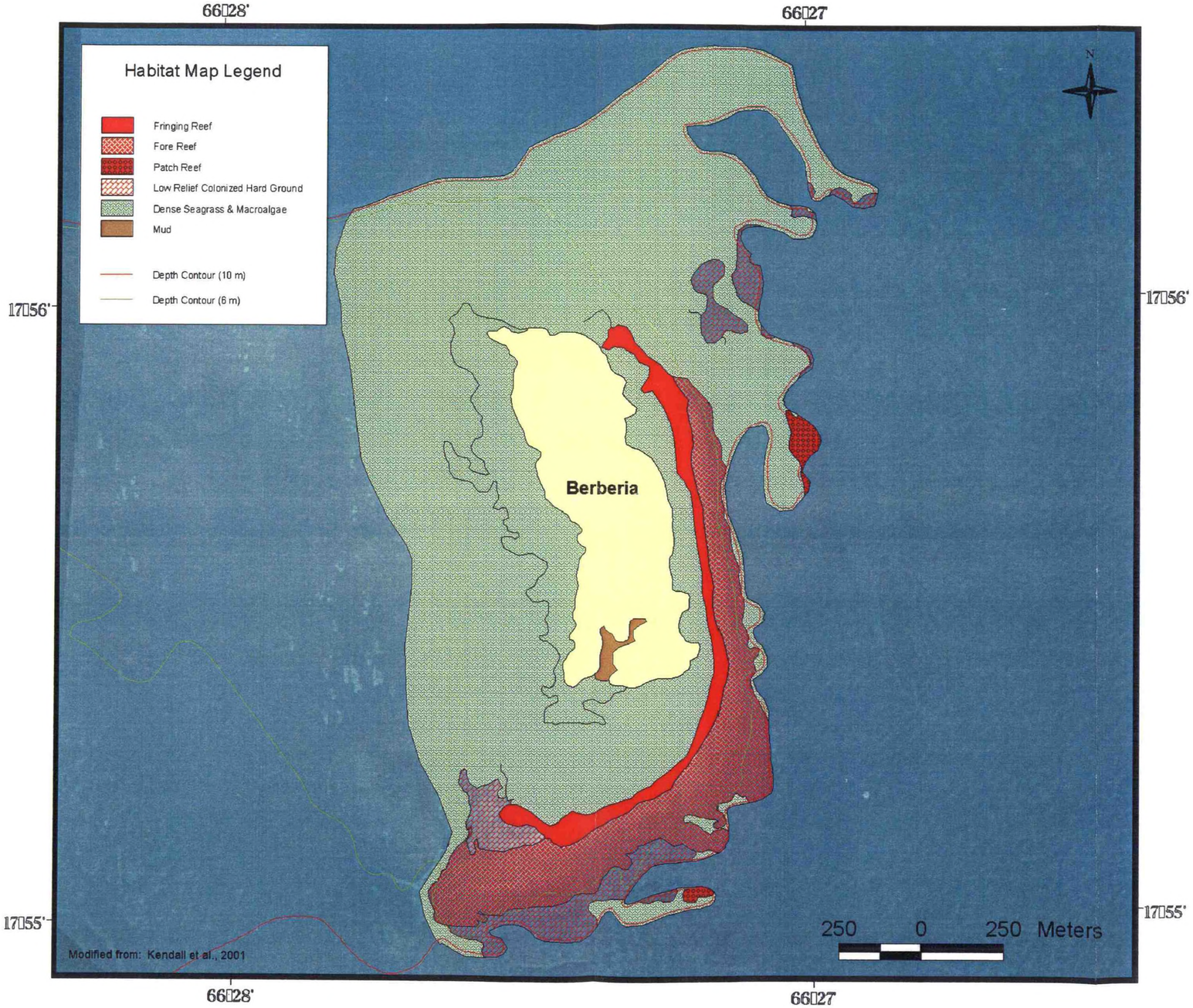

Figure 4. Geographic distribution of benthic habitats at Cayo Berbería. Modified from Kendall et al. (2001). Bathymetric contours are from NOAA Electronic Navigation Charts US5PR42M and US5PR45M, modified based on field observations.

Benthic Habitat Type	Area (m^2)	%
Mixed Seagrass & Macroalgae	1,884,348	78.0
Low Relief Colonized Hard Ground	131,016	5.4
Fore Reef	289,776	12.0
Patch Reef	14,487	0.6
Fringing Reef	88,223	3.7
Mud	8,607	0.4
Total =	**2,416,457**	**100.0**

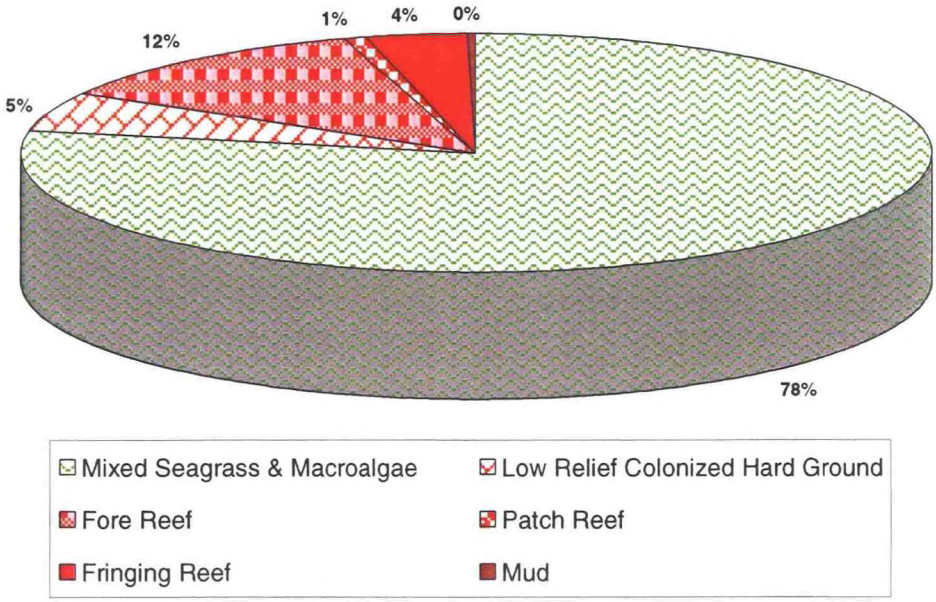

Figure 5. Percent and areal cover of the main benthic habitats of Cayo Berbería.

3.2 Biological Characterization of Marine Communities

Coral Reefs

The main coral reef habitats of the Isla Caja de Muertos Natural Reserve are 1) the backreef lagoon system at the leeward side of Windward Reef (northeast Isla Caja de Muertos); 2) fringing reefs at Isla Caja de Muertos and Cayo Berbería; and 3) patch reef formations at Isla Caja de Muertos.

Backreef Lagoon System at Isla Caja de Muertos

The backreef lagoon is found closest to the shoreline, on the protected side of the emergent fringing reef (Windward Reef). Corals grow throughout the lagoon in patches, promontories and isolated colonies over an otherwise sandy bottom at depths between 1 – 3 meters. Sections of colonized pavement bottom were covered by a dense algal turf with brown and red coralline macroalgae (*Dictyota* sp., *Amphiroa* sp., *Jania* sp.) and abundant colonies of vertically projected soft corals (*Gorgonia* spp., *Pterogorgia* spp., *Pseudopterogorgia* spp., *Plexaura* spp., *Eunicea* spp., and *Briareum asbestinum*). Large massive colonies of stony corals (*Montastrea annularis, M. cavernosa, Siderastrea siderea, D. labyrinthiformis,*) were found growing in promontories, some of which were observed to reach the surface (Plate 8). Fire coral (*Millepora* spp.) was highly abundant over promontories at shallow depths (Plate 9). Mound shaped colonies of mustard hill coral (*Porites astreoides*), symmetrical brain coral (*Diploria strigosa*), and knobby brain coral (*D. clivosa*) were common as isolated colonies over the sandy substrate. A small meadow of turtle grass was found close to the shoreline. Table 1 presents a list of common species observed from coral reef habitats during this study.

An impressive feature of the backreef lagoon is the presence of large, monospecific biotopes of staghorn coral (Plate 10). These form linear mounds of staghorn coral that rise from the bottom at least 2 meters, evidencing continuous growth and accumulation of coral skeleton for prolonged periods of time. The biotope is of extreme significance as a recruitment and nursery habitat for many reef fishes, such as grunts (Haemulidae), snappers (Lutjanidae), and damselfishes (Pomacentridae), among others. Isolated colonies of staghorn coral were also common throughout the lagoon.

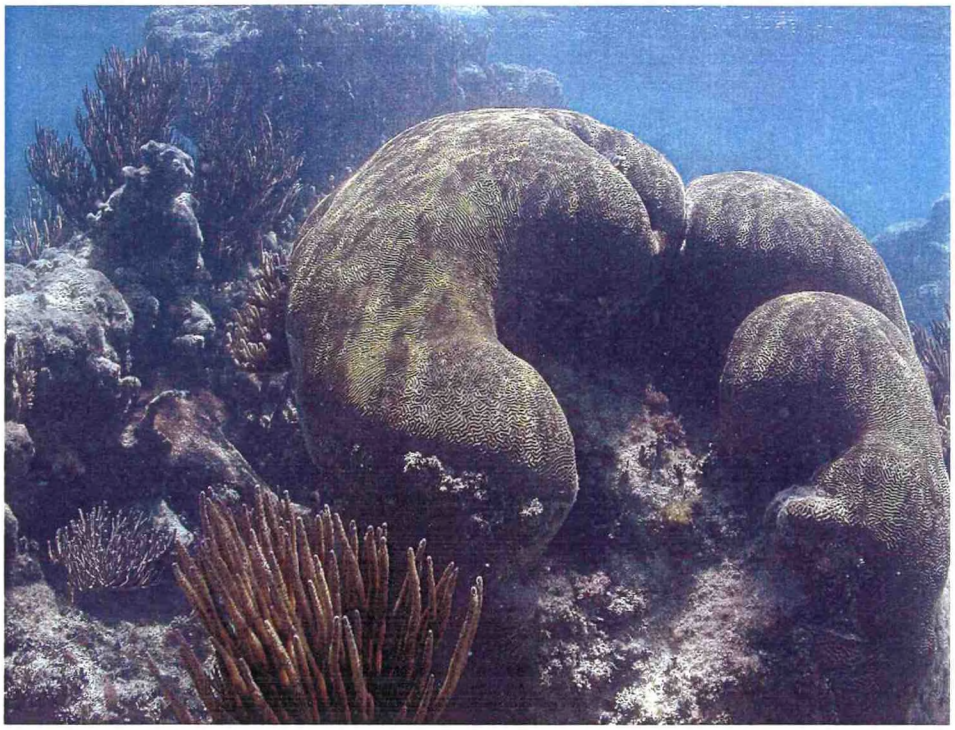

Plate 8. Large colonies of brain coral at the backreef lagoon.

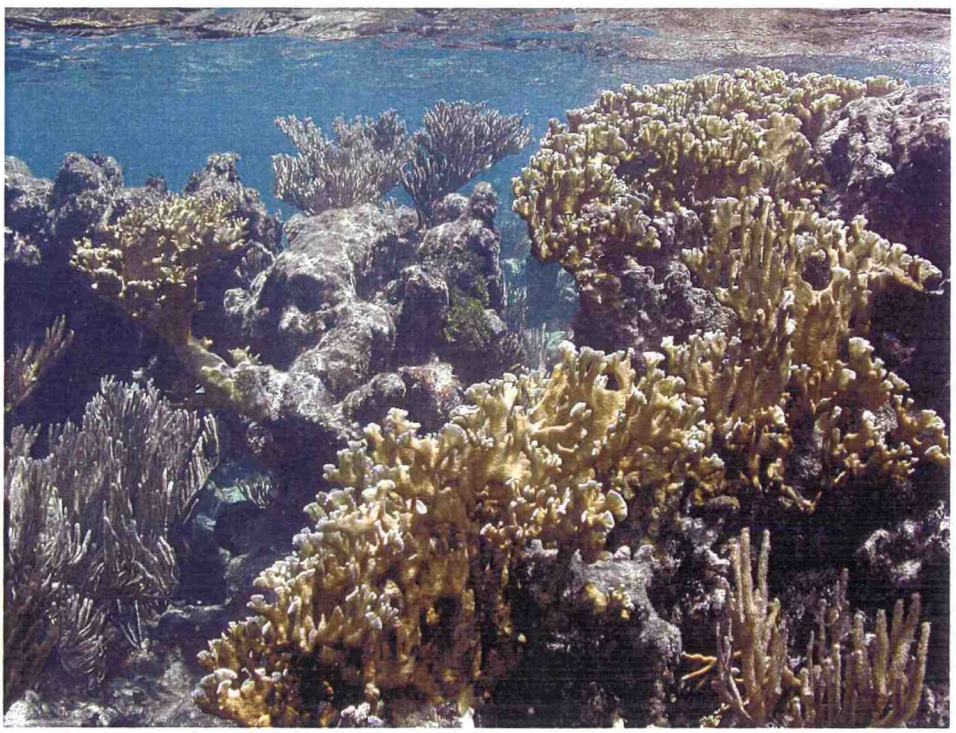

Plate 9. Fire coral growing near the surface at the backreef lagoon system.

Plate 10. Extensive biotopes of staghorn coral at the backreef lagoon.

An extensive biotope of elkhorn coral, now mostly dead and overgrown by macroalgae was observed in the backreef lagoon (Plate 11). Some colonies showed evidence of mechanical damage as their branches were broken over the substrate, but most of them were in growing position, standing dead. Recolonization of hard bottom by new colonies of elkhorn coral was observed, but on a small scale. Likewise, many massive colonies of boulder star coral (*Montastrea annularis*) were in advanced stages of degradation, with large sections overgrown by algae. The cause for such degradation of coral colonies is unknown, but intensive sand (sediment) abrasion during extreme wave action episodes, such as those induced by storms and hurricanes, may be a potential cause. This environment may be prone to bleaching events caused by elevated water temperatures, due to the semi-enclosed hydrography and shallow depth of the lagoon. At the time of our survey, bleaching of coral colonies was not observed. Several coral colonies (*Diploria strigosa, D. labyrinthiformis, Colpophyllia natans*) were affected by "Black-band" disease, but widespread occurrence of this phenomena (or other types of coral disease) was not observed in the coral reef system of Isla Caja de Muertos.

Plate 11. Dead standing colonies of elkhorn coral at the backreef lagoon system.

The fish community from the backreef lagoon is comprised of a highly diverse assemblage of coral reef fishes. A total of 68 species were observed during our qualitative survey. Herbivores are the most abundant, with parrotfishes, surgeonfishes and damselfishes distributed throughout the lagoon. Territorial damselfishes (*Stegastes dorsopunicans, S. planifrons*) dominated reef territories covered by algal turf and other macroalgae. At least six species of parrotfishes were present. The yellowtail parrotfish (*Sparisoma rubripinne*) was particularly abundant and observed from juvenile to full adult stages. Large schools of blue tang (*Acanthurus coeruleus*) were observed grazing on the vegetated surface of the reef. Juvenile grunts (*Haemulon* spp.) were ubiquitous on the backreef lagoon. Schools of many juvenile individuals were associated with mounds of staghorn coral and many other protective habitats within the lagoon (Plate 12). Schools of adult grunts, including the white, French and smallmouth (*H. plumieri, H. flavolineatum, H. chrysargyreum*) were also present. Juvenile and adult snappers, including the yellowtail, mutton, schoolmaster, gray and Cubera (*Ocyurus chrysurus, Lutjanus analis, L. apodus, L. griseus and L. cyanopterus*), and juvenile barracudas (*Sphyraena barracuda*) and jacks (*Carangoides* spp.) were part of the piscivorous

assemblage. Sandy areas were inhabited by gobies (*Coryphopterus spp.*) and mojarras (*Gerres cinereus, Eucinostomus* spp.).

Plate 12. Staghorn coral biotope serves as protective habitat for juvenile grunts and other reef fish species.

Fringing Reefs at Isla Caja de Muertos and Cayo Berbería

The fringing reef located at the northeast of Isla Caja de Muertos is known as Windward Reef (García-Sais et al. 2001). This reef was previously described by Goenaga and Cintrón (1979), Canals et al. (1980b) and most recently by García-Sais et al. (2001). The reef presents three distinct zones; an emergent reef crest, a narrow zone consisting of the elkhorn coral biotope, and a forereef zone (Canals et al., 1980b). The reef crest is a distinct zone of the fringing reef that is emergent and under constant impact by waves. This zone is characterized by encrusting biota highly adapted to wave action. Fire coral and encrusting zoanthids (*Palythoa caribdea*) are the main sessile-benthic invertebrates colonizing the pavement. Turf algae and crustose red macroalgae (*Lithothamnion* sp.) cover most of the reef surface at the crest. Boring sea urchins (*Echinometra lucunter*) and chitons (*Acanthopleura* spp.) are common in this reef zone.

The elkhorn coral biotope extends seaward from the reef crest to a depth of approximately five meters. Canals et al. (1980b) included this zone within the physiographic structure of this reef, but noted that most of the elkhorn coral was dead and overgrown by algae. This is still the situation based on observations made during this study (Plate 13). Very few colonies of elkhorn coral or other corals were present on the forereef. Fire coral, encrusting zoanthids, and sponges (*Anthosigmella varians*) were the main sessile-benthic invertebrates of this zone. Stony corals grow interspersed on the colonized hard ground substrate as isolated encrusting colonies of very low relief and of generally small size. Some of the most common species included the mustard hill coral, symmetrical brain coral, and the great star coral (*Montastrea cavernosa*). The fish community at the reef crest is characterized by a reduced number of species due to limited protective habitat and high wave energy. Some of the resident populations include the redlip blenny (*Ophioblennius atlanticus*), yellowtail damselfish (*Microspathodon chrysurus*), sergeant major (*Abudefduf saxatilis*), bluehead wrasse (*Thalassoma bifasciatum*), and juvenile surgeonfishes and parrotfishes, among others.

Plate 13. Dead colonies of elkhorn coral at the forereef.

The forereef zone is typically the section of highest increase in depth with distance from the top of the reef, also known as the forereef slope. At the Windward Reef of Isla Caja de Muertos, the forereef extends across a relatively gradual slope from a depth of five meters to the base of the reef at a depth of approximately nine meters. The forereef is a relatively flat colonized pavement terrace with minimal topographic relief dominated by stony corals. García-Sais et al. (2001) provided a general characterization of this reef zone based on quantitative determinations of surface cover by sessile-benthic biota along permanent transects and qualitative taxonomic surveys.

The dominant feature of the sessile-benthic community at the forereef zone is the extensive cover of the substrate by a mixed assemblage of short filamentous algae, known as an "algal turf". The algal turf biotope averaged a surface cover of 85.1% (range: 79.8 – 90.1%) along permanent transects studied at a depth of 9.1 meters (García-Sais et al., 2001). Sponges ranked second in surface cover with a mean of 8.9%. Large barrel (*Xestospongia muta*) and encrusting sponges (*Anthosigmella varians, Chondrilla nucula*) were present in the high energy environment of the forereef. Stony corals averaged a surface cover of only 2.8 % (range: 0.8 – 4.9%). The most common assemblage of stony corals included *Montastrea cavernosa, Porites astreoides, Diploria strigosa, Dichocoenia stokesii, Meandrina meandrites, Colpophyllia natans* and *Siderastrea radians*. Soft corals are common but not highly abundant at the forereef zone of the Windward Reef. García-Sais et al. (2001) reported a mean density of 4 colonies intersected by 10-meter long transects. The most common species, generally observed as small colonies, was the sea fan (*Gorgonia ventalina*).

The fringing reef at Cayo Berbería was initially described by Goenaga and Cintrón (1979), followed by Canals et al. (1980). More recently, García-Sais et al. (2001) provided a quantitative baseline characterization of the sessile-benthic, fish and motile megabenthic invertebrates communities associated with this reef. Anecdotal accounts of the existence of a well developed elkhorn coral biotope associated with this fringing reef, later destroyed by the waves generated by Hurricane David in 1979 appear in González et al. (1989). The fringing reef extends along the east and south coasts of Cayo Berbería (Figure 4). It presents a moderately extensive reef crest, with live coral, particularly finger coral (*Porites porites*) and fire corals. Most of the stony coral development occurs at the forereef slope. Mean substrate cover by live corals

measured at a depth of 7.6 meters was 16.0 % (García-Sais et al., 2001). The dominant coral species in terms of surface cover were boulder star coral, great star coral, and mustard hill coral. The combined cover by benthic (turf and fleshy) macroalgae averaged 72.3 %. Soft corals were particularly abundant with a mean number of 25 colonies intersected per 10-meter transect (García-Sais et al., 2001).

Patch Coral Reefs – Isla Caja de Muertos

Coral reefs are found as submerged patch formations on the northwest, west and eastern sections of the Isla Caja de Muertos shelf (Figure 2). The patch reef at the northwest of Isla Caja de Muertos was initially described by García-Sais et al. (2001) during the summer of 1999 as part of the National Coral Reef Monitoring Program sponsored by NOAA and the DNER. The reef lies along a submerged terrace at a depth of 7.6 meters with its base on sandy bottom at a depth of 12.1 meters. The transition from the reef top to the base is along an abrupt, almost vertical wall with irregular channels running perpendicular to the main reef axis. High topographic relief is provided by massive and branching stony corals. Soft corals are moderately abundant and provide additional rugosity and habitat complexity to the reef. Substrate cover by live stony coral averaged 24.4%. The main coral species in terms of substrate cover was the boulder star coral, which represented more than 50 % of the total cover by stony corals. García-Sais et al. previously identified an additional 18 stony coral species at this reef in 1999 (García-Sais et al., 2001).

A recent monitoring survey of this coral reef system (García-Sais et al., 2005) detected a decline of live coral cover of approximately 5 % (from 24.4 to 19.2 %) since the initial baseline characterization during May 1999 (García-Sais et al., 2001). During the 1999 survey, some of the massive branching and stony corals were observed to be in advanced stages of degradation or completely overgrown by algae and other encrusting biota . The decline of live coral cover was mostly associated with the dominant species, boulder star coral, but other massive and encrusting coral species declined in cover also (e.g. great star coral, mustard hill coral). Soft coral (gorgonian) colonies declined along all five transects, from a mean of 25 to 15 colonies per transect. The potential factors influencing such decline of substrate cover by stony corals and gorgonians are being

analyzed at present (García-Sais et al., in preparation). Nevertheless, the effect of mechanical damage associated with exceptionally high wave action (such as that caused by hurricanes) may have been important for coral health at this reef, as suggested by the loss (detachment) of gorgonian colonies and an increase in abiotic cover (García-Sais et al., 2005). Bleaching and/or disease do not appear to have been the driving factor for the decline of coral cover, since cover by benthic algae remained constant between surveys. Human impacts to this reef appear to be minimal. No anchoring, fishing or any other type of human activity was observed on the reef during this survey.

A total of 57 fish species were reported from this reef by García-Sais et al. (2001) during their baseline survey. The mean density of fishes was 61.8 individuals/30 m^2. Seven species represented 66 % of the total individuals. The bluehead wrasse (*Thalassoma bifasciatum*) was the most abundant. The herbivorous fish assemblage, comprised of damselfishes (Pomacentridae), surgeonfishes (Acanthuridae) and parrotfishes (Scaridae) represented 33 % of the total fish abundance within belt-transects surveyed by García-Sais et al. (2001). During a recent monitoring survey of the fish community at this reef, Garcia-Sais et al. (2005) identified 77 species, 55 of which were present within belt-transects with a mean density of 398 Ind/transect. The sharp increment of fish density was mostly related to the presence of several swarms (large aggregations) of masked goby (*Coryphopterus personatus*) within crevices in the reef. This reef represents an important habitat for commercially important snappers, particularly the lane, mutton and schoolmaster snappers (*Lutjanus synagris, L. analis, L. apodus*). One juvenile yellowfin grouper (*Mycteroperca venenosa*) was also observed.

Table 1. List of common species identified from coral reef habitats at Isla Caja de Muertos Natural Reserve during this and other 2005 surveys.

Common Name	*Scientific Name*
Green Algae	**Chlorophyta**
Sea Pearl	*Ventricaria ventricosa*
Watercress Alga	*Halimeda opuntia*
Brown Algae	**Phaeophyta**
Y-Branched Alga	*Dictyota* sp.
Sargassum	*Sargassum natans*
Red Algae	**Rhodophyta**
Segmented Alga	*Jania* sp.
Y-Twig Alga	*Amphiroa* sp.
Crustose Algae	*Lithothamnion sp.*
Sponges	**Porifera**
Fire Sponge	*Tedania ignis*
Green-Finger Sponge	*Iotrochota birotulata*
Brown Variable Sponge	*Anthosigmella varians*
Coral Encrusting Sponge	*Cliona* sp.
Giant Barrel Sponge	*Xestospongia muta*
Black-Ball Sponge	*Ircinia strobilina*
Cnidarians	**Cnidaria**
Hydrozoan	Unidentified
Fire Coral	*Millepora* spp.
Portuguese Man-of-War	*Physalia physalis*
Moon Jelly	*Aurelia aurita*
Giant Anemone	*Condylactis gigantea*
Sun Anemone	*Stichodactyla helianthus*
Mat Zoanthid	*Zoanthus pulchellus*
White Encrusting Zoanthid	*Palythoa caribdea*
Elkhorn Coral	*Acropora palmata*
Staghorn Coral	*Acropora cervicornis*
Finger Coral	*Porites porites*
Mustard Hill Coral	*Porites astreoides*
Pillar Coral	*Dendrogyra cylindrus*
Boulder Star Coral	*Montastrea annularis*
Great Star Coral	*Montastrea cavernosa*
Golfball Coral	*Favia fragum*
Massive Starlet Coral	*Siderastrea siderea*
Lesser Starlet Coral	*Siderastrea radians*
Symmetrical Brain Coral	*Diploria strigosa*
Knobby Brain Coral	*Diploria clivosa*
Brain Coral	*Diploria labyrinthiformis*
Boulder Brain Coral	*Colpophyllia natans*
Lettuce Coral	*Agaricia agaricites*
Common Sea Fan	*Gorgonia ventalina*
Encrusting Gorgonian	*Erythropodium caribaeorum*
Sea Rods	*Plexaura* spp.
Knobby Candelabrums	*Eunicea* spp.
Slit-Pore Sea Rods	*Plexaurella* spp.
Spiny Sea Fans	*Muricea* spp.
Rough Sea Plume	*Muriceopsis* sp.
Sea Plumes	*Pseudopterogorgia* spp.
Sea Whips	*Pterogorgia* spp.

Table 1. (Continued)

Crustaceans	**Crustacea**
Spiny Lobster	*Panulirus argus*
Arrow Crab	*Stenorhynchus seticornis*
Banded Coral Shrimp	*Stenopus hispidus*
Batwing Coral Crab	*Carpilius corallinus*
Clinging Crab	*Mithrax* spp.
Molluscs	**Mollusca**
Queen Conch	*Strombus gigas*
Flame Helmet	*Cassis* sp.
Amber Penshell	*Pinna carnea*
Octopus	*Octopus vulgaris*
Sea Hare	*Aplysia* sp.
Echinoderms	**Echinodermata**
Brittle Star	*Ophiocoma* spp.
Black Sea Urchin	*Diadema antillarum*
Rock-Boring Sea Urchin	*Echinometra lucunter*
Worms	**Annelida**
Bearded Fireworm	*Hermodice carunculata*
Magnificient Feather Duster	*Sabellastarte magnifica*
Christmas Tree Worms	*Spirobranchus* sp.
Fish	**Pisces**
Silversides	Atheriniidae
Timucu	*Strongylura timucu*
Houndfish	*Tylosurus acus*
Ballyhoo	*Hemiramphus brasiliensis*
Blue Runner	*Carangoides crysos*
Bar Jack	*Carangoides ruber*
Yellowfin Mojarra	*Gerres cinereus*
Green Moray	*Gymnothorax funebris*
Goldentail Moray	*Gymnothorax miliaris*
Sand Diver	*Synodus intermedius*
Squirrelfish	*Holocentrus rufus*
Black-bar Soldierfish	*Myripristis jacobus*
Red Hind	*Epinephelus guttatus*
Rock Hind	*Epinephelus adscensionis*
Coney	*Cephalopholis cruentatus*
Harlequin Bass	*Serranus tigrinus*
Yellowfin Grouper	*Mycteroperca venenosa*
Mutton Snapper	*Lutjanus analis*
Schoolmaster Snapper	*Lutjanus apodus*
Yellowtail Snapper	*Ocyurus chrysurus*
Lane Snapper	*Lutjanus synagris*
French Grunt	*Haemulon flavolineatum*
Tomtate	*Haemulon aurolineatum*
White Grunt	*Haemulon plumieri*
Porgy	*Calamus pennatula*
Spotted Goatfish	*Pseudupeneus maculatus*
Yellow Goatfish	*Mulloides martinicus*
Four-eye Butterflyfish	*Chaetodon capistratus*
Banded Butterflyfish	*Chaetodon striatus*
Queen Angelfish	*Holacanthus ciliaris*
Rock Beauty	*Holacanthus tricolor*
French Angelfish	*Pomacanthus paru*
Grey Angelfish	*Pomacanthus arcuatus*
Beaugregory	*Stegastes leucostictus*
Brown Chromis	*Chromis multilineata*

Table 1. (Continued)

Fish	Pisces
Bicolor Damselfish	*Stegastes partitus*
Three-spot Damselfish	*Stegastes planifrons*
Dusky Damselfish	*Stegastes dorsopunicans*
Sargeant Mayor	*Abudefduf sexatilis*
Clown Wrasse	*Halichoeres maculipinna*
Blue-Head Wrasse	*Thalassoma bifasciatum*
Spanish Hogfish	*Bodianus rufus*
Slippery Dick	*Halichoeres bivittatus*
Puddinwife	*Halichoeres radiatus*
Hogfish	*Lachnolaimus maximus*
Bucktooth Parrotfish	*Sparisoma radians*
Stripped Parrotfish	*Scarus iserti*
Queen Parrotfish	*Scarus vetula*
Princess parrotfish	*Scarus taeniopterus*
Yellowtail Parrotfish	*Sparisoma rubripinne*
Rainbow Parrotfish	*Scarus guacamaia*
Stoplight Parrotfish	*Sparisoma viride*
Great Barracuda	*Sphyraena barracuda*
Saddled Blenny	*Malacoctenus triangulatus*
Redlip Blenny	*Ophioblennius atlanticus*
Blennies	Cliniidae
Gobies	Gobiidae
Masked Goby	*Coryphopterus personatus*
Ocean Surgeon	*Acanthurus bahianus*
Doctorfish	*Acanthurus chirurgus*
Blue Tang	*Acanthurus coeruleus*
Balloonfish	*Diodon holocanthus*
Porcupinefish	*Diodon histrix*
Trunkfish	*Lactophrys* spp.
Sharpnose Puffer	*Canthigaster rostrata*

Seagrass Beds

Seagrass beds comprise approximately 750 ha of seafloor within the Isla Caja de Muertos Natural Reserve. Seagrasses grow mostly as continuous meadows west, northwest and northeast of Isla Caja de Muertos, on the narrow shelf connecting Isla Caja de Muertos with Cayo Berbería, and bordering almost the entire mangrove key at Berbería. The most common assemblage is a mixed stand of turtle and manatee grasses with interspersed green calcareous macroalgae (e.g. *Udotea* sp., *Halimeda* spp., *Penicillus* sp., *Caulerpa* spp.) (Plate 14). In terms of biomass, turtle grass is dominant. Seagrasses grow over a wide depth range at the reserve, from intertidal depths within the backreef lagoon of Isla Caja de Muertos and at the interface with the fringing red mangrove forest of Cayo Berbería to depths of 7 - 8 meters on the west coast of Isla Caja de Muertos. The depth extension of seagrasses around Isla Caja de Muertos is undoubtedly related to the very clear waters surrounding

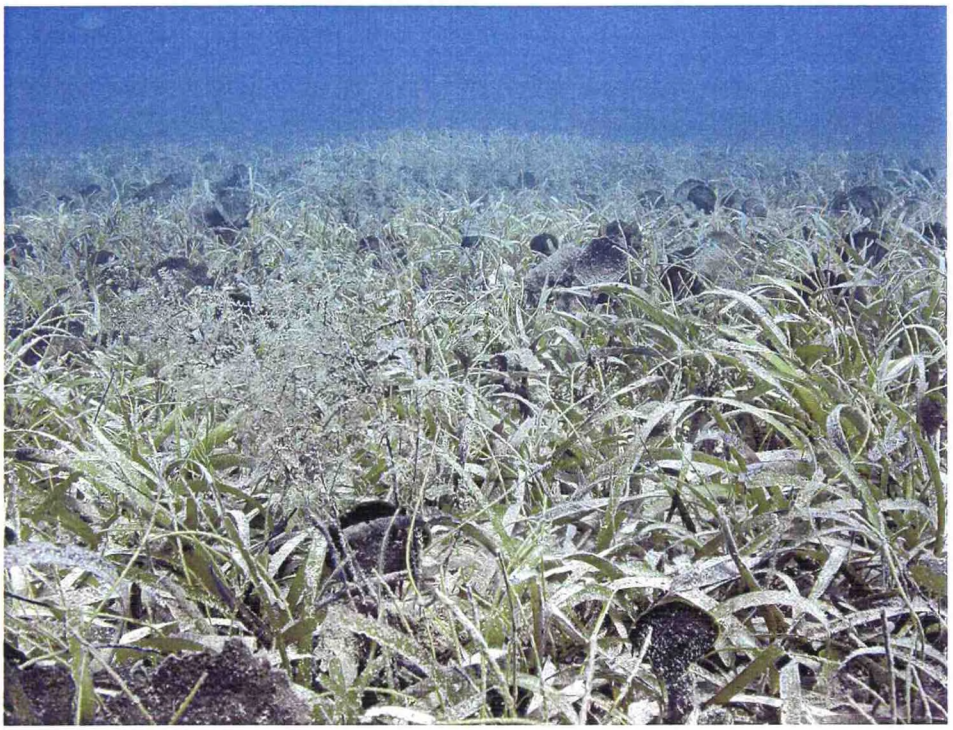

Plate 14. Mixed stand of turtle and manatee seagrasses with interspersed macroalgae at Isla Caja de Muertos.

the offshore islands. Propeller scars were not observed in any seagrass habitat within the reserve. The distribution of seagrasses is too deep for propeller damage at Isla Caja de Muertos. A potential problem may exist in Cayo Berbería, because seagrasses are distributed along a shallow shelf, but recreational motorboats were not observed to penetrate the shallow areas at Cayo Berbería and commercial/subsistence fishermen use oars to access the mangrove shoreline in areas of shallow seagrasses. Fishing impacts to these habitats and associated species are difficult to assess because of the lack of baseline information regarding natural populations of queen conch and the seagrass beds in the area. However, damage by anchoring associated with fishing activities is probably minor because queen conch fishermen were not observed anchoring in seagrass habitats during the survey. At Cayo Berbería, commercial fishermen were observed to fish for queen conch in pairs with one serving as a diver to collect conch and the other piloting the boat.

Seagrass beds provide habitat for numerous benthic and pelagic organisms, constitute important recruitment and nursery sites for a diverse assemblage of coral reef fishes and

invertebrates, and represent vital foraging habitats for adult reef fishes, marine mammals and aquatic birds. Table 2 presents a list of the organisms observed in seagrass beds at Isla Caja de Muertos Natural Reserve during this survey. Some of the resident populations include echinoderms, such as the green, black and white urchins (*Lytechinus variegatus, Diadema antillarum, Tripneustes esculentus,* respectively), the cushion, beaded and two-spined sea stars (*Oreaster reticulatus, Astropecten articulatus, A. duplicatus,* respectively) and sea cucumbers (*Isostichopus badionotus, Holothuria mexicana, Actinopygia agassizii*). The mollusk assemblage includes the commercially important queen conch, which is heavily fished inside the reserve, the Atlantic triton's trumpet (*Charonia variegata*), which is an important predator of sea stars in seagrass beds (Plate 15), the flame helmet (*Cassis flammea*), and other smaller species previously reported by González et al. (1989), including the true tulip snail (*Fasciolaria tulipa*), common dove snail (*Columbella mercatoria*), netted olive (*Olivia reticularis*), chestnut turban (*Turbo castanea*), apple murex (*Murex pomum*), milk conch (*Strombus costatus*), measled cowrie (*Cyprea zebra*), and amber penshell (*Pinna carnea*). Blue crabs (*Callinectes* spp., *Portunus* spp.), clinging crabs (*Mithrax* spp.), box crabs (*Calappa* sp.) and arrow crabs (*Stenorynchus seticornis*) inhabit sandy areas and coral heads interspersed within the seagrass beds, along with juveniles of the commercially important spiny lobster (*Panulirus argus*). Resident fish include the bucktooth parrotfish (*Sparisoma radians*), blackear wrasse (*Halichoeres poeyi),* rosy razorfish *(Xyrichthys martinicensis*), ballyhoo (*Hemiranphus brasiliensis*), balloonfish (*Diodon holacanthus*) and a mixed assemblage of forage fish species, such as anchovies (*Anchoa* spp.) and sardines (*Jenkinsia lamprotaenia*, *Harengula* spp.).

Plate 15. Atlantic triton's trumpet, a large predator of sea stars in the seagrass bed.

A diverse assemblage of juvenile reef fishes that includes species of high commercial value, such as the yellowtail snapper (*Ocyurus chrysurus*), great barracuda (*Sphyraena barracuda*) and grunts use the seagrass as nursery habitats. Transitory predators that forage in seagrass beds include adult grunts, hogfish (*Lachnolaimus maximus*), cero mackerel (*Scomberomorus regalis*), jacks (*Carangoides crisos, C. ruber*), and lane and mutton snappers (*Lutjanus synagris, L. analis*), among others. The brown pelican feeds upon schooling forage fishes near the surface over seagrass beds (e.g. anchovies, sardines, silversides). The green sea turtle and the Caribbean manatee feed directly on seagrass blades.

Table 2. List of common species identified from seagrass habitats at Isla Caja de Muertos Natural Reserve during this and other 2005 surveys.

Common Name	*Scientific Name*
Seagrasses	**Angiospermae**
Turtle Grass	*Thalassia testudinum*
Manatee Grass	*Syringodium filiforme*
Green Algae	**Chlorophyta**
Sea Pearl	*Ventricaria ventricosa*
Green Grape Alga	*Caulerpa racemosa*
Green Feather Alga	*Caulerpa sertularioides*
Watercress Alga	*Halimeda opuntia*
Bristle Brush Alga	*Penicillus* sp.
Mermaid's Alga	*Udotea* sp.
Brown Algae	**Phaeophyta**
Y-Branched Alga	*Dictyota sp.*
Sargassum	*Sargassum natans*
Red Algae	**Rhodophyta**
Pink Segmented Alga	*Jania* sp.
Y-Twig Alga	*Amphiroa* sp.
Sponges	**Porifera**
Fire Sponge	*Tedania ignis*
Cnidarians	**Cnidaria**
Hydrozoan	Unidentified
Rose Coral	*Manicina aereolata*
Ivory Bush Coral	*Oculina diffusa*
Mangrove Upside-down Jelly	*Cassiopea xamachana*
Giant Anemone	*Condylactis gigantea*
Corkscrew Anemone	*Bartholomea annulata*
Crustaceans	**Crustacea**
Crab	*Callinectes* spp.
Crab	*Portunus* sp.
Juvenile lobster	*Panulirus argus*
Arrow Crab	*Stenorhynchus seticornis*
Banded Coral Shrimp	*Stenopus hispidus*
Giant Hermit Crab	*Petrochirus* sp.
Clinging Crab	*Mithrax* spp.
Box Crab	*Calappa* sp.
Mollusks	**Mollusca**
Queen Conch	*Strombus gigas*
Milk Conch	*Strombus costatus*
Atlantic's Triton	*Charonia variegata*
Flame Helmet	*Cassis flammea*
Amber Penshell	*Pinna carnea*
Octopus	*Octopus vulgaris*
Sea Hare	*Aplysia* sp.
True Tulip	*Fasciolaria tulipa*
Common Dove-Shell	*Columbella mercatoria*
Chestnut Turban	*Turbo castanea*
Murex	*Murex pomum*
Measled Cowrie	*Cypraea zebra*

Table 2. (Continued)

Echinoderms	**Echinodermata**
Beaded Sea Star	*Astropecten articulatus*
Two-spined Sea Star	*Astropecten duplicatus*
Cushion Sea Star	*Oreaster reticulatus*
Brittle Star	*Ophiocoma* spp.
Sea Cucumber	*Holothuria mexicana*
Three-Rowed Sea Cucumber	*Isostichopus badionotus*
Toothed Sea Cucumber	*Actinopygia* sp.
White Sea Urchin	*Tripneustes esculentus*
Black Sea Urchin	*Diadema antillarum*
Green Sea Urchin	*Lytechinus variegatus*
Rock-Boring Sea Urchin	*Echinometra lucunter*
Worms	**Annelida**
Southern Lugworm	*Arenicola crustata*
Fishes	**Pisces**
Silversides	Atheriniidae
Dwarf Herring	*Jenkinsia lamprotaenia*
Anchovies	*Anchoa* sp.
Timucu	*Strongylura timucu*
Ballyhoo	*Hemiramphus brasiliensis*
Sea Bream	*Archosargus rhomboidalis*
Yellowfin Mojarra	*Gerres cinereus*
Black-ear Wrasse	*Halichoeres poeyi*
Clown Wrasse	*Halichoeres maculipinna*
Blue-head Wrasse	*Thalassoma bifasciatum*
Surgeonfishes	*Acanthurus* spp.
Grunts	*Haemulon* spp.
Mutton Snapper	*Lutjanus analis*
Lane Snapper	*Lutjanus synagris*
Hogfish	*Lachnolaimus maximus*
Juvenile Yellowtail Snapper	*Ocyurus chrysurus*
Beaugregory	*Stegastes leucostictus*
Bucktooth Parrotfish	*Sparisoma radians*
Stripped Parrotfish	*Scarus iserti*
Razorfish	*Xyrichthys martinicensis*
Balloonfish	*Diodon holocanthus*
Trunkfish	*Lactophrys* spp.
Blue Runner	*Carangoides crysos*
Juvenile Yellow Goatfish	*Mulloides martinicus*
Cero Mackerel	*Scomberomorus regalis*
Blue Runner	*Carangoides crysos*
Sea Turtles	**Reptilia**
Green Turtle	*Chelonia midas*
Sea Mammals	**Mammalia**
Caribbean Manatee	*Trichechus manatus*

3.3 Areas Where Recreational and Commercial Fishing Activities Occur

The geographic distribution of recreational facilities and activities taking place within marine habitats of the reserve is presented in Figure 6. At present, the marine-oriented recreational activities include:

1) DNER visitor center and picnicking facilities – at Pelican Beach. Facilities provide support for recreational/educational activities. Include housing for DNER rangers and manager, 15 gazebos, 4 bathrooms, one visitor center with exhibit rooms, reserve manager's office, infirmary and conference room. Exhibit facilities are designed to operate on natural lighting. Electric power is available from a solar system and wind power generators. Water reserves of approximately 35,000 gals. are replenished by rainfall and by a water barge that supplies 5,000 gal. per trip.

2) Ferry boat transport and docking – at Pelican Beach. A concession from DNER is extended to Mr. Rafael Vega, owner and captain of the ferry boat "Island Venture II." The ferry boat makes one or two trips per day with a maximum capacity of 80 persons per trip. A large cement dock is available and in use for docking of passenger type vessels. Smaller docks on the west coast at Punta Carrucho (Conch Point) and Coast Guard Beach were destroyed by hurricanes.

3) Sailboat and yacht overnight anchoring – protected cove at Pelican Beach is used by large boats to spend weekends and/or stay overnight anchored offshore in deep sections of the cove (there are no mooring buoys). During our survey, there were on average 2 – 3 sailboats/yachts anchored at this locality and staying overnight within reserve waters (Plate 16). Anchoring was only observed in areas of sandy bottom.

4) Shoreline anchoring by inboard and outboard boats – at Pelican and Coast Guard Beach. Boats anchor perpendicular to the shoreline with two anchors (bow and stern) to access the shallow sections of the beach (there are no mooring buoys). At Pelican Beach, up to 8 boats were observed in one day anchored at the shoreline and up to 5 boats were present at the Coast Guard Beach (Plate 17). Anchoring was only observed in areas of sandy bottom.

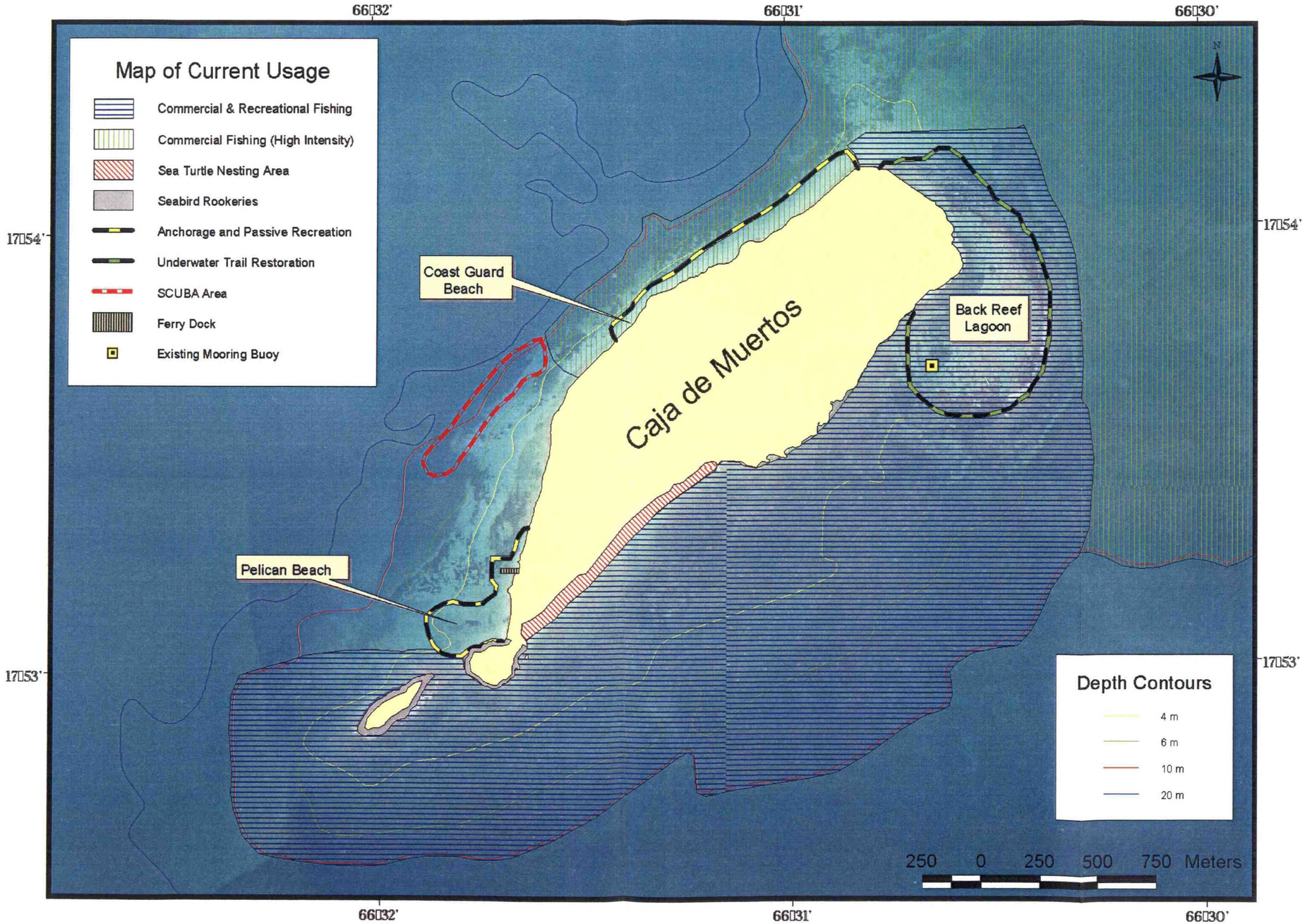

Figure 6. Map of current recreational activities at Isla Caja de Muertos. Bathymetric contours are from NOAA Electronic Navigation Charts US5PR42M and US5PR45M, modified based on field observations.

5) Swimming/bathing beach activities – mostly at Pelican Beach. Numbers of people are related to the number of private boats and trips by the ferry boat. The number of private boats, ferry boat trips and passengers increase during weekends and summer, but do not exceed 200 persons per day (Plate 18). During the summer, DNER demarcates a swimming area at Pelican Beach by the placement of buoys (Plate 19).

6) Snorkeling – best areas are the seagrass beds off Coast Guard Beach and at the northeast backreef lagoon (activity not evident during our visits to the reserve).

7) SCUBA diving – best places are the patch reefs and seagrass beds off the west coast of Isla Caja de Muertos (recreational activity not evident during our visits to the reserve).

8) Recreational Fishing – low intensity trolling and jigging for neritic pelagic species (mackerel, barracuda, jacks, snapper) was observed along the northwest and northeast of Isla Caja de Muertos (2 boats) and South off Cayo Berbería (1 boat) during our 10 day survey.

9) Commercial Fishing – free diving for queen conch with fins, mask and snorkel was the most common commercial fishing activity observed. Fishing for queen conch is concentrated along the platform connecting Isla Caja de Muertos and Cayo Berbería. A total of 15 - 20 fishermen from Ponce, Peñuelas, Santa Isabel and Juana Díaz fish within reserve waters, mostly for conch (C. Cianchini, DNER, personal communication). There is a seasonal closure for queen conch in effect from July 1 through September 30, enforced by DNER. A total of ten (10) small artisanal fishermen boats (yolas) with two fishermen aboard were observed during this survey, one of these was fishing with a gill net for surface dwelling species (sold as bait), mostly ballyhoo (*Hemiramphus brasiliensis*). Six (6) fish traps were observed soaking within reserve waters during our 10-day survey. Fish traps were deployed with surface buoys along the platform connecting Isla Caja de Muertos and Cayo Berbería and west off Isla Caja de Muertos in deeper sections of the shelf.

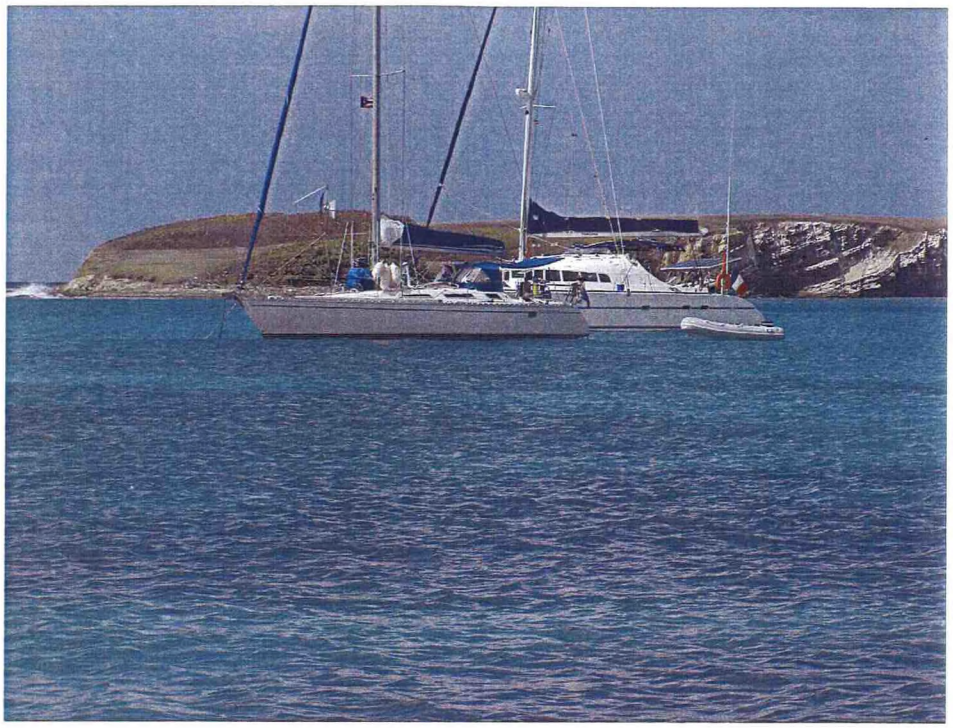

Plate 16. Sailboats anchored off Pelican Beach.

Plate 17. Shoreline anchoring by motorboats at Coast Guard Beach.

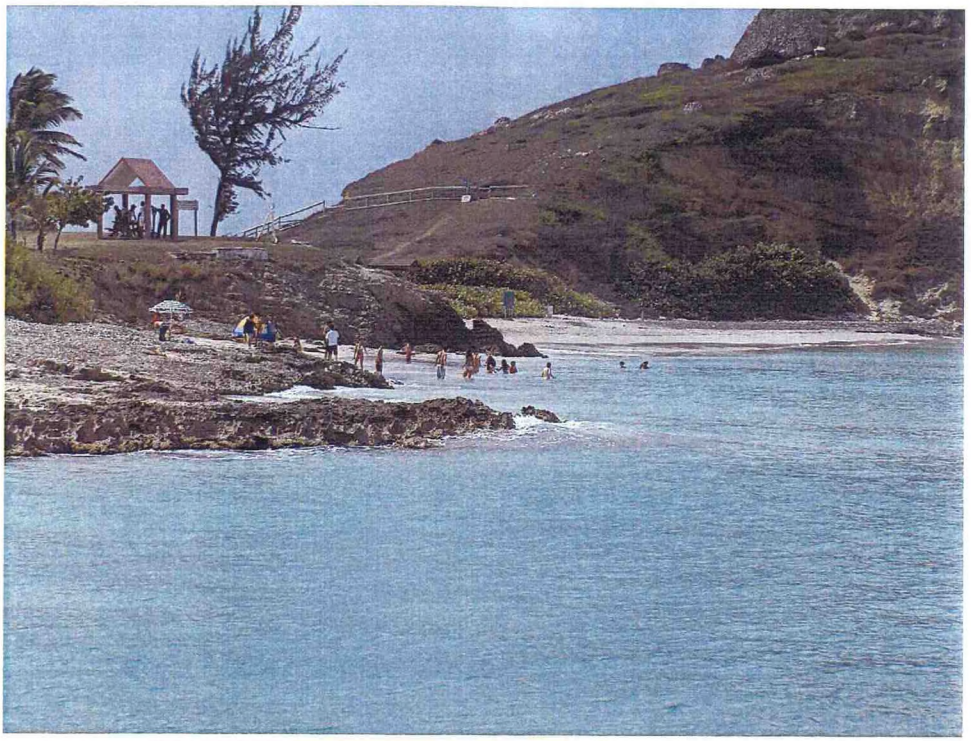

Plate 18. Swimming/bathing activities at Pelican Beach.

Plate 19. Swimming buoys seasonally placed at Pelican Beach.

3.4 Proposed Management of Recreational and Commercial Fishing Activities

Isla Caja de Muertos has an extraordinary potential for recreational development due to its offshore location and exceptional beauty of protected coralline sandy beaches, marine habitats, and terrestrial landscape. There have been a series of proposals to exploit the economic recreational potential of the island, including the construction of hotel/resort facilities and promotion of high intensity public recreational utilization of the reserve (González et al., 1989). However, the option of a large scale recreational (tourism) development within the reserve is in conflict with its ecological value, particularly for marine populations, some of which include endangered and protected species. According to Robert Matos (DNER, personal communication), the previous initiative and government support during the late 1980's for high intensity public recreational utilization of Isla Caja de Muertos resulted in economic failure and negatively impacted the natural resources of the reserve.

The main conflicts between high intensity recreational development and preservation of the island's natural resources include:

1) Adverse effects of lighting, noise levels and presence of people in the vicinity of sea turtle nesting areas at Playa Larga, located near Pelican Beach.
2) Increased number of visitors would require construction of additional shaded areas, bathrooms and other visitor facilities, which would directly impact the limited resources of space, water and power.
3) Production of garbage would cause a problem with rats, ants and other pests that would require control measures in conflict with the survival of natural populations.
4) Construction of roads for transportation of people to and from distant recreational areas would conflict with survival of rare animals, such as the sigueria lizard (*Ameiba wetmorei*).
5) Shoreline anchoring and effective sandy beach space is limited. Increased private boat visits may lead to anchoring in seagrass beds and other important benthic habitats.

6) The research and educational value of the reserve may be impaired by the interference of the public with research areas and experiments.
7) High intensity recreational use of the reserve would require increased personnel support and infrastructure, thereby significantly increasing the operational costs.

The present public use of the Isla Caja de Muertos Natural Reserve is one of low intensity passive recreation, kept to a maximum carrying capacity of 200 persons per day. Such level of use of the reserve's facilities and infrastructure is currently reached only during certain weekends and holidays.

The proposed modifications to the present infrastructure and recreational support facilities at Isla Caja de Muertos include installation of mooring and marker buoys, designation of closed fishing areas and seasonally closed access areas, recommended SCUBA and snorkeling areas with mooring buoys, and areas for passive water recreation only (see Figures 7 and 8) :

1) Installation of buoys – mooring buoys are proposed to avoid boat anchoring in coral reef and seagrass areas. Velocity restriction buoys are recommended in the vicinity of passive recreation areas, such as bathing/swimming and anchoring areas. Marker buoys are recommended for identification of shallow seagrass areas around Cayo Berbería and the passage to the south.
2) Designation of anchorage areas on sandy bottom off of Playa Larga Beach and from Coast Guard Beach to the northern tip of Isla Caja de Muertos.
3) Designation of SCUBA and snorkeling areas north of the dock at Isla Caja de Muertos.
4) Designation of the backreef lagoon as a closed fishing area is proposed for protection of an important coral reef habitat and to avoid potential conflicts between fishermen and passive recreation activities, such as snorkeling along an underwater trail.

5) DNER established an underwater trail in the backreef lagoon of Isla Caja de Muertos in 2001, but abandoned it due to lack of personnel for maintenance of the underwater signs and other infrastructure. The difficulty of maintaining the trail is exacerbated by the relatively long distance between DNER headquarters in Pelican Beach and the backreef lagoon. Given the exceptional value of this marine area for recreational snorkeling activities, the reconstruction of the trail has been included as part of the Port of the Americas mitigation plan for Isla Caja de Muertos (CSA Group, 2004). This study supports the initiative included in such mitigation plan and recommends that additional personnel and maintenance equipment be provided, including SCUBA gear and a motorboat to facilitate transportation to the backreef lagoon.
6) Seasonal closure of Playa Larga Beach, which is the nesting site of hawksbill sea turtles, to the public, May through December. Additionally, waters adjacent to this beach will also be closed to fishing during this period.
7) Remodeling and refurbishing of DNER housing facilities and the Visitor Center.
8) Reestablishment of scientific/educational exhibits of the island's marine and terrestrial habitats and associated communities.
9) Modification of the existing main dock to facilitate docking of smaller vessels that provide support to DNER personnel in the island.
10) Establishing signs showing special use areas (snorkeling, anchorage areas etc.) at the dock and at Coast Guard Beach, and at the ferry dock in Ponce.

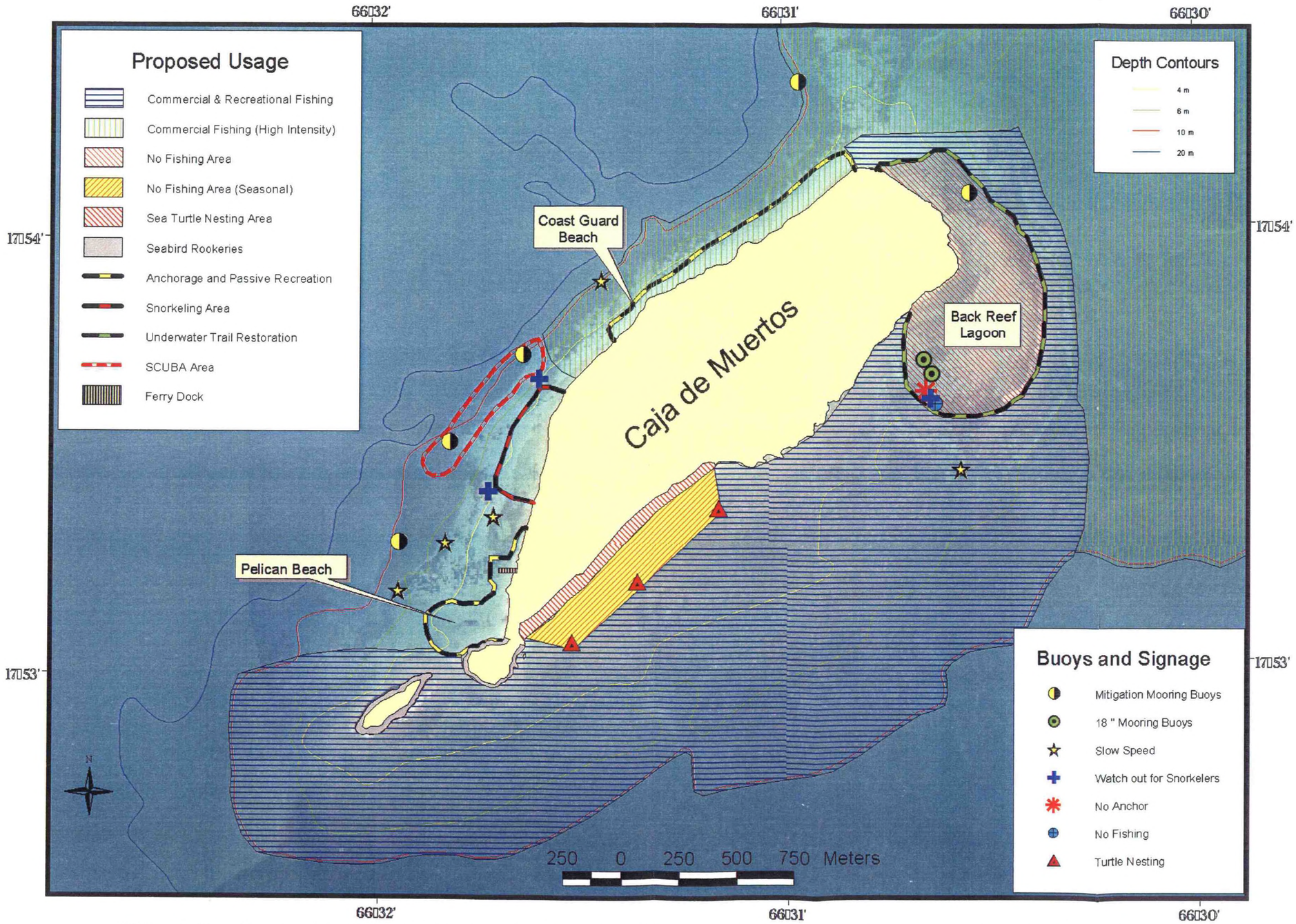

Figure 7. Map of proposed recreational activities, buoys, and signage at Isla Caja de Muertos. Bathymetric contours are from NOAA Electronic Navigation Charts US5PR42M and US5PR45M, modified based on field observations.

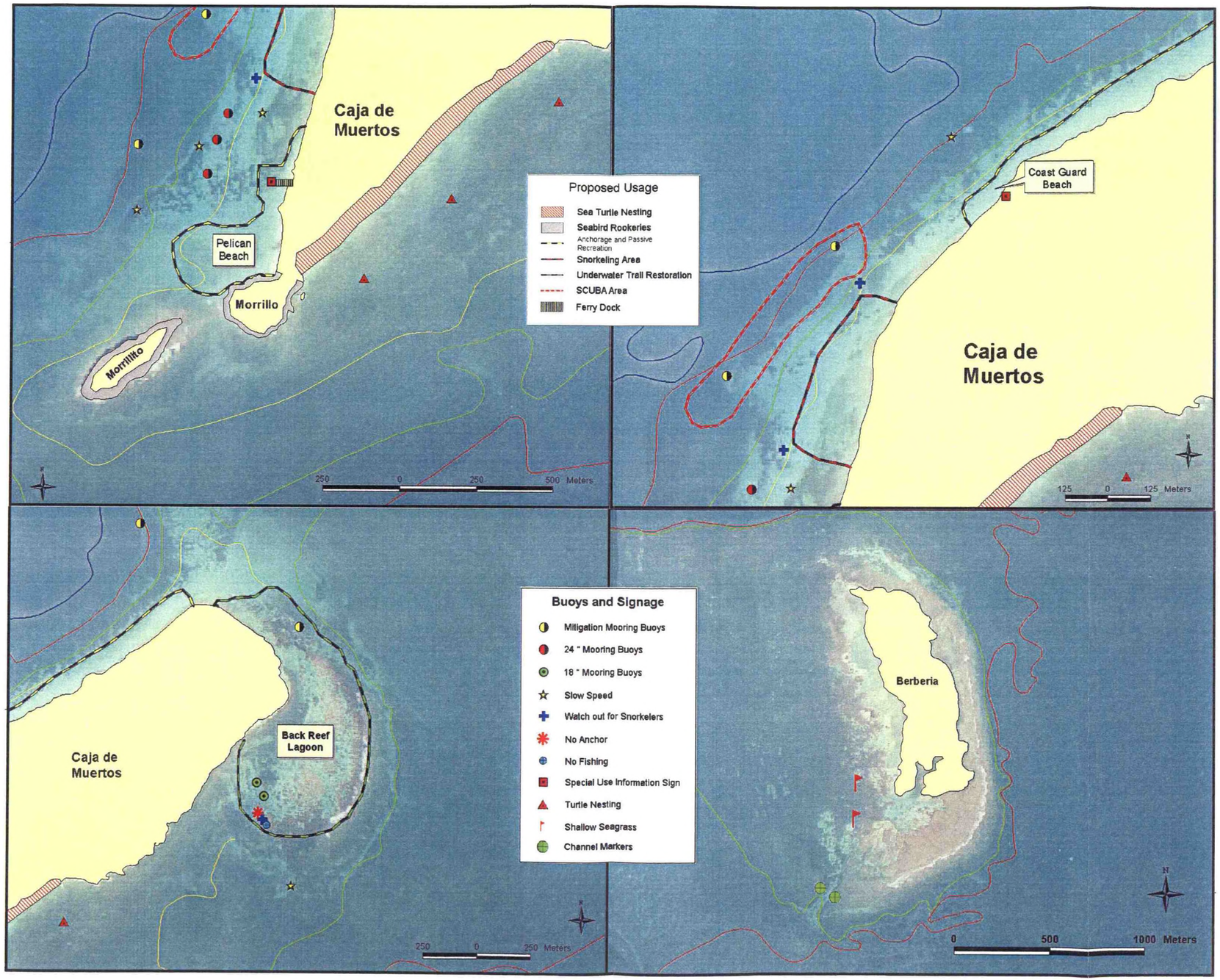

Figure 8. Map of proposed buoys and signage at Isla Caja de Muertos Natural Reserve. Bathymetric contours are from NOAA Electronic Navigation Charts US5PR42M and US5PR45M, modified based on field observations.

4.0 CONCLUSIONS

1) Isla Caja de Muertos Natural Reserve is a unique ecosystem on the south coast of Puerto Rico where communities associated with coral reefs, seagrass beds, mangroves, and rocky/sand intertidal zones closely interact to produce a system of high biological diversity, functioning both as a source of larval production and export for biological replenishment of adjacent marine systems, and as recruitment, nursery, resident and foraging habitats for a myriad of aquatic and terrestrial populations, some of which are endangered and/or of high commercial value.

2) The island's terrestrial landscape features a sub-tropical dry forest with its typical xerophytic community, including species that are rare and only found on other oceanic islands of the Puertorrican archipelago. Its shoreline presents habitats that are of critical importance as seabird rookeries and sea turtle nesting grounds.

3) The existence of protected anchoring coves and coralline sandy beaches, along with the exceptional richness of natural resources and existing public facilities provided by the DNER makes Isla Caja de Muertos an area of very high recreational value.

4) Isla Caja de Muertos has an extraordinary potential for recreational development due to its location, island condition and the exceptional beauty of its marine habitats and terrestrial landscape. However, the option of a large scale recreational development in the reserve is in conflict with its ecological value.

5) There are no significant impacts to benthic communities that can be associated with recreational activities based on observations.

6) The main impacts to marine communities are associated with the passing of Hurricane Georges in 1998, which removed large areas of sandy beach and

caused detachment, mechanical breakage and intense scouring in shallow coral reefs.

7) The present public use of the Isla Caja de Muertos Natural Reserve is one of low intensity passive recreation, kept to a maximum carrying capacity of 200 persons per day. Such level of use of the reserve's facilities and infrastructure is currently reached only during certain weekends and holidays.

8) Proposed modifications to the present visitor facilities at Isla Caja de Muertos include the installation of mooring and marker buoys, the designation of a closed fishing area and a seasonally closed access areas, the designation of anchorage areas, the use of recommended SCUBA and snorkeling areas supported by mooring buoys, and the designation of areas for passive recreation only.

5.0 RECOMMENDATIONS

1) **Mooring buoys** – in order to minimize impacts from recreational utilization of the marine resources at Isla Caja de Muertos, a series of mooring and marker buoys should be set within reserve waters. This recommendation incorporates the Port of the America's mitigation plan for Isla Caja de Muertos that has been prepared in consultation with DNER (CSA Group, 2004). The number and geographic location of mooring and marker buoys are shown in Table 3 and Figure 8.

    a) Five (5) 24" mooring buoys for sailboats, yachts and motorboats in the size range of 25 – 65'. Mooring buoys are proposed in coral reef and colonized pavement areas in agreement with the Port of the Americas mitigation plan for Isla Caja de Muertos (CSA Group, 2004).
    b) Three (3) 24" mooring buoys for sailboats, yachts and motorboats in the size range of 25 – 65'. These mooring buoys are proposed over seagrass bottom at depths of 4 to 6 meters, to the west of the dock.
    c) Two (2) 18" mooring buoys for boats under 25' proposed over a seagrass bottom at the southern end of the backreef lagoon. There is one existing mooring buoy in this location.

Table 3. Geographic location of proposed buoys at Isla Caja de Muertos Natural Reserve

Buoy Type	General Location	Geographic Location	
		Latitude (°)	Longitude (°)
Mooring Buoys			
Mooring Buoy (24 ")			
1*	Pelican Beach	17.88878 N	066.53239 W
2*	Patch reef (NW of CDM)	17.89258 N	066.53028 W
3*	Back Reef Lagoon	17.90194 N	066.50906 W
4*	NE of CDM	17.90617 N	066.51600 W
5*	Patch reef (NW of CDM)	17.89586 N	066.52733 W
6	Seagrass west of dock	17.88967 N	066.52967 W
7		17.88891 N	066.53001 W
8		17.88790 N	066.53031 W
Mooring Buoy (18 ")			
1	Back Reef Lagoon	17.89555 N	066.51103 W
2		17.89500 N	066.51070 W
Special use Buoys			
Speed Limit			
1	Pelican Beach	17.88969 N	066.52857 W
2		17.88873 N	066.53054 W
3		17.88691 N	066.53245 W
4	Coast Guard Beach	17.89868 N	066.52413 W
5	Back Reef Lagoon	17.89132 N	066.50954 W
Watch Out for Snorkelers			
1	Between Pelican Beach and Coast Guard Beach anchorage areas	17.89496 N	066.52672 W
2		17.89070 N	066.52883 W
4	Back Reef Lagoon	17.89404 N	066.51077 W
Shallow seagrass			
1	SW Berbería	17.92410 N	066.45889 W
2		17.92243 N	066.45901 W
Channel markers			
1	SW Berbería	17.91922° N	066.46090° W
2		17.91885° N	066.46025° W
Sea Turtle Nesting			
1	Playa Larga	17.88989 N	066.51946 W
2		17.88711 N	066.52279 W
3		17.88483 N	066.52548 W
No anchorage			
1	Back Reef Lagoon	17.89434 N	066.51094 W
No Fishing			
1	Back Reef Lagoon	17.89383 N	066.51058 W
* Port of the Americas Mitigation Plan			

2) **Designation of anchorage areas**—in order to encourage the appropriate practice of anchoring on sandy bottom, the designation of anchorage areas off of Playa Larga Beach and from Coast Guard Beach to the northern tip of Isla Caja de Muertos is recommended. Informational signs would also be placed at island access areas (see below) to inform boaters of anchorage areas.

3) **Special use buoys**
   a) Speed Limit Markers - Seven (7) slow speed marker buoys specifying boat speed limit of 5 mph. Three (3) at Pelican Beach, Three (3) at Coast Guard Beach and one near the entrance of the backreef lagoon.
   b) Watch Out for Snorkelers - Three (3) marker buoys alerting use of area for snorkeling activity: one (1) at the entrance to the backreef lagoon; and two (2) between Coast Guard Beach and Pelican Beach.
   c) Shallow Seagrass Marker – Two (2) marker buoys at the SW end of Berbería to avoid propeller damage to the seagrass.
   d) Sea Turtle Nesting Markers – Three (3) markers buoys parallel to the shoreline off Playa Larga. Markers should have a No-Fishing label from May through December.
   e) No Anchorage Markers – One (1) no-anchoring marker buoy at the entrance of the backreef lagoon
   f) No Fishing Marker – One (1) No-Fishing marker buoy at the entrance of the backreef lagoon.
   g) Channel markers (two buoys, one on each side) to mark the deep channel at the southwest tip of Cayo Berbería and protect nearby shallows from vessel groundings.

4) **Closed fishing area** – a permanently closed fishing area is proposed for the backreef of Isla Caja de Muertos to aid in recuperation of exploited coral reef and seagrass fish and invertebrate communities, and for the safety of snorkeling activities recommended for that area. The fishing closure should stimulate accumulation of large fish and invertebrates in residential and foraging habitats. It is expected that the increased abundance of large fish will result in an attraction for snorkeling activities and a contribution to the replenishment of

exploited populations by the concomitant increase in spawning stock biomass associated with increased size and abundance of parental stocks.

5) **Seasonal fishing closure of Playa Larga** – is recommended for protection of the seasonal (May – December) nesting of the hawksbill turtle on the littoral and supra-littoral areas of the sandy shoreline. Information about the seasonal nesting of the hawksbill turtle must be displayed in an exhibit at the Visitor's Center at Pelican Beach.

6) **Cayo Berberia** – used mostly by local fishermen to rest and clean their catch. Shallow seagrass signage is recommended to alert fishermen and boaters of the presence of shallow seagrass habitats around the west and south sections of the island. Additionally, channel markers are recommended at the southwest tip of the island to protect nearby shallows from vessel groundings.

7) **Refurbishing of DNER recreational/educational support facilities** – includes restoration of the Visitors Center building's infrastructure and landscaping; and production of new educational/scientific exhibits representative of the island ecological systems for public education and awareness.

    a) The Visitors Center building suffered infrastructural damage from Hurricane Georges, it looks deteriorated and abandoned and needs to be restored to its original condition. A landscape of typical xerophytic vegetation should be constructed adjacent to the building to enhance the appearance of the facilities.
    b) Educational/scientific exhibits initially proposed in the Management Plan for the Isla Caja de Muertos Natural Reserve (González et a. 1989) should be prepared and presented at the Visitor's Center. These include:

        i. The Coral Reef
        ii. The Dry Forest
        iii. The Island
        iv. History and Legends
        v. Island Nesters

8) **Establishing signage** portraying special use areas (anchorage areas, SCUBA areas, mooring buoy locations, etc.) at the dock and at Coast Guard Beach, and at the ferry dock in Ponce.

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