Habitat Use/Habitat Zoning Study
Cayo Aurora, Guánica Natural Reserve, Puerto Rico

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

FINAL REPORT

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EXECUTIVE SUMMARY

Cayo Aurora, commonly known as "Guilligan's Island", is a mangrove islet in the reef system of Cayos de Caña Gorda. It is one of the principal marine oriented recreational destinations for south and southwest coast residents and tourists, including guests at the Copa Marina Hotel and several guest houses in Guánica. As Cayo Aurora is part of Guánica State Forest and Biosphere Reserve, the Department of Natural and Environmental Resources (DNER) has constructed infrastructure for recreational activities and has implemented a management program with trained personnel for protection of the island marine resources. To manage the more than 70,000 tourists who visit Cayo Aurora each year, DNER has established a maximum capacity of 325 visitors per day. The most popular recreational activities include boating, fishing, kayaking, wind and kite surfing, snorkeling, bathing/swimming and SCUBA diving.

Cayos de Caña Gorda is part of an extensive coral reef system located off the Guánica coast that is of high ecological value and economic importance. The presence of estuarine, mangrove, seagrass beds and coral reef habitats 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 fishes and invertebrates. Thus, the Cayos de Caña Gorda reef ecosystem also represents an important source of larvae of many marine species that replenish adjacent areas of the Puertorrican shelf.

The emergent reef at Cayos de Caña Gorda acts as a barrier to wave action and provides conditions for development of seagrass beds and mangroves in the backreef zone. On the leeward side, there is a reef flat and a sandy backreef lagoon with red mangroves, seagrasses and macroalgae, and a finger coral biotope. On the windward side, the forereef presents a well-developed elkhorn coral zone, a narrow and abrupt slope with mixed stony corals and gorgonians, and a platform of colonized pavement that extends offshore across the shelf, connecting with a spur-and-groove coral reef formation at the shelf-edge. Mixed stands of turtle grass and manatee grass, with associated brown and calcareous green macroalgae occupy most of the shallow section

of the backreef at Cayo Aurora. Seagrasses grow over a sandy/coral rubble bottom, mostly comprised of dead finger coral. Isolated live coral colonies are interspersed within the seagrass bed. Submerged mangrove roots at the backreef of Cayo Aurora function as important nursery and recruitment habitat for a diverse assemblage of reef fishes.

Present threats or conflicts imposed by recreational and commercial utilization of marine resources at Cayo Aurora include high-speed operation of powerboats and jet skis; commercial/subsistence fisheries on shallow reef habitats; anchoring over seagrass and reef habitats; garbage disposal in marine habitats; and fringing mangrove deforestation.

Recommendations for protection of marine benthic habitats and improvement of recreational activities include: installation of mooring buoys and speed limit buoys; establishment of a closed fishing area throughout the shallow backreef zone between the reef flat and the mangrove keys of Cayos de Caña Gorda; reforestation of red mangroves at Cayo Aurora; increase of DNER personnel during peak recreational season; preparation of educational exhibits descriptive of the marine habitats at Cayo Aurora; and designation of the marine basin between Punta Jacinto, Punta Ballena and Cayos de Caña Gorda as an area of high ecological value. The Navigation and Aquatic Security Law of Puerto Rico (Law 430, Article 35, Section 22) states that "no vessel should exceed a speed of five knots in areas that have been designated as habitats of high ecological value or ecologically sensitive". This designation would greatly reduce the impacts of boating on benthic habitats in this area, and would effectively close the area to jet skis, which are particularly disruptive to wildlife. Other benefits of this designation would be a greatly reduced risk of vessel groundings and collisions with manatees and sea turtles.

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 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 Forests, has the important responsibility of habitat conservation in the state forest system, but the lack of data regarding management needs based on uses within the reserves has delayed management actions.

The purpose of this study is to continue an effort to conduct habitat use and habitat mapping studies in natural reserves and other marine protected areas 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) Regional Office, Habitat Conservation Division, Caribbean Field Office in La Parguera Natural Reserve in Lajas (García-Sais and Sabater-Clavell, 2004), Canal Luis Peña Natural Reserve in Culebra (Hernández-Delgado, 2003 a, b, c, d), and Los Arrecifes de la Cordillera Natural Reserve off Fajardo (CSA Group, 2005). 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, although it includes only the development of management recommendations based on observations, not their implementation.

Based on a meeting held on November 10, 2004, in Río 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 the Guánica State Forest and Biosphere Reserve were selected for study.

This work provides maps of the most important benthic habitats and marine oriented activities in the areas surrounding San Jacinto, Cayo Aurora (also known as Guilligan's Island), and Punta Ballena, in Guánica State Forest and Biosphere Reserve. This study focused primarily on the area around Cayo Aurora, as it encompasses the primary marine recreational areas in the reserve where intense levels of human activity occur. A general characterization of marine communities associated with the benthic habitats is included, along with an assessment of impacts and potential conflicts between recreational and commercial fishing activities and the ecological health of natural communities around Cayo Aurora. Recommendations are also presented both for improvement of the recreational facilities and protection of marine communities.

1.2 Background

The Governor of Puerto Rico, Arthur Yager, initially proclaimed Guánica an Insular Forest in 1919. The Guánica Forest was designated as a Biosphere Reserve by the UNESCO in 1981, in recognition of it being one of the best examples of a sub-tropical dry forest on the planet and for preservation of its natural habitats that contain a high diversity of plants, birds and terrestrial fauna (Gleason and Cook, 1927; Kepler and Kepler, 1970; Woodbury et al. 1975; González-Liboy et al., 1976; Lugo et al., 1978). Following its Biosphere Reserve designation, the Puerto Rico Planning Board (PRPB) designated it also as a Natural Reserve in 1985. The natural reserve initially comprised an area of 5,000 hectares (ha), including 4,400 ha of upland forest. In 1997, the PRPB approved a request by the DNER to extend the reserve boundaries to include the sector of Bahía Ballena (Resolution PU-002).

Guánica Natural Reserve includes a variety of marine ecosystems, such as estuaries, mangroves, salt flats, saltwater lagoons, rocky and sandy beaches, seagrass beds, coral reefs, and colonized pavement. Guánica Bay serves as a maritime landing port for small-scale industrial enclaves and artisanal fishing activities. It was formerly an important port for the sugarcane industry of Puerto Rico.

Cayos de Caña Gorda is the largest reef system within Guánica Reserve. It includes Cayo Aurora, also known as "Guilligan's Island", which is one of the principal marine recreational areas for south and southwest coast residents and tourists (Plate 1). The DNER has constructed infrastructure for recreational activities and has implemented a management program with trained personnel for protection of the island and its marine resources. Over 70,000 tourists visit Cayo Aurora each year, and DNER has established a maximum capacity of 325 visitors which is controlled through various management measures. The most popular recreational activities include boating, fishing, kayaking, wind and kite surfing, snorkeling, SCUBA diving, bathing/swimming and bird-watching.

Plate 1. Aerial view of Cayo Aurora and surrounding waters looking southeast.

Geographic Location

Guánica is located on the southwest coast of Puerto Rico. The marine section of the Guánica Natural Reserve extends 8.9 km (5.5 mi) along the coastline from the eastern corner of Guánica Bay in the east, almost to Punta Ventana in the west, and approximately 1.6 km (1 mi) offshore from Punta Jacinto (Figure 1). Reserve boundaries of the marine section are:

Northeast: 17°57.00N/66°54.00W
Southeast: 17°56.00N/66°54.00W
Center (north): 17°56.50N/66°51.50W
Center (south): 17°58.00N/66°51.50 W
Northwest: 17°57.70N/66°49.00W
Southwest: 17°57.00N/66°49.00W.

Cayo Aurora is an emergent section of Cayos de Caña Gorda, a fringing coral reef system that extends southwesterly from Punta Ballena (east) towards Punta Jacinto (west). The reef is approximately 2.3 km (1.4 mi) long and at least 1 km (0.6 mi) wide. The coral reef system at Cayos de Caña Gorda is part of a much larger marine ecosystem that includes the Guánica Bay estuary, extensive seagrass beds on the shelf, fringing mangroves along the coastline and adjacent coral reefs, such as Cayo Coral (west of Cayo Aurora) and the shelf-edge reef. There is a deep submarine canyon associated with Guánica Bay that cuts through the insular shelf and extends easterly towards the shelf-edge.

Climatology

DNER has monitored daily climatological data (rainfall and air temperature) for Guánica Reserve since 1984 at Camp Borínquen (Barrio Carenero), in the vicinity of the forest visitor center. The mean annual temperature is 25.3 °C (77.5°F), ranging from a mean of 23.5 °C (74.3°F) during January to a mean of 26.7 °C (80°F) in August and September. The mean annual rainfall is 79.1 cm (31 in), with a relatively dry period from January through March, and a rainy season that starts in May and extends through

November. Approximately 55 percent of the mean annual rainfall occurs between August and November. The greatest recorded rainfall was 120.1 cm (47 in) in 1990, and the lowest was 45.5 cm (18 in) in 1991. This geographic region is within the ecological zone classified as a Subtropical Dry Forest (Ewel and Whitmore, 1973).

Figure 1. Aerial view of Cayos de Caña Gorda within the Guánica Natural Reserve.

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. Cold fronts, tropical waves and hurricanes markedly influence the climatological pattern of the Guánica coast. Between April and November, 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 cold fronts as they pass over the island.

Tropical waves are seasonally experienced during the summer and fall in Puerto Rico (May – October). These may bring considerable rainfall and may develop 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 terrestrial infrastructure of Cayo Aurora. During 1979, Hurricane David caused considerable damage to shallow marine communities of the south coast of Puerto Rico, including those associated with the elkhorn coral (*Acropora palmata*) biotope at Cayo Aurora (Pacheco et al., in press). Hurricane Georges in 1998 caused significant damage to Cayo Aurora's infrastructure and produced changes in coastal geomorphology, removing coralline sand from beaches and reducing the extension of red mangrove in various sections. During September 2004, strong wave action associated with the passing of Hurricane Ivan destroyed the DNER dock and other infrastructure at Cayo Aurora (Plate 2). The coastal erosion associated with the high waves and surge action caused changes in the geomorphology of the island as it removed significant amounts of sand, detached seagrasses and massive corals, and exposed red mangrove roots along the shoreline.

Geology

Tertiary sedimentary limestone rocks are the main constituent of the Guánica shelf and forest. Cretaceous volcanic and sedimentary rocks represent less than 10 percent of the formation at the reserve. Tertiary rocks include the Ponce Limestone, deposited during the Miocene epoch, and the Juana Díaz Formation, deposited during the Oligocene and Miocene epochs (Silander et al., 1986). The Ponce Limestone, which prevails near the coastline and shelf, is a highly cemented formation of coral deposition with abundant fossils of relict coral reefs. The Cayos de Caña Gorda reef system is situated on the Ponce limestone. The cays themselves are primarily composed of sand and alluvium deposited on top of this limestone. More than 82 percent of the soil in the reserve is of calcium carbonate origin. There are approximately 11 hectares of beaches within the reserve, primarily located in the San Jacinto area and Bahía Ballenas.

Plate 2. Damage to DNER infrastructure by Hurricane Ivan in September 2004.

Economic Importance

Cayos de Caña Gorda is part of an extensive coral reef system located off the Guánica coast that is of high ecological value and economic importance. The presence of mangrove roots, seagrass beds, coastal lagoons and embayments, and coral reef habitats make this ecosystem an important recruitment, nursery and residential habitat for coral reef fishes and invertebrates, many of which are of commercial value (CFMC 1993). The 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. Thus, the Cayos de Caña Gorda ecosystem is an important source of larvae of many marine species that disperse and replenish adjacent areas of the Puertorrican shelf (personal communication, Dr. Reni Garcia, University Puerto Rico, February 2006).

There is an artisanal commercial/subsistence fishery comprised of approximately 60 fishermen who utilize the reef and seagrass habitats of Cayos de Caña Gorda. Queen

conch (*Strombus gigas*) is the main target of the fishery, and is fished by divers from small wood boats, or "yolas". There is also a small-scale octopus fishery, which is conducted by walking over the reef flats. Targeted finfish species include baitfish, such as sardines (*Harengula* spp.), white mullet (*Mugil curema*) and ballyhoo (*Hemiramphus ballyhoo*) that are caught with gillnets and cast nets. Fish traps are used to capture snappers, grunts, trunkfish and jacks. Trolling, spinning, and hand lines are used to fish for pelagic species, such as jacks and mackerel. During the summer, there is a locally important commercial fishery for king mackerel (*Scomberomorus cavalla*) at the mouth of Guánica Bay. Most of the commercial fishing activities occur very early in the morning and at night. During our visits to the reserve, two fish traps were observed without floating markers within the Cayo Aurora backreef lagoon.

Shoreline fishing is an important recreational activity that is organized, promoted and monitored by the Guánica Natural Reserve management (DNER) with funding from the Dingell-Johnson Program (Pacheco and Canals, 2004). During 2003-04, the estimated fishing effort for shoreline fishing was 5,595 hours, with the highest fishing activity recorded during October-November and March-April. Of the 20 species harvested by a total of 827 individuals, schoolmaster and yellowtail snappers (*Lutjanus apodus* and *Ocyurus chrysurus*, respectively) and French grunt (*Haemulon flavolineatum*) were the most common. Based on creel surveys performed by Pacheco and Canals (2004), the total expenditure for shoreline fishing activities during 2003-04 within Guánica Natural Reserve (in terms of bait, equipment etc.) was approximately $105,000.

Cayo Aurora is also an important marine recreational area for local and international tourists along the southwest coast. It is one of the main recreational destinations of boats and yachts from Guánica, Yauco, Guayanilla and Peñuelas. It is also the primary offshore marine recreational site visited by tourists from the Copa Marina Hotel and guest houses in Guánica. Cayo Aurora receives between 70,000 and 100,000 visitors each year, of which approximately 60 percent arrive by boat, 30 percent by jet skis, and 10 percent by kayak. The highest visitor activity occurs during the summer and long weekends. One concessionary carries visitors to Cayo Aurora on a ferry boat "La Libertad", with a maximum capacity of 49 persons, and a limit of five trips per day. The maximum of 325 visitors at Cayo Aurora established by DNER is managed through the use of mooring buoys and passengers limits on boats accessing the island.

Cayo Aurora represents an important incentive for the economy of Guánica and adjacent municipalities because of the direct tourist expenditures and the direct and indirect employment generated by businesses associated with lodging, food, gasoline, boats, and other maritime industries in Puerto Rico. Cayo Aurora is also an important educational and scientific resource.

1.3 Biotic communities

Terrestrial Vegetation

More than 700 species of vascular plants, including 45 considered rare and/or endangered, have been reported from the Guánica Reserve (Woodbury et al. 1975; DNR 1986). Terrestrial vegetation at Cayo Aurora is mostly associated with mangrove forests, which include white, black and button mangrove (*Laguncularia racemosa, Avicennia germinans,* and *Conocarpus erectus*, respectively) within the interior section of the island, and fringing red mangrove (*Rhizophora mangle*). Other plants at Cayo Aurora include sea grape (*Cocoloba uvifera*), beach morning glory (*Ipomea prescaprae*), seashore dropseed (*Sporobolus virginicus*), saltwort (*Batis maritima*), and sea pickle (*Sesuvium portalacastrum*).

Marine Communities

Marine communities associated with coral reefs, seagrass beds and submerged mangrove roots are present at Cayo Aurora. The geographic distribution and detailed biological characterization of these habitats and associated communities is presented in the results section (Section 3.0) of this report.

As part of the general inventory of coral reefs in Puerto Rico, Goenaga and Cintrón (1979) briefly mention the presence of a fringing reef protecting the coastline off Caña Gorda and comment on the scarcity of live coral on the reef. However, they did not present any data to support their assessment of a degraded reef condition, nor did they

describe the reef community in detail. Pacheco et al. (in press) observed substantial coral growth of elkhorn coral on the reef crest of Cayo Aurora and interpreted the initial assessment by Goenaga and Cintrón (1979) as an example of the mechanical destruction to shallow reef communities of the south coast of Puerto Rico caused by Hurricane David in 1979. At present, a healthy elkhorn coral biotope is growing along the entire reef crest of Cayos de Caña Gorda, including a section off Cayo Aurora.

A baseline biological characterization of reef communities associated with Cayos de Caña Gorda was prepared by García-Sais et al. (2001) as part of the National Coral Reef Monitoring Program for Puerto Rico. The survey was performed at a depth of 10 meters (33 ft) near the base of the forereef. The high abundance of soft corals, or gorgonians, (37 colonies intersected per transect) was the most prominent biological feature of this reef. Stony corals were also prominent in terms of substrate cover with a mean of 29.4% (range: 16.9 – 39.1%) along five 10-meter long transects. Both massive and encrusting growth forms were common and contributed, along with gorgonians, substantial rugosity and habitat complexity to the reef (García-Sais et al., 2001). A total of 21 species of hermatypic corals were reported from Cayos de Caña Gorda in the survey by García-Sais et al. (2001), 13 of which were intersected by transects. Four species represented approximately 90 percent of the total linear cover by stony corals. The boulder star coral, *Montastraea annularis* was the dominant scleractinian species with a mean of 14.1 percent, and along with the great star coral, *M. cavernosa* was present in all transects surveyed. Other prominent species were the mustard hill coral, *Porites astreoides* and the symmetrical brain coral, *Diploria strigosa*. Turf algae was the dominant biological component of the reef sessile-benthos with a mean of 49 percent along transects surveyed (García-Sais et al., 2001). Only 20 fish species were observed at Cayos de Caña Gorda during the survey by García-Sais et al. (2001), but these were probably underestimated due to poor underwater visibility at the time of the survey or time of day.

Seagrass beds constitute an important marine benthic habitat at Cayo Aurora. These beds are composed of turtle grass (*Thalassia testudinum*) and manatee grass (*Syringodium filiforme*) and also contain various species of algae. They serve as a recruitment and nursery habitat for many coral reef fishes and invertebrates, and are the primary habitat for a diverse assemblage of resident populations, including the

commercially valuable queen conch. Many adult and juvenile coral reef fishes forage in the seagrass beds. Seagrass beds in the backreef of Cayo Aurora also constitute a foraging habitat for the endangered Caribbean manatee, *Trichechus manatus*. There are no studies available that provide quantitative characterizations of the communities associated with the seagrass bed habitats of Cayos de Caña Gorda.

Submerged red mangrove roots at Cayo Aurora serve as recruitment, nursery and foraging habitats for an assemblage of resident estuarine populations and juvenile coral reef fishes. Resident populations of small pelagic schooling zooplanktivorous fishes, such as silversides (*Atherinomorus* spp.), sardines (*Jenkinsia lamprotaenia*) and anchovies (*Anchoa* spp.) sustain piscivorous juvenile reef fishes, including snappers (*Lutjanus griseus, L. apodus, L. synagris*), barracudas (*Sphyraena barracuda*), jacks (*Carangoides ruber, C. crysos*), squirrelfishes (*Holocentrus* spp., *Myripristis jacobus*) and estuarine adult fishes, such as the tarpon (*Megalops atlanticus*). The brown pelican (*Pelecanus occidentalis*) is a predator of schooling fishes associated with the submerged mangrove root habitat at Cayo Aurora. Butterflyfish (*Chaetodon capistratus*), which feed on hydrozoans attached to the red mangrove roots, appear to be using the submerged mangrove roots as a recruitment habitat, as well as juvenile snappers and barracudas.

1.4 Objectives

This study focused primarily on the area around Cayo Aurora, as it encompasses the primary marine recreational areas in the reserve where intense levels of human activity occur. The objectives of this study are the following:

- Prepare a revised map of marine benthic habitats in the area between San Jacinto, Cayo Aurora, and Punta Ballena in Guánica Natural Reserve
- Identify the location, types and intensity of recreational and commercial activities in this area
- Evaluate the present condition of marine benthic habitats and identify potential impacts by recreational and commercial activities
- Provide management recommendations for the protection of marine habitats

2.0 METHODS

2.1 Distribution of Benthic Habitats

The distribution of benthic habitats in the study area was based on field validation and pertinent modifications of NOAA's benthic habitat map for Puerto Rico and the US Virgin Islands (Kendall et al., 2001). The digitized aerial photograph from NOAA's benthic habitat map for the area 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. More than 300 ground truth observations were made in the field and saved as X, Y georeferenced points. This set of observations (points) were superimposed over NOAA's benthic habitat map for the study area and were used to modify existing polygons where necessary. Habitat areas south and east of Punta Ballena were not groundtruthed and are unmodified from the NOAA (Kendall et al. 2001) mapping.

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

1) Reclassification of seagrass patches inside the backreef lagoon as finger coral biotope
2) Reclassification and mapping of the elkhorn coral biotope at the forereef of Cayo Aurora
3) Separation of the reef flat and fringing reef from the all-inclusive "linear reef" original classification
4) Simplification of seagrass cover categories into one including "mixed seagrass and macroalgae" based on field observations

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

- **Dense seagrass and macroalgae** : densely vegetated bottom dominated by a seagrass (turtle grass and manatee grass) and associated macroalgae

- **Sparse seagrass and macroalgae**: sparse seagrass and macroalgae covering less than 20 percent of the sandy-silt bottom
- **Macroalgae** : sparse macroalgal stand growing over fine sediments
- **Fringing Reef** : emergent section of the coral reef located at the northeast of Cayo Aurora
- **Patch Reef** : submerged coral reef formation within the insular shelf
- **Shelf-edge reef** : submerged coral reef formation at the shelf-edge
- **Elkhorn Coral Biotope** : relatively large live coral formations constructed by elkhorn coral
- **Finger Coral Biotope** : live coral formations mostly constructed by finger coral
- **Reef Flat** : relatively flat, emergent section of the fringing reef behind the reef crest
- **Colonized pavement** : hard bottom with low cover and/or low topographic relief contributed by stony corals
- **Sand** : abiotic, unconsolidated sediments mostly from coralline biogenic origin
- **Mangrove :** littoral zones with growth of mangroves

2.2 Biological Characterization of Benthic Habitats

Taxonomic characterizations of the dominant biological components of the coral reefs, seagrass beds and submerged red mangrove root habitats within Cayo Aurora were performed to supplement and update previous surveys by Pacheco et al. (in press) and García et al. (2001). Aspects of benthic habitat "ecological health", such as coral bleaching, dead corals and/or mechanical damage to corals and/or seagrasses were noted. Particular attention was given to the assessment of impacts by recreational activities, such as propeller scars, entangled fishing lines in corals, garbage, clothing and other materials present within the benthic habitats of Cayo Aurora. Digital underwater photographic documentation of the marine communities associated with relevant marine habitats within Cayo Aurora is included to support biological characterizations.

2.3 Recreational and Commercial Activities in the Marine Environment

Geographic mapping of recreational and commercial activities in the study area was accomplished by the same technique applied to mapping benthic habitats. Areas of recreational and commercial activity, including docking, boat anchoring, fishing, snorkeling, windsurfing/kite surfing, water skiing, swimming/bathing, and navigation routes for kayaks, jet skis, and larger boats were georeferenced by navigating to the location of the activity and identifying it as a way point with annotations in a computer (Hypack software). The coordinates were then superimposed on a digitized and georeferenced map of the island. Likewise, proposed geographic locations of recommended actions to mitigate recreational impacts to benthic habitats were also mapped with the same technique. In order to identify and map the critical habitats for threatened and endangered marine species in the reserve, the Management Officer for Cayo Aurora, Mr. Miguel Canals and Mr. Carlos Pacheco, former Reserve Biologist were consulted. Photographs of areas where recreational and commercial fishing 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 are derived from previous scientific publications, such as the technical works by Goenaga and Cintrón (1979), Pacheco et al. (in press), García et al. (2001), and from field observations made during the survey. Special attention was focused on the existing Management Plan (DNR, 1976). Reserve management vision and specific alternatives were discussed with the Management Officer for Cayo Aurora, Mr. Miguel Canals, and with the Director of the Division of Natural Reserves and Refuges of DNER, Mr. Robert Matos. Casual interviews with several local fishermen and visitors to the reserve were conducted to gain insights into their views of reserve management fishing regulations, recreational activities, infrastructure, and commercial development in the area.

3.0 RESULTS

3.1 Map of Benthic Habitats

Cayos de Caña Gorda is a fringing coral reef system that extends southwesterly from Punta Ballena (east) towards Punta Jacinto and Guánica Bay (west). The reef is approximately 2.3 km (1.4 mi) long and at least 1 km (0.6 mi) wide. Cayo Aurora is an emergent section on the western side of the reef dominated by a mangrove forest, where DNER has constructed recreational facilities and a dock on the northern (protected) section of the backreef. The geographic distribution of benthic habitats in Cayos de Caña Gorda is presented in Figure 2.

The fringing reef reaches the surface and acts as a protective barrier to wave action, which has allowed the growth of red mangroves and seagrasses in the backreef. Wave energy dissipates across a rather narrow reef flat comprised of coral rubble, macroalgae, sparse turtle and manatee grass, and live corals, particularly finger coral and fire coral (*Millepora complanata*). Encrusting biota, such as zoanthids (*Palythoa caribdea, Zoanthus sociatus*) and sponges (*Chondrilla nucula*) are also present.

The reef flat of Cayos de Caña Gorda occupies an area of approximately 13.5 ha, representing about 2.7 percent of the total benthic habitat surveyed between San Jacinto and Punta Ballena, extending off to the shelf edge (Figure 3). A dense, mixed stand of turtle grass and manatee grass with brown (*Dyctiota* sp.) and green macroalgae (*Caulerpa racemosa*, *Udotea flabellum, Penicillus capistratus, Halimeda* spp.) growing as a continuous bed over sandy/coral rubble substrate is widely distributed between the reef flat and the mangrove islets, as well as surrounding shallow sections of Cayos de Caña Gorda.

Isolated coral colonies of symmetrical brain coral, finger coral, mustard-hill coral and star coral (*Siderastrea siderea*) are interspersed with seagrass in the shallow seagrass bed between the reef flat and the red mangrove fringe. Dense seagrass and macroalgae grow in fine sand and silt and fringe most of the shoreline from San Jacinto to Punta Ballenas. A continuous bed of dense seagrass and macroalgae stretches from Cayo Aurora to Bahía Ballenas. This study focused primarily on the area around Cayo Aurora, as it encompasses the primary marine recreational areas in the reserve where intense levels of human activity occur.

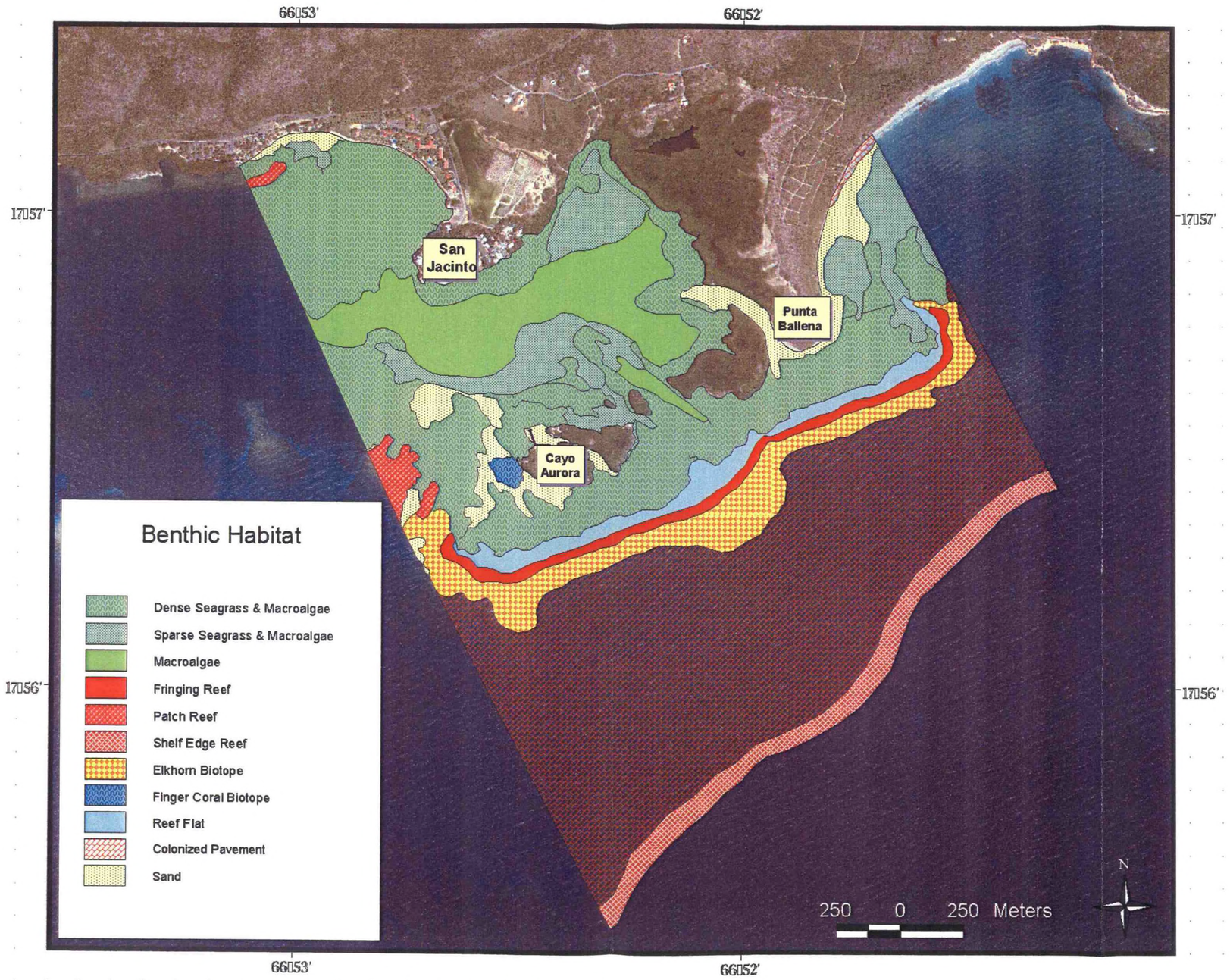

Figure 2. Map of benthic habitats in the study area (limited primarily to Cayo Aurora), Guánica Natural Reserve, modified from Kendall et al. (2001).

Dense mixed seagrass/macroalgae covers approximately 130.1 ha. With increasing depth, seagrass cover declines sharply. A transition zone of very sparse seagrass growth (< 20 percent) is present throughout the backreef slope at depths between 3 and 5 meters (10 -16 ft). Below 5 meters, the substrate consists of silt and mud, with sparse growth of green macroalgae (*Caulerpa racemosa*) and benthic infauna mounds.

Along the western side of Cayo Aurora, there is a broad sand/coral rubble channel fringing the mangrove shoreline. Other sand channels cut across Cayo Aurora's mangrove islet, and between Punta Ballena and the eastern (and largest) mangrove key of Cayos de Caña Gorda (Plates 3-5). The sand channels at Cayo Aurora are the main recreational areas for bathing, swimming and snorkeling close to the submerged red mangrove root habitat. The total area of sandy bottom is approximately 21.1 ha. DNER has installed several cement "reef balls" within the sand channels, as a reserve management initiative (personal communication, Miguel Canals, Management Officer for Cayo Aurora, February 2006). Several species of coral have been cemented to the reef balls.

Patches of finger coral are found in the broad sand channel along the western side of Cayo Aurora (Figure 2), forming a live coral biotope associated with turtle grass, sponges, gorgonians, calcareous macroalgae (*Halimeda opuntia*), juvenile fishes, and motile invertebrates. Finger coral patches cover an estimated area of 1.2 ha.

Benthic Habitat Type	(ha)	%
Colonized Pavement	184.5	36.5
Dense Seagrass & Macroalgae	130.1	25.8
Macroalgae	40.3	8.0
Sparse Seagrass & Macroalgae	36.5	7.2
Elkhorn Coral Biotope	28.9	5.7
Sand	21.1	4.2
Shelf-edge Reef	19.8	3.9
Mangrove	15.0	3.0
Reef Flat	13.5	2.7
Fringing Reef	9.7	1.9
Patch Reef	4.6	0.9
Finger Coral Biotope	1.2	0.2
Total =	**505.0**	

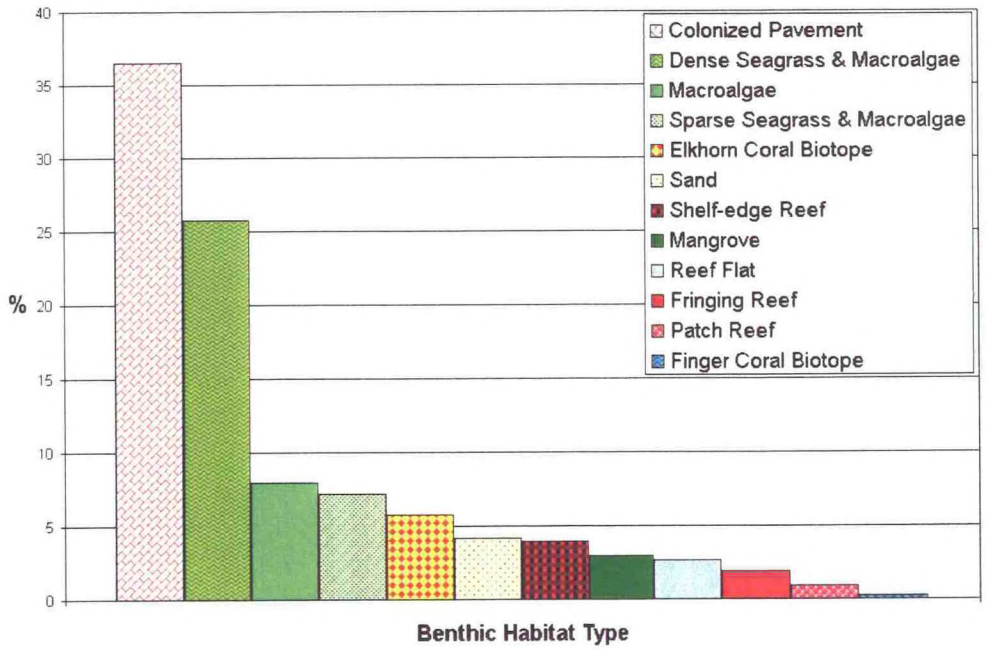

Figure 3. Benthic habitat surface area coverage at Cayos de Caña Gorda.

Plate 3. Sand channels fringed by red mangrove cut through Cayo Aurora, Guánica Natural Reserve.

Seaward from the reef crest, the forereef is characterized by a gently sloping terrace where elkhorn coral constitutes the most prominent benthic habitat, creating a biotope intermixed with sparsely distributed massive and encrusting corals and gorgonians at depths between 2 and 4 meters (6-13 ft) (Figure 2). The elkhorn coral biotope covers an area of approximately 23.5 ha along the Cayos de Caña Gorda forereef. Elkhorn coral declines sharply in abundance with increasing depth down the forereef slope. At the base of the forereef slope, there is an extensive hard ground platform, or pavement, colonized mainly by turf algae, with isolated and sparsely distributed encrusting stony corals and gorgonians. The colonized pavement habitat extends across most of the outer shelf, increasing gradually with depth towards the shelf-edge. At depths of 16 to 18 meters (52-60 ft), sand channels begin to cut through the hard ground perpendicular to the shelf edge and the colonized pavement habitat merges into a low relief spur-and-groove coral reef formation. A well-developed spur-and-groove coral reef dominated by massive stony corals and gorgonians is present at depths between 18 and 34 meters (60-112 ft) associated with the shelf edge.

3.2 Biological Characterization of Marine Communities

Coral Reefs

The coral reef system at Cayos de Caña Gorda is an emergent fringing reef formation that acts as a barrier to wave action and provides adequate conditions for the development of seagrass beds and mangrove forest in the backreef. This reef formation extends from Cayo Aurora eastward into Bahía Ballenas. On the protected (leeward) side, there is a reef flat and a sandy backreef lagoon with submerged red mangrove roots, seagrasses and macroalgae, and a finger coral biotope. On the seaward (windward) side, the forereef contains an extensive elkhorn coral zone, a narrow and abrupt slope with mixed stony corals and gorgonians, and a platform of colonized pavement that extends offshore across the shelf, connecting with a spur-and-groove coral reef formation at the shelf edge.

The reef flat is a relatively narrow and elongated section that becomes exposed at low tide. Waves break at the reef crest and move across the reef flat reaching the backreef during heavy surf. Thus, the reef flat is a high wave energy zone and the benthic biota are adapted to withstand high abrasion and scouring. Encrusting biota, such as fire coral, and the zoanthid, *Palythoa caribdea*, prevail along with turf algae and encrusting sponges. Most of the hard substrate consists of coral rubble. Patches of live finger coral and calcareous macroalgae (*Halimeda opuntia*) are present in deeper sections of the reef flat. Other stony corals that grow encrusted, or in low relief mounds (*Porites astreoides, Diploria clivosa, D. strigosa*) are also present. Boring sea urchins (*Echinometra lucunter, E. viridis*), chitons (*Acanthopleura* sp.), brittle stars (*Ophiocoma* spp., *Ophioderma* spp.), whelk (*Cittarium pica*) and other gastropods are typical of this shallow habitat. The common octopus (*Octopus vulgaris*) is present during the warmer months and feeds mostly upon bivalves that live in shallow habitats of the reef. An assemblage of small fishes such as blennies, clinids and gobies that occupy microhabitats in the rubble and tide pools, are the main components of the fish fauna on the reef flat.

The backreef of Cayos de Caña Gorda comprises a significant section of the reef system, with a series of six emergent mangrove islets separated by sand channels that

enable seawater to flow across the reef. Two finger coral patches located on the west side of Cayo Aurora's backreef rise from a sandy/coral rubble bottom at a depth of two meters (6 ft), reaching the surface during low tide (Plates 4-9). Turtle grass and fleshy macroalgae grow intermixed with the coral. The corals appear healthy and growing, with low incidence of dead and degraded colonies overgrown by encrusting biota. Several colonies of mustard-hill coral grow intermixed within the finger coral biotope, along with colonies of the green finger sponge (*Iotrochota birotulata*) and scattered pore rope sponge (*Aplysina fulva*), the sea pearl (*Ventricaria ventricosa*) and the amber penshell (*Pinna carnea*). Territorial damselfishes (*Abudefduf saxatilis*, *Stegastes planifrons, S. leucostictus, S. partitus*) appear to be residents of the finger coral biotope. Juvenile reef fishes associated with the finger coral biotope included the bluehead, clown and slippery dick wrasses (*Thalassoma bifasciatum, Halichoeres maculipinna,* and *H. bivittatus*, respectively), juvenile parrotfishes (*Sparisoma rubripinne, S. radians, S. viride*), grunts (*Haemulon* spp.), Spanish hogfish (*Bodianus rufus*), surgeonfishes (*Acanthurus* spp.), and butterflyfish (*Chaetodon capistratus, C. ocellatus*), among others (Table 1).

Plates 4 – 9. The finger coral biotope and associated marine community west of Cayo Aurora.

Plate 4

Plate 5

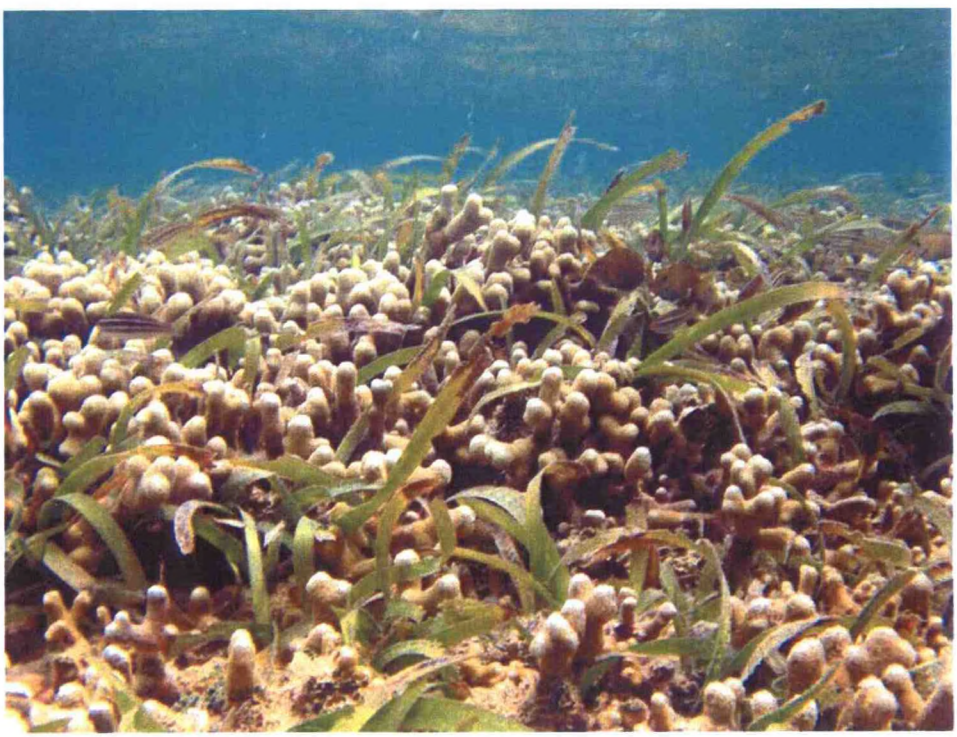

Plate 6

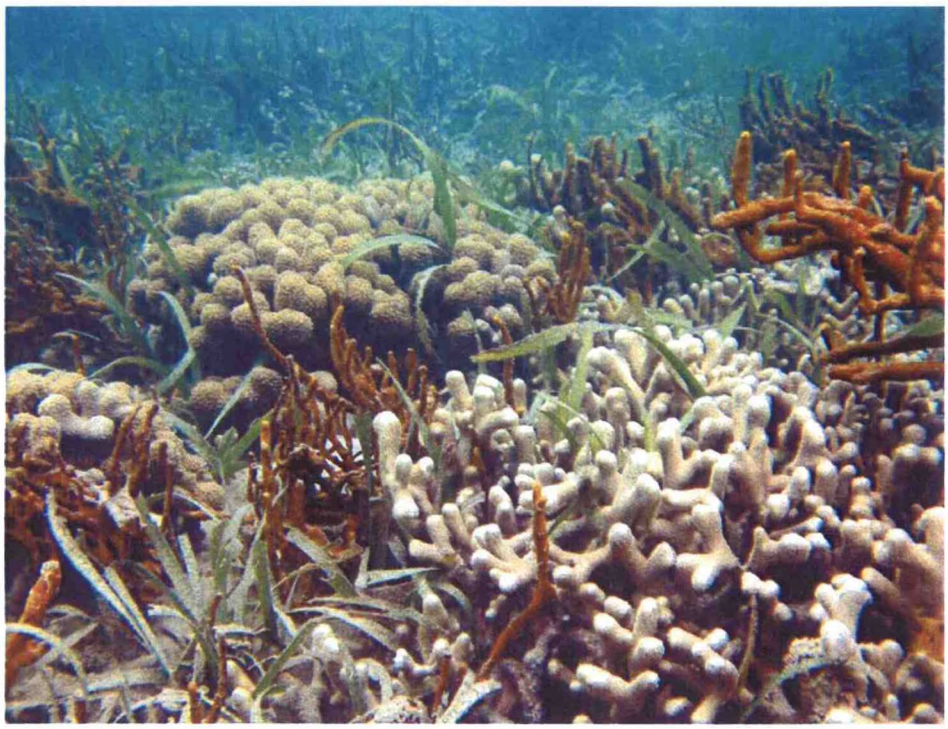

Plate 7

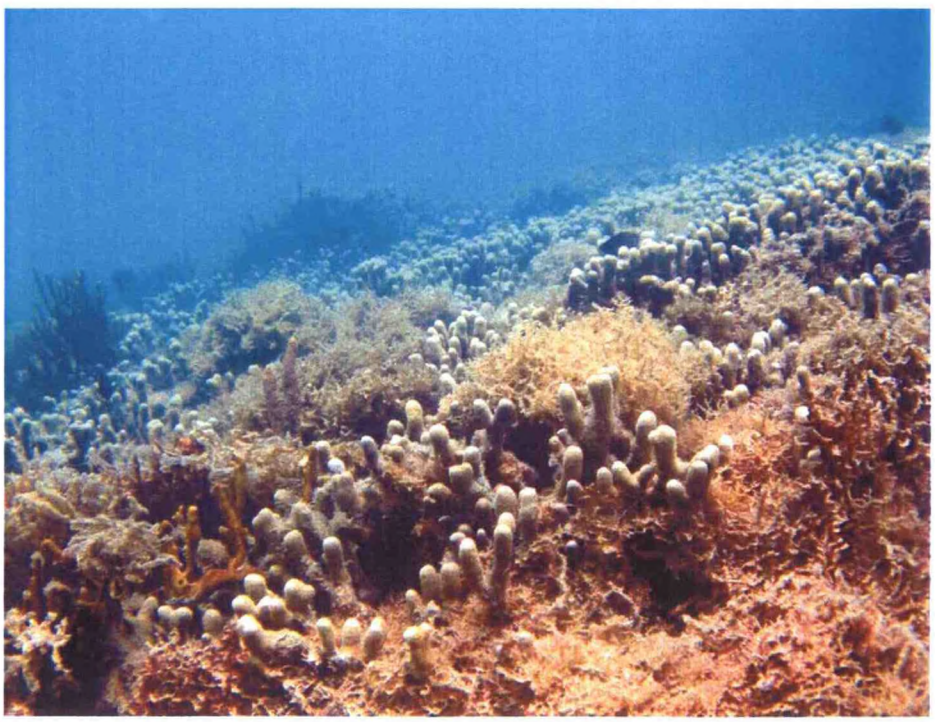

Plate 8

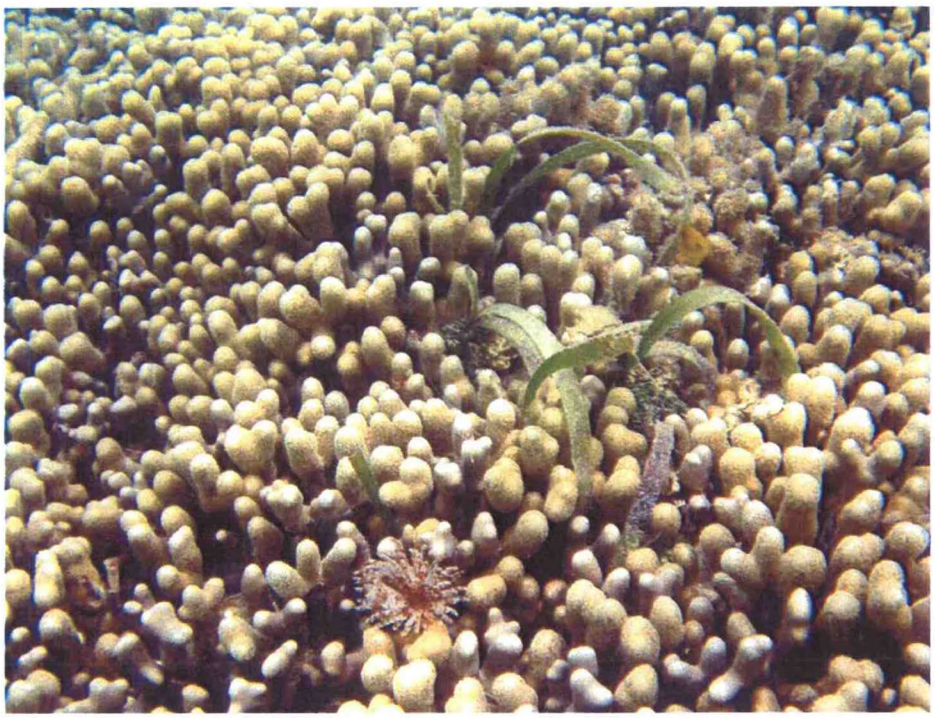

Plate 9

An abandoned cargo net was entangled in the finger coral biotope causing extensive damage to the corals and associated community (Plate 10). Also, two fish traps without marker buoys were observed adjacent to the finger coral biotope during the survey (Plate 11). These traps captured several parrotfishes (*S. rubripinne*) and trunkfishes (*Lactophrys trigonus, L. triqueter*).

The reef crest zone, extending from the surface to a depth of two meters, is a breaking wave environment and shares some of the biological features of the reef flat. The hard ground substrate is dominated by turf algae. Stony corals are not abundant and mostly present as isolated encrusting colonies (e.g. fire coral, mustard-hill coral, knobby brain coral (*D. clivosa*)). Patches of the encrusting zoanthid, *Palythoa caribdea*, are common. Below the reef crest, at depths between 3 and 5 meters (10-16 ft), there is a zone of prolific elkhorn coral growth. Large standing colonies, some reaching two meters in diameter, are common and provide substantial topographic relief within this zone (Plates 12 and 13). Encrusting colonies of elkhorn coral are also present. Pacheco et al. (in press) reported on the growth dynamics and recuperation of this biotope after the severe damage caused by Hurricane David in 1979.

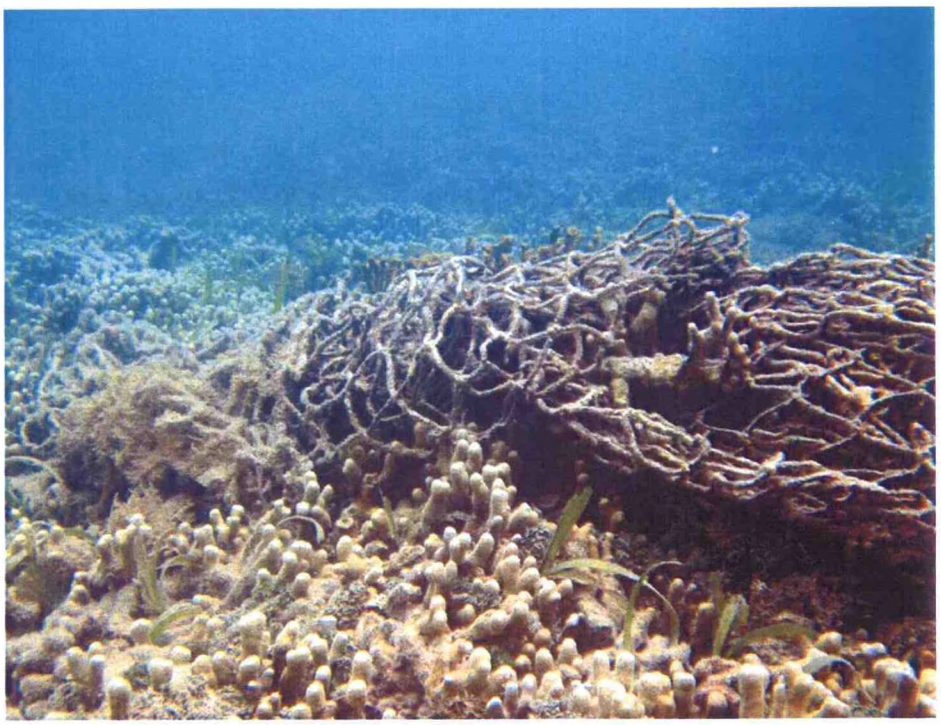

Plate 10. Abandoned cargo net entangled in finger coral at Cayo Aurora.

Plate 11. Fish trap deployed without marker buoys in the vicinity of the finger coral biotope at Cayo Aurora.

Plates 12-13. Elkhorn coral on the forereef of Cayo Aurora.

Plate 12

Plate 13

Abrasion and scouring are stress factors in the elkhorn coral zone during high wave action. Turf algae dominate most of the hard ground substrate. Patches of fire coral and the encrusting zoanthid, *P. caribdea*, overgrow dead corals and other hard substrate with topographic relief. The deeper section of the elkhorn coral biotope contained growing staghorn coral, brain corals (*D. labyrinthiformis, D. strigosa, D. clivosa*) and mustard-hill coral colonies. Gorgonians, particularly the common sea fan (*Gorgonia ventalina*), were moderately abundant. Coral bleaching or diseases were not observed.

A diverse assemblage of coral reef fishes was found associated with the elkhorn coral biotope at Cayo Aurora. Some of the most abundant fishes observed included the sergeant major and yellowtail damselfish (*Abudefduf saxatilis* and *Microspathodon chrysurus,* respectively). Juveniles of the yellowtail damselfish were typically seen in close association with fire coral colonies. Wrasses, including the bluehead, clown and slippery dick, were highly abundant. These fish are opportunistic carnivores that feed

upon infaunal invertebrates that become exposed during mechanical disturbances, such as those caused by wave action. The herbivorous fish assemblage was highly prominent, with schooling surgeonfishes (*Acanthurus coeruleus, A. chirurgus, A. bahianus*) and parrotfishes (*Sparisoma rubripinne, S. viride, Scarus iserti*) grazing on the abundant turf algae. Schools of brown chromis (*Chromis multilineata*), juvenile grunts (*Haemulon flavolineatum, Haemulon* spp.) and schoolmaster snapper inhabit the deeper section of the elkhorn coral biotope, along with other reef fishes typical of shallow coral reef habitats (Table 1).

The forereef slope south of Cayo Aurora extends seaward almost 1.5 km (0.9 mi) along a colonized pavement habitat. This is a low relief, hard ground platform dominated by turf algae, sponges, gorgonians and isolated encrusting and mound-shaped stony coral colonies. At a depth of about 13 meters (45 ft), low relief spur-and-groove coral formations start to appear. Coral spurs measure approximately one meter high where the spur-and-groove formation begins, and gradually increase with depth towards the shelf edge. Gorgonians dominate at the shallow end of the spur-and-groove coral reef. Massive coral colonies become more prominent with increasing depth towards the shelf-edge. Massive coral colonies of a wide variety of stony corals, particularly *Montastraea annularis, M. cavernosa, Diploria* spp., *Colpophyllia natans, Dendrogyra cylindrus*, were common along the spurs. The grooves are channels of coarse sand and coral rubble that are relatively wide (3 - 4 m; 10 - 13 ft) at the shallow end of the reef at depths of 13 – 17 m (43 - 56 ft), but become more compressed (1 - 2 m; 3 - 6 ft) towards the shelf edge. At the shelf-edge, the spurs are 5 - 6 meters (16 - 20 ft) high and the grooves are deep narrow channels surrounded by prolific coral growth along the vertical walls on both sides of the spurs.

The shelf edge reef off Cayo Aurora is one of the best developed coral reef systems in Puerto Rico (García-Sais et al. 2001). The spur-and-groove formation extends to a depth of at least 35 m (115 ft) with live coral cover exceeding 50 percent in many sections of the reef. A baseline characterization of the coral reef community associated with the shelf edge reef system off Guánica was prepared by García-Sais et al. (2001).

Table 1. List of common species identified from coral reef habitats in Guánica Natural Reserve, during this study.

Common Name	Scientific Name
Seagrasses	**Angiospermae**
Turtle Grass	*Thalassia testudinum*
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**
Unidentified Crustose Coralline Alga	Rhodophyta
Segmented Alga	*Jania* sp.
Y-Twig Alga	*Amphiroa* sp.
Sponges	**Porifera**
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*
Scattered Pore Rope Sponge	*Aplysina fulva*
Cnidarians	**Cnidaria**
Fire Coral	*Millepora* spp.
Moon Jelly	*Aurelia aurita*
Giant Anemone	*Condylactis gigantea*
Sun Anemone	*Stichodactyla helianthus*
Mat Zoanthid	*Zoanthus sociatus*
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	*Montastraea annularis*
Great Star Coral	*Montastraea cavernosa*
Golf-Ball 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.
Crustaceans	**Crustacea**
Spiny Lobster	*Panulirus argus*
Arrow Crab	*Stenorhynchus seticornis*

Table 1. Continued

Banded Coral Shrimp	*Stenopus hispidus*
Pederson Cleaner Shrimp	*Periclimenes pedersoni*
Batwing Coral Crab	*Carpilius corallinus*
Clinging Crab	*Mithrax* spp.
Mollusks	**Mollusca**
Chiton	*Acanthopleura* sp.
Queen Conch	*Strombus gigas*
Flame Helmet	*Cassis* sp.
Amber Penshell	*Pinna carnea*
Octopus	*Octopus vulgaris*
Sea Hare	*Aplysia* sp.
Whelk	*Cittarum pica*
Echinoderms	**Echinodermata**
Giant Basket Star	*Astrophyton muricatum*
Brittle Star	*Ophiocoma* spp.
Brittle Star	*Ophioderma* spp.
Black Sea Urchin	*Diadema antillarum*
Rock-Boring Sea Urchin	*Echinometra lucunter*
Reef Urchin	*Echinometra vividis*
Worms	**Annelida**
Bearded Fireworm	*Hermodice carunculata*
Magnificent Feather Duster	*Sabellastarte magnifica*
Christmas Tree Worms	*Spirobranchus* sp.
Fishes	**Pisces**
Silversides	Atherinidae
Dwarf Herring	*Jenkinsia lamprotaenia*
Anchovies	*Anchoa* spp.
Timucu	*Strongylura timucu*
Bicolor Damselfish	*Stegastes partitus*
Three-spot Damselfish	*Stegastes planifrons*
Dusky Damselfish	*Stegastes dorsopunicans*
Sergeant Major	*Abudefduf saxatilis*
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*
Striped 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*
Houndfish	*Tylosurus acus*
Ballyhoo	*Hemiramphus brasiliensis*
Blue Runner	*Carangoides crysos*
Bar Jack	*Carangoides ruber*
Yellowfin Mojarra	*Gerres cinereus*
Green Moray	*Gymnothorax funebris*
Sand Diver	*Synodus intermedius*
Squirrelfish	*Holocentrus rufus*
Black-bar Soldierfish	*Myripristis jacobus*
Red Hind	*Epinephelus guttatus*

Table 1. Continued

Coney	*Cephalopholis cruentatus*
Harlequin Bass	*Serranus tigrinus*
Mutton Snapper	*Lutjanus analis*
Schoolmaster Snapper	*Lutjanus apodus*
Yellowtail Snapper	*Ocyurus chrysurus*
Lane Snapper	*Lutjanus synagris*
Juvenile Grunts	*Haemulon* spp.
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*
Saddled Blenny	*Malacoctenus triangulatus*
Redlip Blenny	*Ophioblennius atlanticus*
Blennies	Cliniidae
Gobies	Gobiidae
Ocean Surgeon	*Acanthurus bahianus*
Doctorfish	*Acanthurus chirurgus*
Blue Tang	*Acanthurus coeruleus*
Balloonfish	*Diodon holacanthus*
Porcupinefish	*Diodon histrix*
Trunkfish	*Lactophrys* spp.
Sharpnose Puffer	*Canthigaster rostrata*

Artificial reefs, of the pre-constructed cement "reef ball" type have been deployed by DNER in the sand channels separating the fringing mangrove islets at Cayo Aurora. Four reef balls have been deployed, and several species of coral have been cemented to them. The reef balls are mostly covered by an algal turf packed with fine sediments (Plate 14). Live stony corals (*Diploria strigosa, Porites porites, P. astreoides, Siderastrea siderea, S. radians*), are found growing on the reef balls, mostly as isolated encrusting colonies. Juvenile lobsters and reef fishes were observed using the artificial reef structures as nursery habitats. There are plans to move the reef balls to deeper water, as they are experiencing high sedimentation which is affecting the corals on them. Also, because of their location, people sometimes climb on them.

Plate 14. Artificial reefs deployed in the sand channels of Cayo Aurora.

Seagrass Beds

Seagrass beds cover much of the area between San Jacinto, Cayo Aurora, and Punta Ballena, and are also present in Bahía Ballenas. The study area focused on Cayo Aurora. A mixed stand of turtle grass and manatee grass, with associated brown (*Dictyota* spp.) and calcareous green macroalgae (*Penicillus* sp., *Halimeda* spp., *Caulerpa* spp., *Udotea* spp.) occupies most of the shallow section of the backreef at Cayo Aurora, between the reef flat and the red mangrove fringe. The seagrasses grow over a sandy/coral rubble bottom, mostly comprised of dead finger coral (Plates 15 – 20). Isolated coral colonies are interspersed within the seagrass bed. Other sessile-benthic invertebrates associated with the shallow seagrass bed include the amber penshell and the scattered pore rope sponge (*Aplysina fulva*). Table 2 lists the organisms observed in the seagrass habitat during our field survey.

Motile megabenthic invertebrates observed include the sea stars, *Oreaster reticulatus* and *Astropecten duplicatus*, green, white and long-spined sea urchins (*Lytechinus variegatus, Tripneustes ventricosus, Diadema antillarum*, respectively), sea cucumbers

(*Holothuria* spp., *Isostichopus badionotus*), and several mollusks, including the queen and milk conch (*Strombus gigas* and *S. costatus*, respectively), the flame helmet (*Cassis tuberosa*), murex (*Murex pomum*) and the true tulip (*Fasciolaria hepatica*). Upside-down jelly (*Cassiopea frondosa*) were present at the soft sediment sections. Juvenile spiny lobsters were observed associated with small coral heads interspersed within the seagrass bed. Other prominent crustaceans include the blue crabs (*Callinectes* spp.), hermit crabs (*Paguristes* spp), clinging crabs (*Mithrax* spp.) and stomatopod shrimps (*Gonodactylus* spp.).

Turtle grass grows in deeper sections of the backreef of Cayo Aurora (north of the mangrove islet) to a maximum depth of approximately 4 m (13 ft) over an unconsolidated substrate of silt and fine sand. Manatee grass starts growing at a depth of about 3 m (10 ft) intermixed with turtle grass over a more packed sandy-silt substrate within this region. Below 4 m (13 ft), the silt-mud substrate is sparsely covered by growth of green feather alga (*Caulerpa sertularioides*) and other calcareous green macroalgae (e.g. *Udotea* sp., *Penicillus* sp., *Halimeda* sp.).

Plates 15 – 20. Shallow seagrass bed and associated marine community in the backreef of Cayo Aurora.

Plate 15

Plate 16

Plate 17

Plate 18

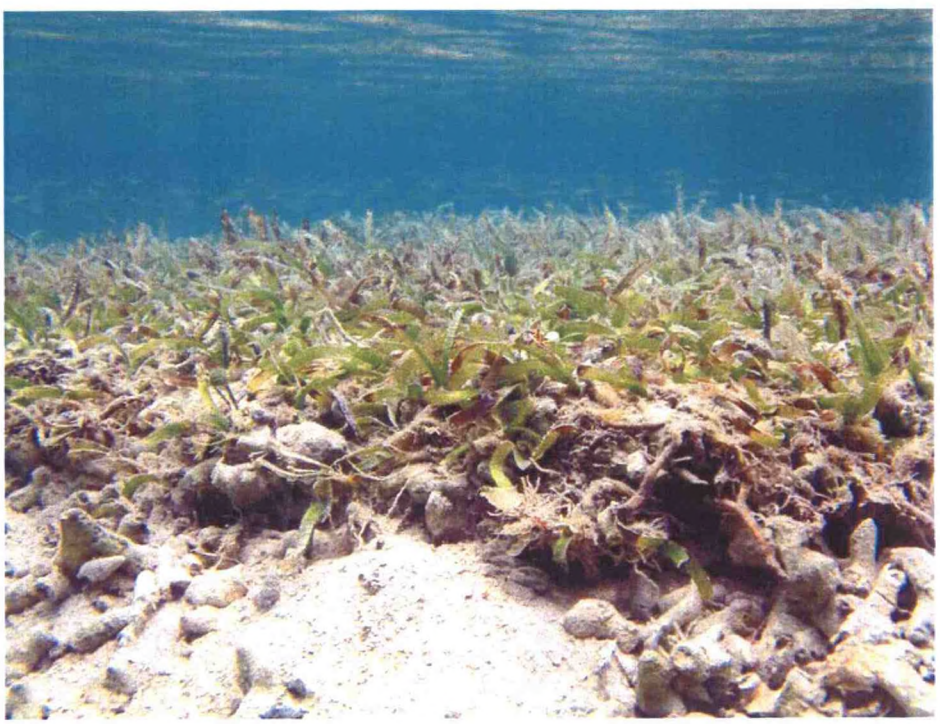

Plate 19

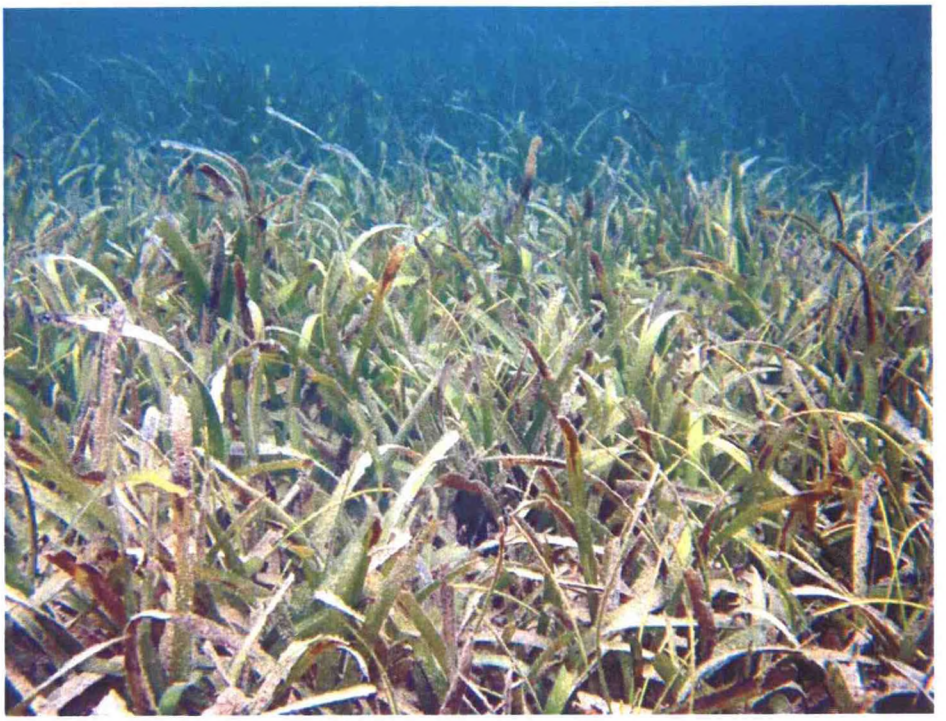

Plate 20

The fish community associated with the seagrass bed habitat at Cayo Aurora includes an assemblage of resident populations, transient pelagic predators and coral reef juveniles and adults that use the seagrass as foraging grounds. The most prominent demersal resident fish include the bucktooth and yellowtail parrotfishes (*Sparisoma radians* and *S. rubripinne*, respectively), the black-ear and slippery dick wrasses (*Halichoeres poeyi*, and *H. bivittatus,* respectively), the cocoa damselfish (*Stegastes variabilis*), southern stingray (*Dasyatis americana*), razorfish (*Xyrichthys* spp.) and gobies (*loglossus* sp., *Coryphopterus* spp.). Lined seahorses (*Hippocampus erectus*) and pipefishes (Family Syngnathidae) are common within manatee grass patches in the shallow mixed seagrass stand. Several mojarras (*Gerres cinereus*, *Eucinostomus argenteus, E. melanopterus*) that forage for small infaunal invertebrates were present over the silty-sand substrate. Pelagic species included the leatherjacket (*Oligoplites saurus*) and an assemblage of schooling fishes comprised of sardines (*Jenkinsia* sp.), anchovies (*Anchoa* spp.) and silversides (Family Atherinidae) which alternate between the submerged red mangrove roots and seagrass habitats. Beloniform fishes, including needlefishes (*Strongylura* spp., *Tylosurus acus, Platybelone atlanticus*) and ballyhoo (*Hemiramphus ballyhoo*), were observed at the water surface.

Transient pelagic predators include the tarpon, barracuda, juvenile and adult jacks (*Carangoides ruber, C. crysos*), adult mutton and lane snappers (*Lutjanus analis* and *L. synagris*, respectively) and trunkfishes *(Lactophrys* spp., *Acanthostrascion* spp.). Coral reef juvenile fish that were common in the seagrass beds of Cayo Aurora included the yellowtail snapper (*Ocyurus chrysurus*), spotted goatfish (*Pseudupeneus maculatus*), grunts (*Haemulon* spp.), surgeonfishes (*Acanthurus chirurgus, A. bahianus*), yellowtail parrotfish, and porcupine fishes (*Diodon histrix, Chilomycterus antillarum*). A small population of Caribbean manatees has been reported using the seagrass habitat in the backreef of Cayo Aurora (M. Canals, personal communication).

Table 2. List of common species identified in seagrass habitats in Guánica Natural Reserve during this study.

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*
Sponges	**Porifera**
Scattered Pore Rope Sponge	*Aplysina fulva*
Fire Sponge	*Tedania ignis*
Cnidarians	**Cnidaria**
Rose Coral	*Manicina areolata*
Ivory Bush Coral	*Oculina diffusa*
Upside-down Jellyfish	*Cassiopea frondosa*
Giant Anemone	*Condylactis gigantea*
Corkscrew Anemone	*Bartholomea annulata*
Crustaceans	**Crustacea**
Blue Crab	*Callinectes* spp.
Swimming Crab	*Portunus* sp.
Juvenile Spiny 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.

Table 2. Continued

Stomatopod Shrimp	*Gonodactylus* sp.
Hermit Crab	*Paguristes* 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*
Murex	*Murex pomum*
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 ventricosus*
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	Atherinidae
Dwarf Herring	*Jenkinsia lamprotaenia*
Anchovies	*Anchoa* sp.
Timucu	*Strongylura timucu*
Ballyhoo	*Hemiramphus brasiliensis*
Leatherjacket	*Oligoplites saurus*
Sea Bream	*Archosargus rhomboidalis*
Yellowfin Mojarra	*Gerres cinereus*
Black-ear Wrasse	*Halichoeres poeyi*
Clown Wrasse	*Halichoeres maculipinna*
Blue-head Wrasse	*Thalassoma bifasciatum*
Doctorfishes	*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* sp.
Balloonfish	*Diodon holacanthus*
Trunkfish	*Lactophrys* spp.
Blue Runner	*Carangoides crysos*
Juvenile Yellow Goatfish	Mulloides martinicus
Southern Stingray	*Dasyatis americana*
Goby	*Ioglossus* sp.,
Goby	*Coryphopterus* spp
Lined Seahorse	*Hippocampus erectus*

Table 2. Continued

Spotfin Mojarra	*Eucinostomus argenteus*
Flagfin Mojarra	*Eucinostomus melanopterus*
Agujon	*Tylosurus acus*
Needlefish	*Platybelone atlanticus*
Bar Jack	*Carangoides ruber*
Spotted Goatfish	*Pseudupeneus maculatus*
Porcupinefish	*Didion histrix*
Web Burrfish	*Chilomycterus antillarum*
Cero Mackerel	*Scomberomorus regalis*

Red Mangrove Root Community

Submerged red mangrove roots in the study area support diverse fish and benthic communities. Table 3 lists the organisms observed in the red mangrove root habitat during our field survey. The San Jacinto area formerly contained a significant amount of red mangrove habitat, but much has been trimmed back or lost due to development. Submerged roots in the study area contain growth of blue green, green, brown, and red algae. Corals identified in this habitat include fire coral, lesser star coral (*Siderastrea radians*), golfball coral (*Favia fragum*), upside-down jellyfish (*Cassiopea frondosa*), corkscrew anemone (*Bartholomea annulata*), and mat zoanthid (*Zoanthus* sp.). Crustaceans observed include mangrove crab (*Aratus pisoni*), blue crab, juvenile spiny lobster, arrow crab (*Stenorynchus seticornis*), and barnacles (*Balanus* sp.). Molluscs identified in red mangrove root habitat during the study include snails (*Littorina* sp.), sea hare (*Aplysia* sp.), and oyster (*Isognomon alatus*). Echinoderms identified in this habitat include beaded sea star (*Astropecten articulatus*) and sea cucumber (*Holothuria mexicana*).

Submerged red mangrove roots in the study area, particularly in the backreef of Cayo Aurora represent an important nursery habitat for a diverse assemblage of resident and juvenile reef fishes. The submerged roots are the natural recruitment habitats of small fish, such as the dwarf herring (*Jenkinsia lamprotaenia*), silversides, and anchovies, which form large schooling aggregations under the mangrove canopy. These planktivorous populations are the main prey for piscivorous juvenile reef fish, including the schoolmaster, gray and yellowtail snappers, blue runner, and barracuda. Also, these small schooling fishes serve as main food items for the brown pelican. Other juvenile reef fish present in the submerged red mangrove root habitat of Cayo Aurora (e.g.

damselfishes, grunts) use the habitat for protection and feed upon epibenthic biota attached to the mangrove roots (Plates 21 – 24).

The herbivorous fish assemblage of the submerged red mangrove root habitat at Cayo Aurora includes the sergeant major and night sergeant (*A. taurus*) and juvenile doctorfishes (*Acanthurus chirurgus, A. bahianus*). The sandy-silt bottom is a foraging area for juvenile goatfishes (*Mulloides martinicus, Pseudupeneus maculatus*), as well as for juvenile and adult mojarras (*Gerres cinereus, Eucinostomus* spp.) which may also use the red mangrove roots as recruitment habitat. Due to the close proximity of mangrove and seagrass habitats, schools of juvenile grunts (*Haemulon flavolineatum, H. chrysargyreum, H. plumieri*) that typically forage in the seagrass beds use the red mangrove root habitat for protection. Several needlefishes (*Strongylura* spp.) were present at Cayo Aurora near the water surface.

Plates 21 – 24. Submerged red mangrove root habitat and associated fish community at Cayo Aurora.

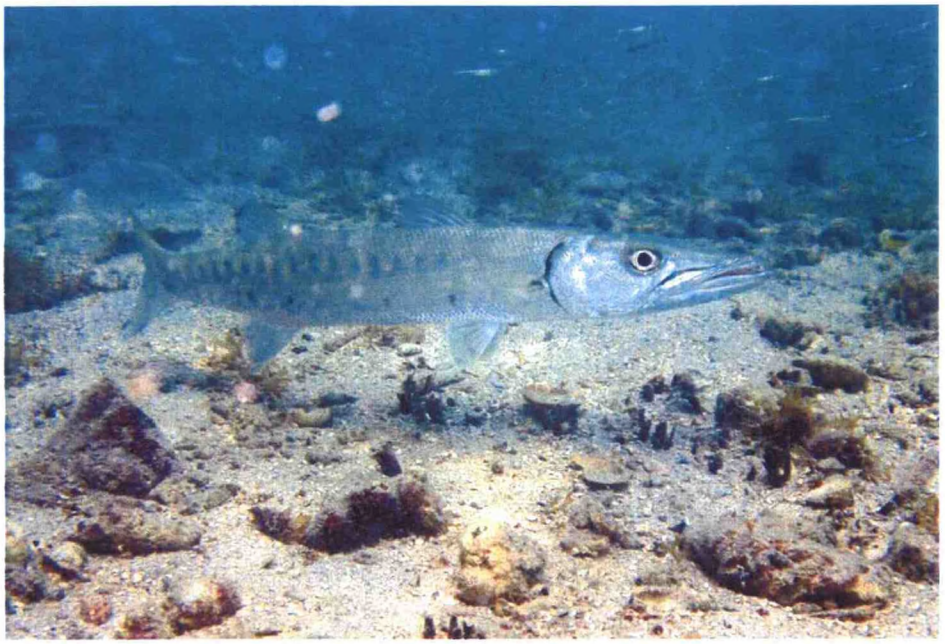

Plate 21

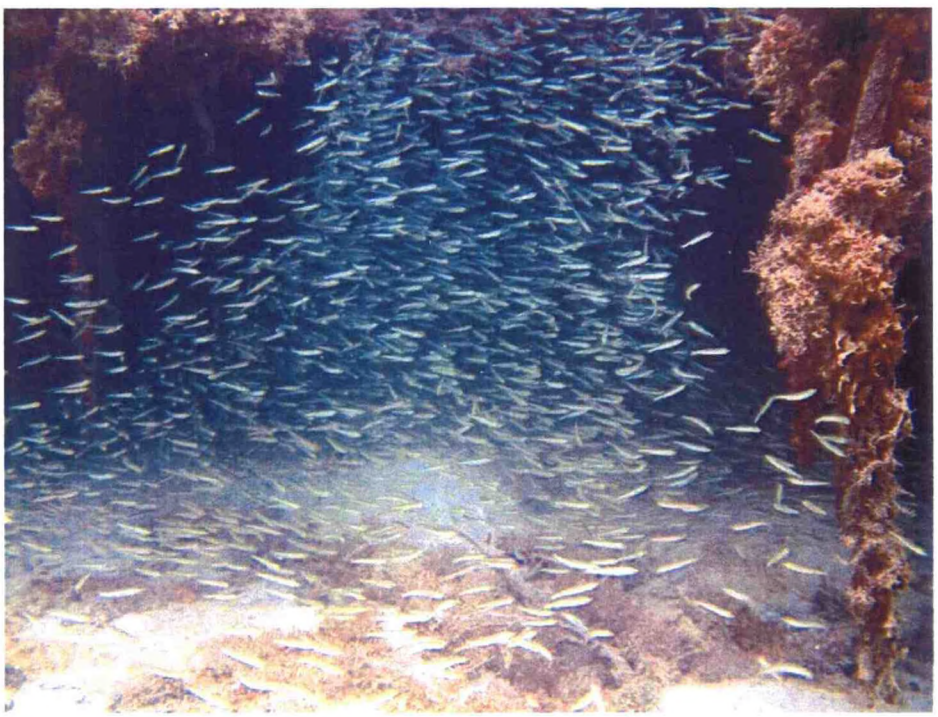

Plate 22

Plate 23

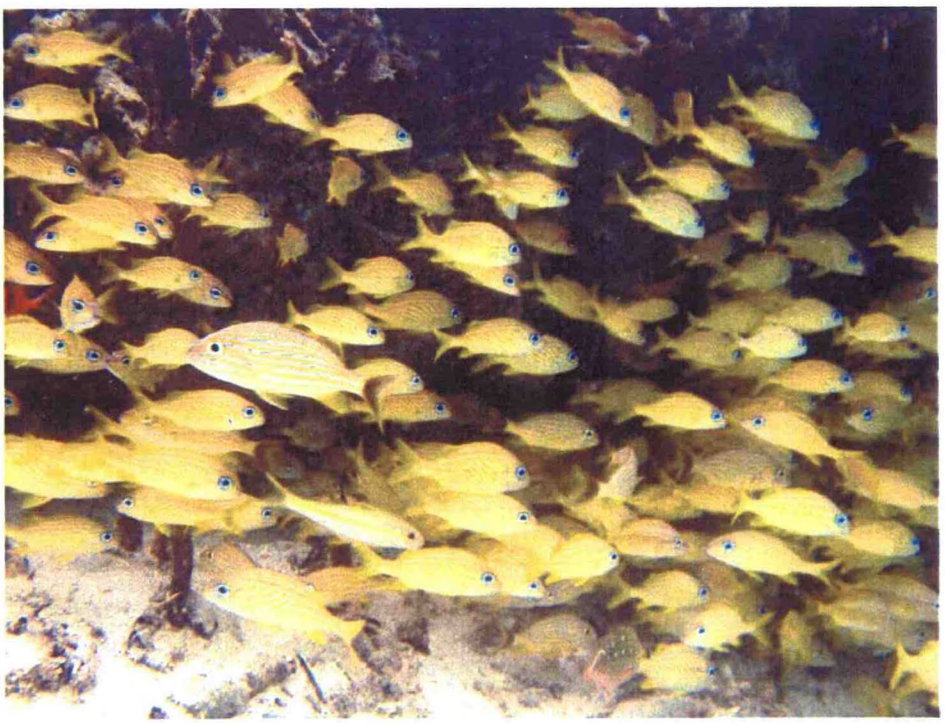

Plate 24

Table 3. List of common species identified in submerged red mangrove root habitat in Guánica Natural Reserve during this study.

Common Name	*Scientific Name*
Blue Green Algae	**Cyanophyta**
Lyngbia	*Lyngbia* sp.
Green Algae	**Chlorophyta**
Sea Pearl	*Ventricaria ventricosa*
Green Grape Alga	*Caulerpa racemosa*
Brown Algae	**Phaeophyta**
Y-Branched Alga	*Dictyota* sp.
Red Algae	**Rhodophyta**
Spiny Seaweed	*Acanthophora* sp.
Sponges	**Porifera**
Fire Sponge	*Tedania ignis*
Cnidarians	**Cnidaria**
Hydrozoan	Unidentified
Fire Coral	*Millepora* sp.
Lesser Star Coral	*Siderastrea radians*
Golfball Coral	*Favia fragum*
Mangrove Upside-down Jelly	*Cassiopea frondosa*
Corkscrew Anemone	*Bartholomea annulata*
Mat Zoanthid	*Zoanthus* sp.
Crustaceans	**Crustacea**
Mangrove Crab	*Aratus pisoni*
Blue Crab	*Callinectes* sp.
Juvenile Spiny Lobster	*Panulirus argus*
Arrow Crab	*Stenorhynchus seticornis*
Barnacle	*Balanus* sp.
Mollusks	**Mollusca**
Mangrove Snail	*Littorina* spp.
Sea Hare	*Aplysia* sp.
Mangrove Oyster	*Isognomon alatus*
Echinoderms	**Echinodermata**
Beaded Sea Star	*Astropecten articulatus*
Sea Cucumber	*Holothuria mexicana*
Fishes	**Pisces**
Silversides	Atherinidae
Dwarf Herring	*Jenkinsia lamprotaenia*
Anchovies	*Anchoa* sp.
Juvenile Doctorfishes	*Acanthurus* spp.
Timucu	*Strongylura timucu*
White Mullet	*Mugil curema*
Sea Bream	*Archosargus rhomboidalis*
Yellowfin Mojarra	*Gerres cinereus*
Flagfin Mojarra	*Eucinostomus* sp.
Juvenile Grunts	*Haemulon* spp.
Juvenile Mutton Snapper	*Lutjanus analis*
Juvenile Lane Snapper	*Lutjanus synagris*
Juvenile Schoolmaster	*Lutjanus apodus*
Mangrove Snapper	*Lutjanus griseus*
Juvenile Yellowtail Snapper	*Ocyurus chrysurus*
Juvenile Barracuda	*Sphyraena barracuda*

Table 3. Continued

Beaugregory	*Stegastes leucostictus*
Sergeant Mayor	*Abudefduf saxatilis*
Night Sergeant	*Abudefduf taurus*
Redfin Parrotfish	*Sparisoma rubripinne*
Redband Parrotfish	*Sparisoma aurofrenatum*
Juvenile Yellow Goatfish	*Mulloides martinicus*
Spotted Goatfish	*Pseudupeneus maculatus*

3.3 Distribution of Recreational and Commercial Activities and Assessment of Their Impacts to Benthic Communities

The geographic distribution of recreational and commercial activities in the area surrounding San Jacinto, Cayo Aurora, and Punta Ballena in Guánica Natural Reserve are presented in Figures 4 - 6. As previously mentioned, Cayo Aurora is the major focus of this study, as it encompasses the primary marine recreational areas in the reserve where intense levels of human activity occur. At present, the marine-oriented activities include:

1) DNER Recreational Facilities at Cayo Aurora - DNER has constructed facilities to support passive recreational activities at Cayo Aurora. Facilities include six gazebos, picnic tables and barbeques, bathrooms, and a visitor information office (Plates 25 and 26). There is no electricity or potable running water on the island. DNER administrators have established a maximum capacity of 325 visitors for Cayo Aurora, based on the quantity of the various visitor facilities. A total of 79,301 people visited the island during 1997 (the most recent year for which complete visitor statistics were available). In that year, 50.6 percent of visitation occurred between June and August; half of these visits were in July. The island is open from 8:30 am to 5:00 pm daily. Camping or other overnight use is prohibited. Despite the daily visitation limits imposed by DNER, substantial cutting of mangrove trees by visitors has been taking place at both the east and west corners of Cayo Aurora. This activity occurs during periods of summer, when the island is saturated with visitors. Cutting of mangrove trees is done to create "beach" space and establish additional picnic areas.

Plates 25 – 26. DNER facilities for recreational activities at Cayo Aurora.

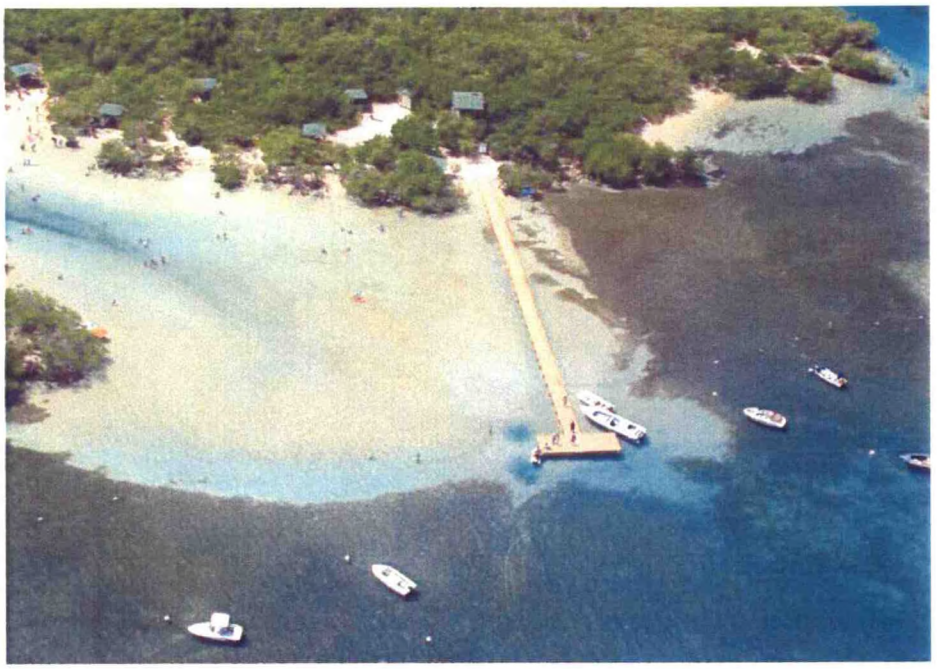

Plate 25

Plate 26

2) Ferry Boat Transport and Docking – A concession from DNER is provided to Mr. Mario Morciglio, owner and captain of the ferryboat "La Libertad". The ferryboat makes a maximum of five trips per day with a maximum capacity of 49 persons per trip. The ferryboat departs from a dock on the west side of Punta Jacinto and stops at Cayo Aurora and Punta Ballena to drop off and pick up passengers. The ferryboat route is shown in Figure 5. During July 2005, "La Libertad" carried a total of 6,798 visitors to Cayo Aurora, representing 86.4 % of the total visitors to the island during this month.

3) Mooring buoys and anchoring– the shallow seagrass zone in the backreef of Cayo Aurora is identified with a demarcation line of floats that prevent boats from entering this zone (Figure 4). Outside of this zone, there are currently 16 mooring buoys (Plate 27). These facilities operate on a first-come first-serve basis. During the long weekends of summer, the mooring buoys may all be occupied. In this case, private boats then proceed to anchor within the seagrass/macroalgae habitat located in the backreef of the eastern mangrove key of Cayos de Caña Gorda (adjacent to Punta Ballena) and in deeper sections of Cayo Aurora's backreef, over a sandy-silt bottom with sparse seagrass and macroalgae (Figure 5). Otero and Carrubba (2002) found numerous propeller scars in the seagrass beds in the backreef of Cayo Aurora as well as entering Bahía Ballena. DNER subsequently replanted seagrass in the scarred areas and red mangroves along the shoreline, with funding from the NOAA Coral Reef Conservation Program (M. Canals, personal communication).

   Anchoring in a shallow seagrass habitat was observed to occur in the backreef of the mangrove key located to the east of Cayo Aurora, adjacent to Punta Ballena (identified as Boat Anchorage on Figure 5). This activity was observed during the study, on long weekends when all of Cayo Aurora's mooring buoys were occupied. Although no propeller scars were observed during this study, this area is shallow and potential damage to the seagrass may be associated with the continuation of this practice. DNER reports that extensive propeller damage has occurred in this area in the past. Additionally, after long summer weekends, substantial amounts of garbage in the form of aluminum cans, clothing and plastic cups were observed in seagrass beds in the backreef of Cayo Aurora.

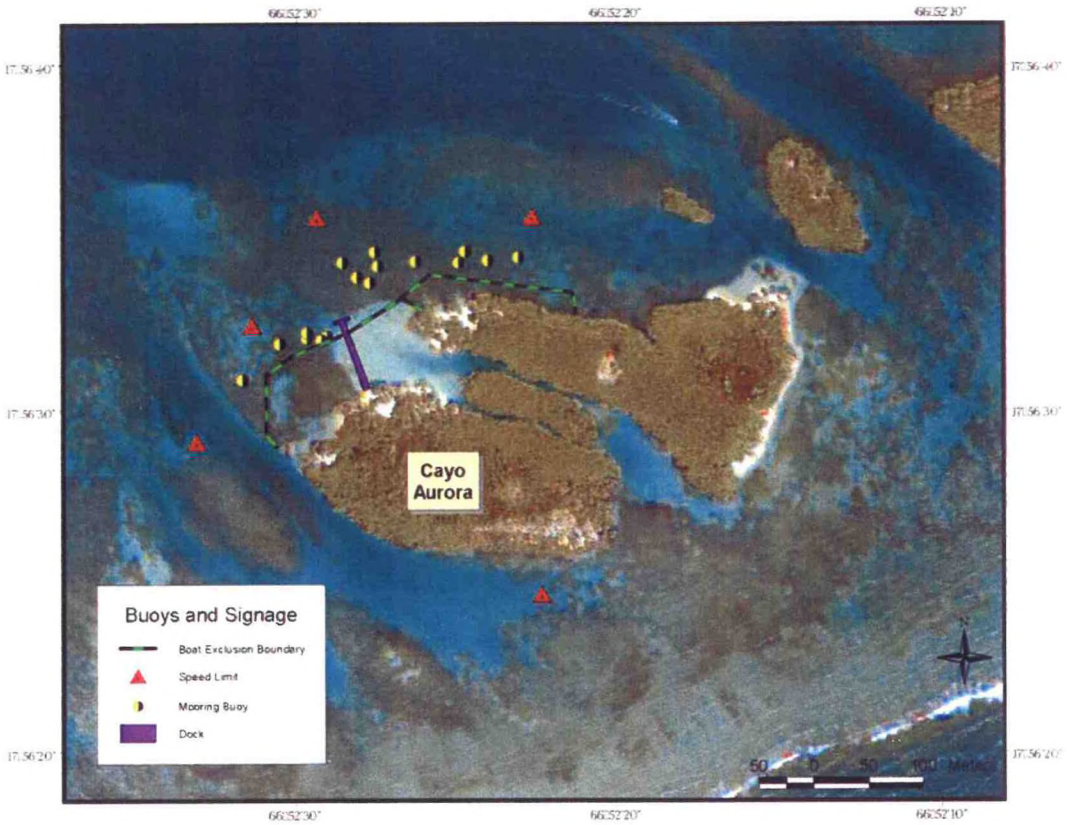

Figure 4. Map of current distribution of mooring buoys and signage at Cayo Aurora.

4) Boating – there is intense boating activity during weekends and holidays along the coastline in the area of the Copa Marina facilities, as well as along San Jacinto (Plate 27) and Punta Ballena towards the backreef of Cayos de Caña Gorda (Figure 5). Boats include yachts (>30 ft long), outboard motor boats of different types and sizes, jet skis, and fishermen's yolas. Following an administrative order from DNER, private boats are limited to transporting a maximum of 10 persons per day per boat to Cayo Aurora. During July 2005, a total of 131 privately owned boats carried 957 visitors to Cayo Aurora. About 25 - 30 fishermen's yolas are anchored at San Jacinto on a regular basis. There are typically 10 to15 privately owned outboard motor boats, 10 to 15 jet skis and 2 or 3 yachts using Cayo Aurora's mooring facilities during weekends, year-round. This usage may double or triple during the long weekends of summer, far

exceeding the capacity of Cayo Aurora's 16 mooring buoys. During weekdays, the private boat activity declines markedly and boating activity is mostly associated with local fishermen, DNER transit vehicles and charter vessels from Copa Marina.

5) DNER has placed five speed limit (5 mph) signs near the shoreline of Cayo Aurora (Plate 28 and Figure 4). High-speed operation of powerboats and jet skis between Punta Jacinto and Cayo Aurora is in conflict with the prevalence of Caribbean manatees. DNER personnel have sighted a total of seven manatees in this area (personal communication, Miguel Canals, DNER, February 2006). These manatees reside in the Guánica area, although one of them is known to travel between Guánica and Rio Guanajibo. Although there have been no reported accidents involving manatees, high-speed boating represents a threat to this endangered species in its natural habitat. High-speed boat operation is also in conflict with the utilization of this area for fishing (conch, fish traps, hook and line, trolling) and passive recreation (wind-surfing and kite-surfing). DNER estimates that approximately 10 vessel groundings occur each year.

Plate 27. Dock and boat ramp at San Jacinto.

Plate 28. DNER speed limit buoy north of Cayo Aurora.

6) Kayaking – because of the relatively short distance between San Jacinto, Punta Ballena, Copa Marina Hotel, and Cayo Aurora, kayaking is a popular means by which people arrive at the island's recreational facilities. A route followed by kayakers is presented in Figure 5. During July 2005, a total of 93 visitors arrived at Cayo Aurora by kayaks. There is a docking station for jet skis at Cayo Aurora.

7) Wind and Kite Surfing – these activities take place throughout the backreef of Cayos de Caña Gorda.

8) Swimming/Bathing – these activities are concentrated at the backreef of Cayo Aurora in shallow sandy bottom areas, including the mangrove channels that cut through the island (Figure 5).

9) Snorkeling – the best areas are the backreef of Cayo Aurora between the reef flat and the mangrove islet, including the broad sand channel in the western section of the backreef, where submerged red mangrove root communities and

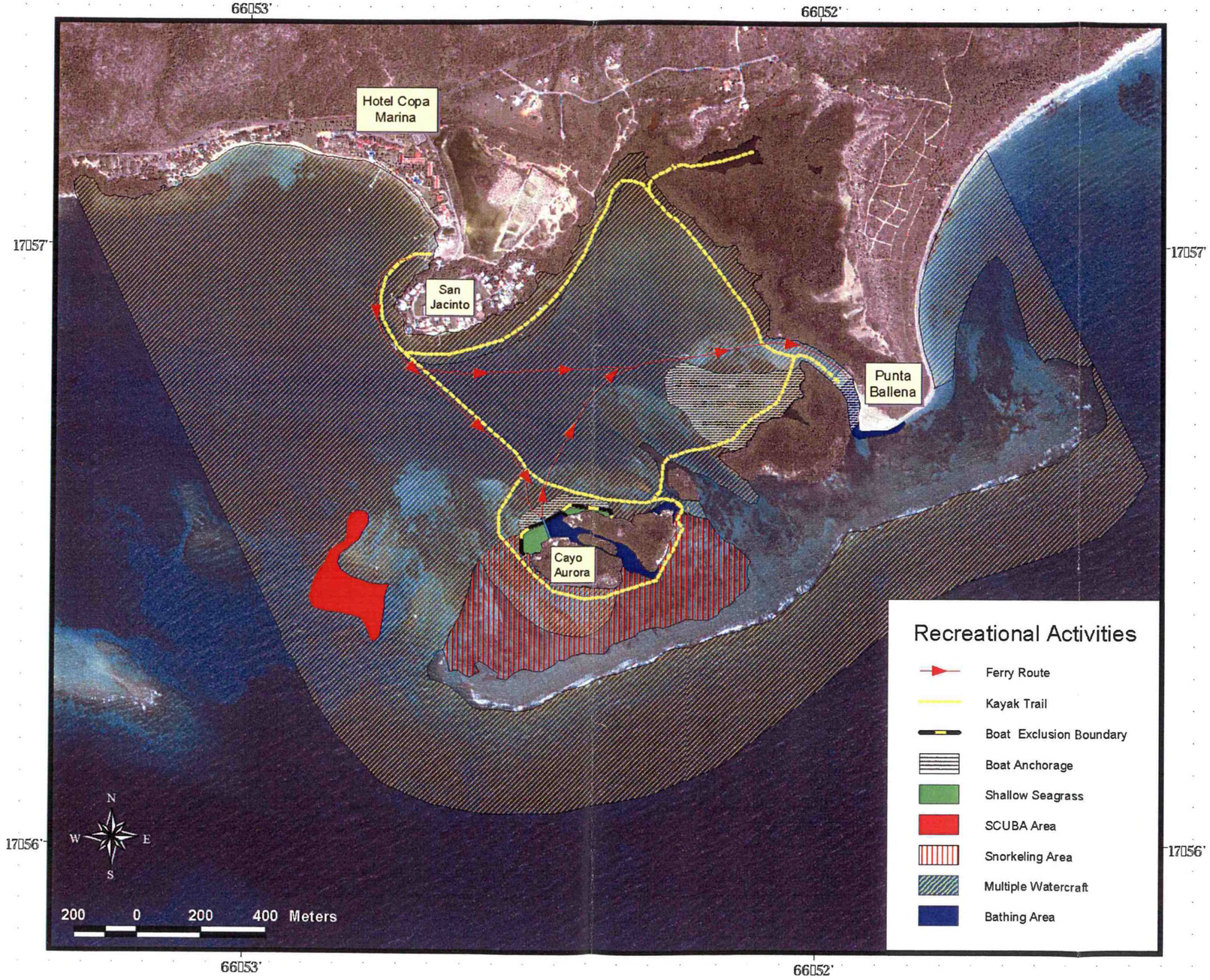

Figure 5. Map of recreational activities around San Jacinto, Cayo Aurora, and Punta Ballena, Guánica Natural Reserve.

the *Porites* biotope are found. Also, the sand channels that cut through the islets are popular snorkeling areas (Figure 5). During periods of calm weather, the forereef of Cayo Aurora is excellent for snorkeling by experienced skin divers.

10) SCUBA Diving – takes place mostly at the northwestern end of Cayo Aurora's forereef (Figure 5). Guests from the Copa Marina Hotel routinely charter SCUBA trips to this dive site. DNER administrators have encouraged charter boat owners that service the Hotel Copa Marina and other local hotels and guest houses to move their SCUBA diving activities to the forereef of Cayo Coral (West of Cayo Aurora). The shelf-edge off Cayos de Caña Gorda is one of the best SCUBA diving spots in Puerto Rico and is recommended for experienced divers. There is currently one mooring buoy approximately 600 meters west of Cayo Aurora.

11) Recreational Fishing – recreational fisheries fisheries are closely linked to benthic habitat types, so their distribution as presented in Figure 6 reflects this. shoreline fishing with hook and line or spinning rod and reel is practiced near the public dock facilities at San Jacinto and along the San Jacinto coastline, particularly from a dock known as "Muelle Los Fernández". Trolling and spinning from private boats that target neritic pelagic species (mackerel, barracuda, jacks and snappers) takes place along the forereef slope of Cayos de Caña Gorda and at the basin off the coast from Copa Marina, San Jacinto and Punta Ballena towards the backreef of Cayos de Caña Gorda. Recreational fishing with hook and line, skin diving with mask and snorkel, and spinning with spinning rod and reel takes place in the backreef of Cayo Aurora from small motor boats that navigate throughout this zone.

12) Commercial/Subsistence Fishing – There are approximately 60 commercial/subsistence fishermen working in the general area of Cayos de Caña Gorda. Commercial/subsistence fisheries are closely linked to benthic habitat types, so their distribution as presented in Figure 6 reflects this. SCUBA diving for queen conch is one of the most important commercial fishing activities. There is a seasonal closure for queen conch in effect from July 1 to September 30 throughout Puerto Rico, enforced by DNER. The fishing activity for queen conch

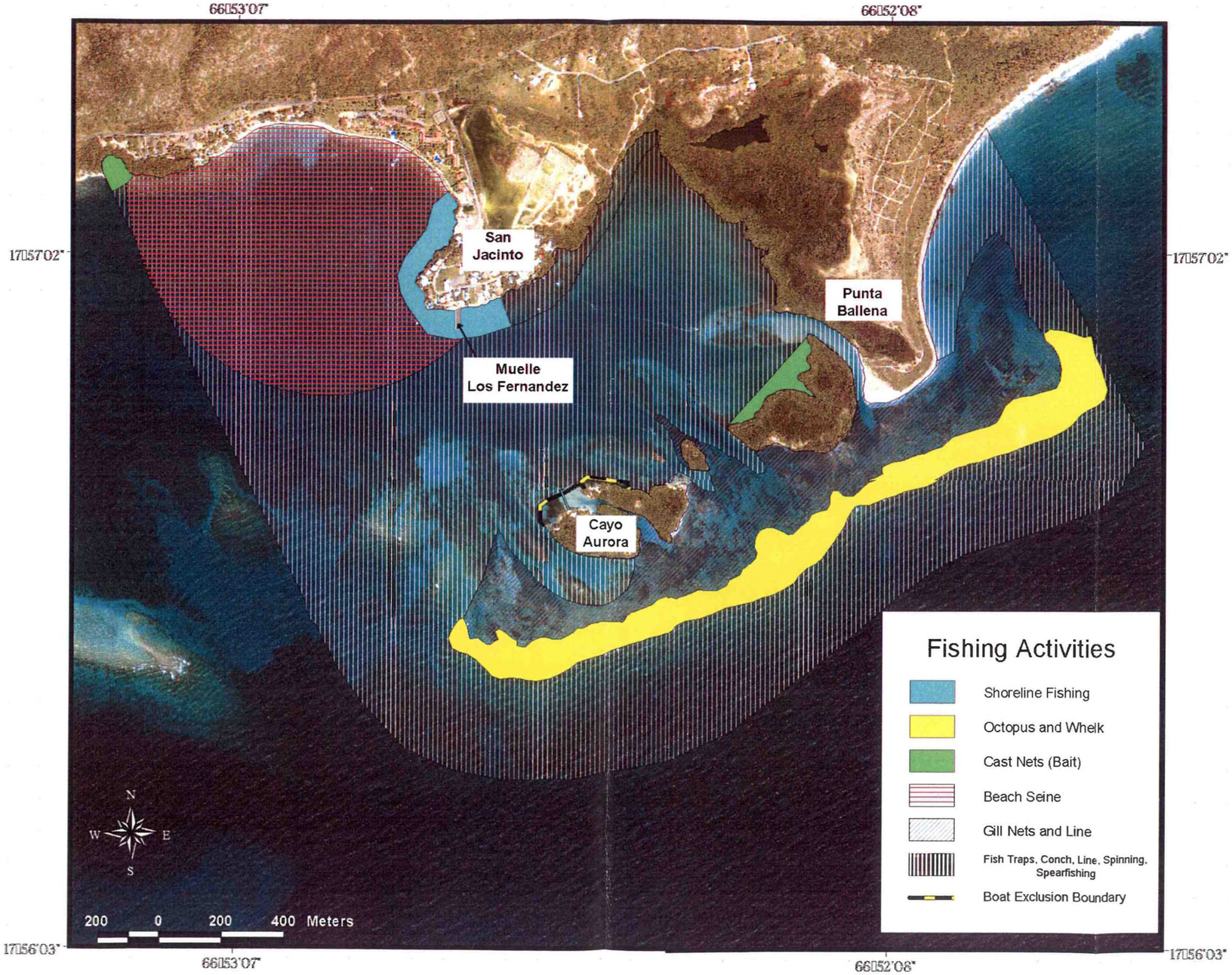

Figure 6. Map of current fishing activities in the area around San Jacinto, Cayo Aurora, and Punta Ballena, Guánica Natural Reserve.

is widely distributed within the mixed seagrass/macroalgal habitat off the coast of Copa Marina, San Jacinto and Punta Ballena towards the backreef of Cayos de Caña Gorda (Figure 6). This is also an area of commercial fishing targeting trunkfish, jacks and lane snapper using fish traps. There are between 15 – 20 traps with marker buoys fishing in this area, as well as some that fish without markers within Cayo Aurora's backreef.

The mixed seagrass/macroalgae basin west of San Jacinto is intensely fished with large beach seines and gillnets. Baitfish (mostly sardines, *Harengula* spp.) are caught with surface gillnets and cast nets in shallow areas to the west of Punta Ballena and to the west of Copa Marina Hotel. DNER reports that approximately a dozen fishermen catch octopus with hand gaffs and gather whelk (*Cittarium pica*) in the intertidal zone of the reef flat at Cayo Aurora. The backreef of Cayo Aurora is also fished with gillnets that capture a multi-species assemblage of fish that include yellowtail, schoolmaster, grey and mutton snappers, trunkfishes, parrotfishes, jacks, grunts, barracuda, and others.

The octopus and whelk fisheries are conducted by fishermen walking on the reef and searching for hiding places, which causes mechanical damage to corals and other living reef biota. This activity and other commercial and recreational fishing in Cayo Aurora's backreef are in conflict with the utilization of this habitat for passive recreational activities, such as bathing, swimming and snorkeling. Although not observed during our field survey, DNER personnel report massive mortalities of juvenile fish and invertebrates as by-catch with possible degradation of seagrass habitat caused by large-scale seine net fisheries set off the Copa Marina Hotel beach and San Jacinto.

4.0 CONCLUSIONS

1) The areas surrounding San Jacinto, Cayo Aurora, and Punta Ballena in Guánica Natural Reserve, contain coral reefs, seagrass beds, and red mangrove habitats of high ecological and socioeconomic value. Due to intense utilization by recreational and commercial stakeholders, these habitats are under considerable stress and require the implementation of conservation measures.

2) High speed boating in the basin between Punta Jacinto, Punta Ballena and Cayos de Caña Gorda represents a threat to the health of several threatened and endangered species in this are, including the Caribbean manatee, hawksbill and green sea turtles, brown pelicans, and bottlenose dolphins. It is also in direct conflict with utilization of this zone for queen conch and finfish fisheries, and threatens the safety of other recreational activities, such as wind and kite surfing. Wakes generated by vessels operating at high speed can resuspend fine sediments, creating turbidity which adversely affects seagrass growth and benthic communtities. High speed boating also contributes to vessels groundings within the reserve.

3) There are significant impacts to benthic communities associated with commercial and recreational activities in and around Cayo Aurora. These include: mechanical damage to live corals caused by octopus and whelk fishermen walking on the reef; damage to corals from abandoned fishing gear and debris; cutting of mangrove vegetation by visitors to increase beach space; extensive propeller damage to seagrass beds near Punta Ballena and potential anchoring damage to corals and seagrass during periods of peak recreational activity, when available mooring facilities provided by DNER are fully occupied.

4) Coral reef habitats on the windward side of Cayos de Caña Gorda, including the elkhorn coral biotope, colonized pavement habitat, and the shelf-edge reef appear to be healthy and growing. Massive coral bleaching and disease was not observed during this survey. Shallow reefs on the leeward side of Cayo Aurora, including the reef flat and the finger coral biotope showed signs of stress (partial bleaching)

induced by mechanical damage (breakage) and shading from an abandoned cargo net.

5.0 RECOMMENDATIONS

The proposed modifications to the present facilities and recreational activities at Cayos de Caña Gorda and San Jacinto include: installation of mooring buoys; expansion of signage demarcating shallow seagrass areas and speed limits; reforestation of fringing red mangrove habitats; closed fishing areas; designations of marine area as of high ecological value; educational exhibits; and recommendations for increased DNER support personnel during peak recreational activity (see Figure 7):

1) Installation of mooring buoys:
    a. Six mooring buoys are proposed for protection of the seagrass at the eastern backreef section of Cayos de Caña Gorda (adjacent to Punta Ballena) (Figure 7).
    b. An additional mooring buoy is proposed for protection of the coral reef at the west end of Cayo Aurora, where SCUBA diving boats anchor (Figure 7).

2) Speed limit markers: buoys would mark shallow areas which occur along major boating routes in the study area, as well as the entrance to the study area from the west. A total of 11 speed limit buoys (5 mph) are proposed; three (3) fringing the San Jacinto western shoreline; three (3) along the route from Punta Jacinto to Cayo Aurora; two (2) along the eastern San Jacinto shoreline; one (1) at the entrance of Punta Ballena's channel; one (1) near the center of the basin between Punta Jacinto, Punta Ballena and Cayo Aurora; and one (1) in the shallow seagrass northeast of Cayo Aurora (Figure 7).

3) Shallow seagrass markers: buoys would mark shallow seagrass areas which occur along major boating routes. A total of 9 shallow seagrass buoys are proposed; six (6) fringing the San Jacinto shoreline; one (1) at the entrance of Punta Ballena's channel; one (1) near the center of the basin between Punta

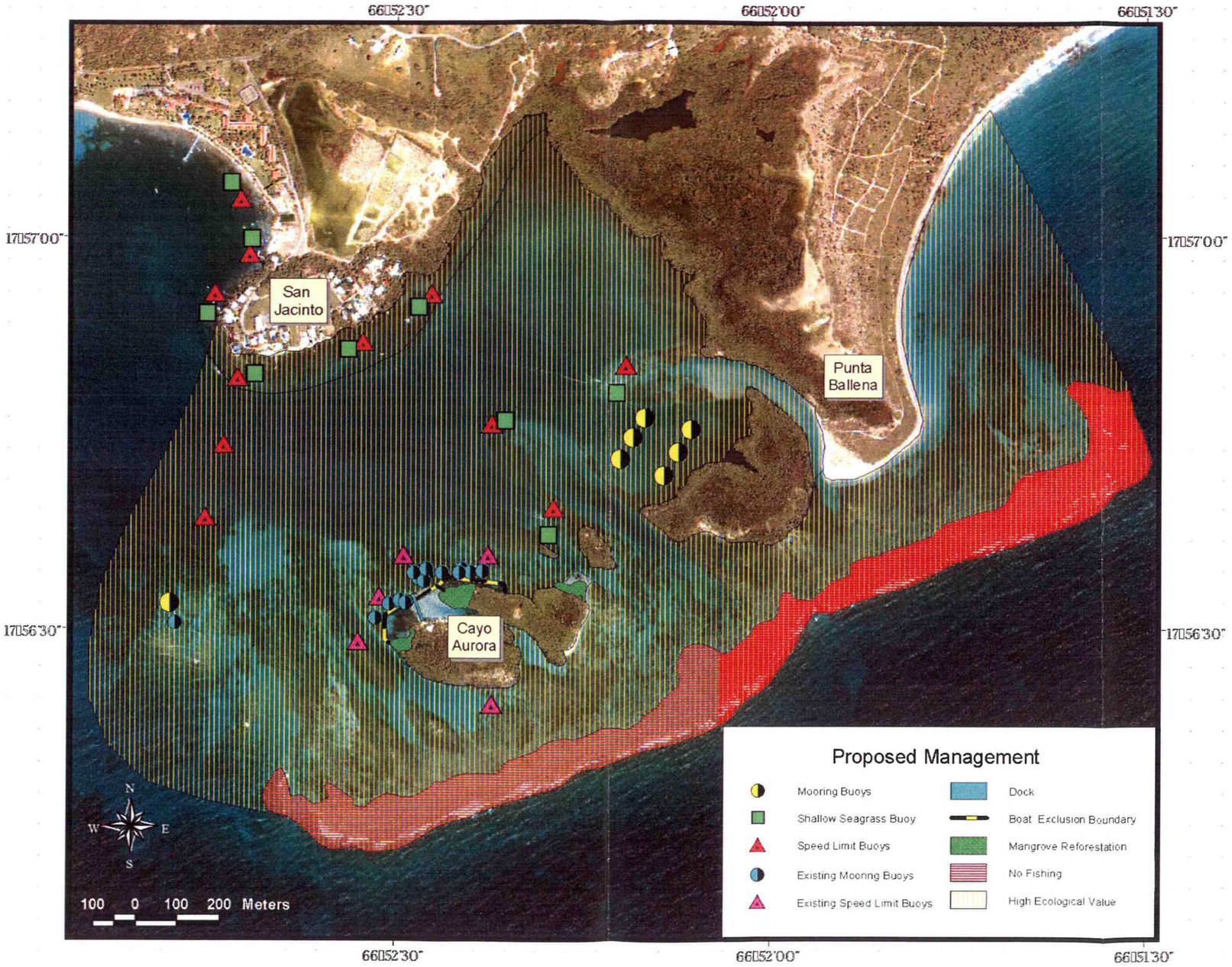

Figure 7. Map of proposed management alternatives for the study area, Guánica Natural Reserve.

Jacinto, Punta Ballena and Cayo Aurora; and one (1) in the shallow seagrass northeast of Cayo Aurora (Figure 7).

4) Area Designation: designation of the marine basin between Punta Jacinto, Punta Ballena and Cayos de Caña Gorda (Figure 7) as an area of high ecological value. This area is a natural habitat for threatened and endangered species including the Caribbean manatee, hawksbill and green sea turtles, brown pelicans, and bottlenose dolphins. This area is also an important habitat for queen conch, mutton and lane snappers, trunkfishes, mackerel, and other fish species of high commercial and recreational value. Impacts to benthic habitats in this area from high speed boating and other activities could impact the health of these populations. The Navigation and Aquatic Security Law of Puerto Rico (Law 430, Article 35, Section 22) states that "no vessel should exceed a speed of five knots in areas that have been designated as habitats of high ecological value or ecologically sensitive". This designation would greatly reduce the impacts of boating on benthic habitats in this area, and would effectively close the area to jet skis, which are particularly disruptive to wildlife. Other benefits of this designation would be a greatly reduced risk of vessel groundings and collisions with manatees and sea turtles.

5) Closed Fishing Area: closure of the reef flat area to the octopus and whelk fisheries. This would protect corals and other associated biota on the reef flat from trampling and breakage currently caused by these fisheries. Signage would likely be required in this area, and outreach to the subsistence fishing community would assist in this effort.

6) Mangrove Reforestation: reforestation of red mangroves at the eastern and western corners of Cayo Aurora (Figure 7) in order to reverse the loss of mangrove habitat due to illegal cutting of the trees by visitors. Red mangrove seedlings planted near the dock to restore habitat damaged by Hurricane Ivan are growing well. Mangrove reforestation efforts should be carefully monitored to assess their success and the potential need to close some areas to visitors in order to assist restoration efforts.

7) DNER Personnel: increase DNER administrative and surveillance personnel at Cayo Aurora during the mid-spring to summer months (April through August), when peak recreational activity occurs. Additional personnel could be tasked to remove trash and debris, particularly after long weekends.

8) Educational Exhibits: prepare educational exhibits descriptive of the marine habitats present at Cayos de Caña Gorda and associated marine communities. For example, posters describing the marine communities associated with coral reefs, seagrass beds and submerged mangrove roots habitats are already available from the Sea Grant Program at UPR and can be mounted in glass or acrylic and presented to the public at the Visitor's Center in the reserve, at the ferry facilities in San Jacinto, Punta Ballena and Cayo Aurora. Educational signs must include aerial photos or maps indicating the location of markers and buoys. General information about Guánica's State Forest and Biosphere designations should also be included as part of the educational exhibits.

9) Outreach activities aimed at increasing public awareness of the ecological and socio-economic value of the Guánica State Forest and Biosphere Reserve should be organized and held at the reserve visitor's center. Activities may include scientific presentations adapted for the general public, as well as briefings of the management strategies and proposed regulations for preservation of the resources in question. The activities should be open for the general public and the principal stakeholders should be invited.

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