**Final Report**

**Contract Number 2006-000951**

**Task CRI-10 Conservation and Management of Puerto Rico's Coral Reefs**
**Award Number NA04NOS4190112**

# Characterization of Mechanical Damage to Seagrass Beds in La Cordillera Reefs Natural Reserve

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## Introduction

*Importance of Seagrasses*

Worldwide, there are approximately 50 species of seagrasses. Hemminga and Duarte (2000) report six species as occurring in the Caribbean region (Hemminga and Duarte, 2000) while Vicente (1992) reports 7 species for Puerto Rico, including *Thalassia testudinum* (turtle grass), *Halophila decipiens*, *H. baillonis* and *H. engelmannii* (paddle grasses), *Halodule beaudettei* (shoal grass), *Syringodium filiforme* (manatee grass), and *Ruppia maritima* (widgeon grass). The most common species found in shallow waters around Puerto Rico are *Syringodium filiforme*, *Thalassia testudinum* and *Halodule beaudettei*. The three species of *Halophila* found around the island are usually not abundant in shallow areas and are thus less frequently reported.

Constanza et al. (1997) state that seagrass/algal beds have twice the ecosystem service value, measured in thousands of dollars per hectare per year, as that of mangrove-saltmarsh complexes and five times the ecosystem service value of reefs. The primary production from seagrasses and epiphytes on their leaves is equal to or greater than that of cultivated terrestrial systems according to Duarte and Chiscano (1999). Dawes (1986) reported the productivity of the turtle grass community to be approximately that of a coral reef community and similar to cultivated herbaceous terrestrial areas.

Globally, seagrasses play an important role in maintaining productivity**,** as they are responsible for approximately 1% of total primary production and 15% of total carbon storage (Hemminga and Duarte, 2000). Biomass and primary productivity in seagrasses can be divided between above and below ground (AG and BG) components. A review by Duarte and Chiscano (1999) estimates the global average of AG/BG seagrass biomass and productivity as 224/237 grams dry weight per square meter (g dry wt/$m^2$) and 3.84/1.21 g dry wt/$m^2$ per day, respectively. For the species found in Puerto Rico, Duarte and Chiscano (1999) reported that the average AG/BG biomass was approximately 250/500 g dry wt $m^{-2}$ for both *Thalassia* and *Syringodium* and 200/100 g dry wt $m^{-2}$ for *Halodule*. The AG/BG average productivity (g dry wt $m^{-2}$ $d^{-1}$) for *Thalassia*, *Syringodium and Halodule* were approximately 3.5/2, 3/2, and 7/1, respectively. These biomass and productivity measurements demonstrate that belowground biomass for turtle and manatee grass is higher than the global average, while AG productivity is similar to the global average for these two species. For shoal grass, the measurements demonstrate its capacity for high AG productivity although its BG productivity was lower than the global average, probably due to the limited development of its rhizome system. In La Parguera, Puerto Rico, Gonzalez (1979) found that the AG productivity of turtle grass ranged from 2-7 g dry wt/$m^2$ per day with an average of 5, again indicating the high productivity of the local system. In addition to the productivity of the grasses, the productivity of other components of seagrass meadows may be more than 20-60% of total production (Hemminga and Duarte, 2000). For instance, epiphytes in *Halodule* stands may be more productive than the grass, possibly accounting for the high AG productivity measurements in the review by Duarte and Chiscano (1999).

The importance of seagrasses in the marine food webs is greater than the extension of their beds. Material from seagrass beds is exported to areas very distant from the beds and often to deep waters as dissolved and particulate material. Leaves of manatee grass, and to a lesser extent turtle grass, have been observed in depths of thousands of meters. Seagrass leaves have been photographed on sediments in the Puerto Rico trench at depths of 7,860m (Webber and Thurman, 1991). At these depths, this material is an important part of the diet of organisms such as echinoderms. Furthermore, accumulation of seagrass wracks on beaches provide significant amounts of nutrients to local biota generating additional production while influencing shore geomorphology by trapping and binding loose sand particles (Hemminga and Duarte, 2000)

Within the beds themselves, organisms such as the green sea turtle, which is a federally protected threatened species in the U.S. Caribbean, feed on seagrass leaves and algae. Tidal embayments containing seagrass beds are important habitat for juvenile green sea turtles in the Caribbean (Musick and Limpus, 1997) that feed on the grasses, as well as on jellyfish and sponges. Similarly, juvenile hawksbill sea turtles frequent estuarine habitats although their feeding preference is for sponges on red mangrove roots rather than seagrass (Musick and Limpus, 1997). In the Caribbean, research indicates that turtle grass dominates the diet of adult green sea turtles, probably because it is the most abundant seagrass. However, manatee grass, shoal grass, and paddle grass were also found in the stomachs of foraging turtles, as were red and green algal species and one species of sponge (Bjorndal, 1997). Adult hawksbills have also been found to consume marine plants, including algae and seagrasses, although sponges dominate the diet of these sea turtles in the Caribbean (Bjorndal, 1997).

In terms of the utilization of materials within seagrass beds, Zimmerman et al. (1979) studied feeding and assimilation of vegetation in a Florida seagrass community by 4 gammaridean amphipods. In general, feeding was equally distributed between seagrass debris and drift algae and epiphytes. Zimmerman et al. (1979) concluded that 41-75% of the carbon assimilated by the amphipods was derived from seagrass epiphytes while 11-24% from drift algae and seagrass debris. Similarly, Hemminga and Duarte (2000) found that gastropod grazing on algae and bacteria growing on seagrass leaves led to the consumption of 20-62% of the net production of these epibionts. In the reef flat, the consumption of epibionts and seagrass was similar in proportion. In addition to direct consumption of seagrass and attached organisms, herbivory results in the transport of nutrients to other locations in the reef ecosystem (Hemminga and Duarte, 2000). Thus the proximity of seagrass beds to other marine systems, such as mangroves and reefs, facilitates trophic transfers and cross-habitat utilization by fishes and invertebrates (Orth, et al. 2007).

The role of seagrass habitats as dominant producers in tropical and subtropical systems enables the development of a rich community of organisms. Garcia-Rios (2001) illustrates the numerous groups of organisms associated with seagrass, including coelenterates, bryozoans, ciliates, flagellates, sarcodines, foraminifera, crustaceans, fishes, echinoderms, mollusks, and algae. *Thalassia* beds in Jamaica were found to be populated by a variety of macrofaunal species, including polychaetes (20), crustaceans

(39), mollusks (61), fishes (41), and others (40) (Greenway, 1995; in Hemminga and Duarte, 2000). Studies of the population biology of decapods in seagrass beds in Dorado, Puerto Rico (Bauer, 1985a,b,c) suggest diversities similar to those found in the Jamaica study as 34 crustaceans species, including shrimp and hermit crabs, reaching densities of 72 ind/$m^2$, were found.

Additionally, seagrasses provide habitat for numerous highly mobile species. Berrios et al. (1985) performed visual observations of fish populations in seagrass beds dominated by turtle grass and coral reefs in Cayos Berbería and Ratones off the coast of Ponce, Puerto Rico. They found approximately 29 species of juvenile fishes in large numbers, including grunts, parrotfish, and yellowtail snappers. They also found young adults of bluestriped grunt (*Haemulon sciurus*), gray snapper (*Lutjanus griseus*), and schoolmaster (*L. apodus*) to be common in seagrass beds around Cayo Berbería. Adult grunts and snappers were also very common in both reef environments, which Berrios et al. (1985) attributed to the presence of seagrass beds in both reefs. Similarly, Aguilar-Perera (2004) evidenced the importance of seagrasses in La Parguera Natural Reserve as habitat for juvenile populations of species of commercial importance such as grunts and snappers. Jenkins and Hamer (2001) found a relationship between the abundance of post settlement fish and meiofaunal crustaceans in seagrass beds. Due to the greater abundance of prey items in seagrass beds in comparison to bare sandy sediments, post settlement fish were more abundant in seagrass beds.

Additionally, studies of juvenile spiny lobsters in the Baja Peninsula (Castaneda-Fernandez de Lara et al., 2005) indicate that the structural complexity of seagrass beds enables *Panulirus sp*. juveniles to use these areas for refuge. The base of the seagrass *Phyllospadix* was where 96% of these individuals were found. Acosta (1999) found that juvenile and adult spiny lobsters were more abundant around coral cays surrounded by seagrass beds than around cays surrounded by rubble. Stomach content analysis of adult spiny lobsters (*Panulirus argus*), observed during nocturnal foraging in seagrasses in reefs in Florida, indicated gastropods found in seagrasses and rubble areas were part of the lobsters' preferred diet (Cox et al. 1997). In shallow seagrass habitats in La Parguera, Otero (per comm) observed a sharptail eel hunting prey associated with the base of *Thalassia* stalks illustrating the importance of seagrass bed structure in supporting biodiversity and trophic interactions.

The complex trophic interactions within seagrasss communities are paramount in sustaining juvenile and adult populations of special interest, including commercially important fishery and protected species. However, because the contribution of any particular seagrass species (evenness) is low within a seagrass bed and associated fauna and algae contribute most of the diversity of seagrass habitats, observers are often wrongly inclined to think seagrass habitats do not sustain significant biodiversity (Hemminga and Duarte, 2000). Because the fauna of seagrass beds is cryptic and the grasses themselves are not as evident as coral reefs, for example, Orth et al. (2007) estimate that the publicity given to seagrasses is 10 to 100 times less than that given to other coastal habitats. This lack of awareness of the importance of seagrass beds on the part of the general public, resource agencies, and lawmakers may explain the lack of protection afforded to this essential habitat.

The underestimation of the extent of seagrass habitats often results in lesser protection to these important communities. The proper definition of the extent of seagrass habitat is confounded by various factors, including temporal changes that may be a function of season, changes in light penetration, wave energy, and direct human disturbances such as dredging, propeller wash and scars, and anchoring (Fonseca et al, 1998). In addition, seagrasses frequently grow in patches of variable morphology and distribution. Species such as *Halophila* rely on seedbanks (seed accumulation in bottom sediments) to maintain their populations. Thus, evaluation of seagrass habitats may result in underestimation of the extent of coverage at times of the year when aboveground growth is not evident or when the adult plants have disappeared due to disturbance events. Considering only the areas covered by seagrass plants as seagrass habitat results in considerable error and underestimation of habitat extent due in part to the dynamism of seagrass growth (bare areas today may sustain seagrass growth later) and because patchy seagrass habitats may be as productive as areas with continuous beds. Juvenile queen conch, for instance, requires a balance between seagrass beds and sandy areas as feeding and refuge habitat. The Caribbean Fishery Management Council (2004) states that the degradation and loss of patchy seagrass habitat, essential for the settlement and development of juvenile conch, may be one of the reasons the species is considered overfished, as a reduction in juvenile habitat results in a loss of productivity. Overall, the proper definition of the extent of seagrass habitats should recognize the variability of seagrass coverage, the reproductive needs of the grasses (vegetative and sexual), and the historical record related to seagrass presence in an area. Estimates of seagrass habitat coverage based on one-time observations will probably result in underestimates.

*Disturbance of Seagrass Habitats*

Godfrey and Wooten (1979) state, “It is held that in the web of life where eelgrass is abundant, it serves as a friction filter for silts and pollutants. In its absence, where waters are silt-laden and polluted, the silts, sewage and other wastes seep out of the river mouths unimpeded wiping out marine life." The epidemic of a fungal disease, known as wasting disease, between 1931 and 1933 resulted in the loss of 90-95% of the eelgrass meadows along the east coast of the U.S. The widespread elimination of eelgrass beds reduced the populations of animals that depended on the beds for food or refuge (Godfrey and Wooten, 1979; Webber and Thurman, 1991). Numbers of geese populations that feed almost exclusively on eelgrass during annual migrations, such as the Canada goose whose populations decreased by 80% in affected areas, also declined (Webber and Thurman, 1991). Thus, it is evident that maintaining healthy seagrass habitats should be a priority to environmental management agencies as they interact in diverse ways with their environment and associated biota.

Seagrasses stabilize the sediments where they grow and act as baffles to slow water movement from waves and currents. The trapping of suspended material by the network of seagrass roots and rhizomes decreases surface erosion (Webber and Thurman, 1991). Significant decreases in seagrass cover can increase the transportation and spatial extent of turbidity plumes, nutrients, and pollutants from terrigenous or coastal sources to the marine environment, resulting in impacts to sensitive organisms such as reef building corals (Godfrey and Wooten, 1979). In fact, many invertebrate populations not directly connected with eelgrass beds declined following the mentioned eelgrass die-off (Webber and Thurman, 1991) possibly due to increased sediments in the water column.

Environmental change such as sea level rise, exacerbated by increased human pressures on coastal systems, leads to decreases in seagrass cover (Orth et al., 2007). For instance, coastal hardening by means of breakwaters prevents the landward migration of grasses as sea level rises. Coastal development, the related increase in marinas, docks and vessels, and inappropriate anchorage practices by boaters, leads to seagrass habitat loss and fragmentation. The increase in waterfront and recreational development, and concomitant increases in the number, size, and power of vessels resulted in widespread scarring of shallow seagrass beds in Florida (Sargent et al., 1995). Durako et al. (1992) found the greatest damage from propeller scars in the passes connecting backwaters within Tampa Bay. Sargent et al. (1995) found the scarring rates in Tampa Bay to be some of the worst in the state with severe scarring averaging nearly 30% of the total seagrass coverage. Francour et al. (1999) studied the effects of boat anchoring in *Posidonia* beds in the Mediterranean and found that the degree of meadow fragmentation was related to anchoring pressure. These losses of seagrass habitat can lead to declines in water quality, in particular due to increases in suspended sediments in the water column.

In a survey of approximately 5,700 hectares of seagrass beds in the Corpus Christi Bay National Estuary along the Texas Coast, Dunton and Schonberg (2002) found moderate and severe scarring of seagrass beds (23-49%) in three areas known to be popular with recreational boaters or in close proximity to densely populated zones, including residential waterfront properties. Overall, 97% of this area was scarred with 75% rated as severe. In other areas, total scarring as a proportion of seagrass present was less than 20% with moderate to severe scarring accounting for 15% or less (Dunton and Schonberg, 2002). The observations of Dunton and Schonberg (2002) agree with those of Sargent et al. (1995) in Florida and indicate that scarring is related to misjudgment by boaters, shortcuts through shallow grassbeds, and ignorance on the part of boaters related to the damage their actions cause and the importance of seagrass. Dunton and Schonberg (2002) also noted that heavy scarring may also reflect differences in the recovery of different species of seagrass. For instance, areas dominated by turtle grass, which doesn't recolonize rapidly, will remain bare longer in comparison to areas dominated by fast-growing species like *Halodule*.

In Puerto Rico, Gonzalez-Liboy (1979) found propeller scarring in areas associated with channels between mangrove cays in La Parguera. Gonzalez-Liboy (1979) reported intense impacts to seagrasses in the channel near Magueyes Island that caused significant patchiness of seagrass beds in this area. More recently, Carrubba et al. (2003) documented major propeller scar impacts in various locations in La Parguera Reserve, including shallows near Magueyes Island, Cayo Caracoles and Cayo Collado backreefs where 43-74% of the area potentially affected by boat traffic showed damage due to propeller scarring.

The loss of seagrass habitat affects the marine community. Sargent et al. (1995) speculated that the location and species composition of seagrass beds in Florida are probably the principal determinants of the kind of animal habitat lost. In La Parguera, Puerto Rico, Uhrin (2001) and Uhrin and Holmquist (2003) found lower mollusk and shrimp abundance and fewer species within propeller scars, although the impacts to the seagrass community at a larger scale were not determined. The total number of fauna in scars was approximately 75 ind/$m^2$, while 200-275 ind/$m^2$ were found in reference sites without scars. The density of mollusks and crabs remained low up to 5 m from the scar relative to non-scarred sites and the dominant shrimp species differed within scars versus outside scars (Uhrin, 2001; Uhrin and Holmquist, 2003). Eckrich and Holmquist (2000) measured the effects of trampling on seagrass beds dominated by *Thalassia testudinum* in La Parguera and found that trampling could decrease seagrass cover, especially in soft bottom communities, and that the abundance of one shrimp species declined moderately. Uhrin and Holmquist (2003) did not find differences in fish abundance within scars versus outside scars, probably due to the mobility of fish. Similarly, Burfeind and Stunz (2005) did not find significant changes in nekton during a study in the Aransas Bay complex where *Halodule beaudettei* is the dominant species. Burfeind and Stunz (2005) concluded that, since the species they studied are highly mobile, the effects of propeller scarring on the faunal community of seagrass beds could have been confounded by the choice of organisms studied. Bell et al. (2002) concluded that high levels of scarring that lead to the degeneration of seagrass bed stability may need to be present before nekton are affected. However, Bell et al. (2002) did find that one shrimp species composed a relatively higher proportion of the shrimp community in scarred sites in Tampa Bay versus non-scarred reference sites.

Seagrass recovery from scarring depends on factors such as sediment composition, water quality, current velocity, wave and wind energy, drift algae, scar depth, seagrass species, water depth, and latitude (Sargent et al., 1995). Durako et al. (1992) estimated that shoal and turtle grass would take up to 2 and 6 years, respectively, to reach normal shoot density after suffering scarring. Dawes et al. (1997) stated that the slow regrowth of *Thalassia testudinum* in propeller scars was the result of no incrementation in shoot productivity and the limited production of rhizome apical meristems. Recovery rates were estimated as 2-5 years in the Florida Keys and 3.6-6.4 years in Tampa Bay (Dawes et al., 1997). Rhizomes damaged by propellers had fewer apical meristems, on which regrowth of affected seagrass depend, than undisturbed rhizomes (Dawes et al., 1997).

*Management of Seagrass Beds*

Orth et al. (2007) noted that the installation of aids to navigation/special markers, improved enforcement, and limiting access to navigation in shallow areas are essential strategies to control impacts to seagrass habitats given the importance of seagrass beds, the lack of knowledge regarding this habitat, and the proliferation of impacts to seagrasses related to human development in coastal areas. In Texas, a regulation prohibiting destruction or uprooting of seagrasses in the Redfish Bay State Scientific Area has been in effect since May 2006 in response to studies documenting the damage caused by recreational boaters (Reed, 2006). Similarly, in Cockroach Bay State Aquatic Preserve, Tampa Bay, Fl., a ban on commercial net fishing was enacted following studies demonstrating that fishing boats and nets dragging on the marine bottom were causing damages to seagrass beds dominated by turtle grass (Dawes et al., 1997). Dawes et al. (1997) noted that studies following the ban showed that propeller scarring had essentially ended in the Preserve indicating that motor boat restrictions would continue to prevent long-term losses of turtle grass and allow it to recover.

In Pinellas County, Florida, the local government has been concerned with seagrass scarring and cumulative effects of boat damage to seagrass beds since the mid-to-late 1980s (Stowers et al., 2001). In 1990, the County began a series of initiatives and involved a coalition of regulatory and citizen representatives in order to establish an ordinance to protect seagrass resources (Stowers et al., 2001). As part of these efforts, the Fort DeSoto Wetland and Aquatic Management Area was divided into zones including: exclusion zones where the use of internal combustion engines was prohibited; caution zones where motorized vessels were allowed but penalties were established for damage to seagrass; areas where idle speed was required in order to protect exclusion zones while enabling boaters to access features such as campsites; and control areas with no protection. The rate at which new scars were found to occur remained constant, despite a large increase in boat use, due to the implementation of exclusion zones, in combination with an extensive public relations campaign and the installation of signs in local marinas (Stowers et al, 2001). Continued studies of use and mechanical damage to seagrass beds from boats led the County to add the Weedon Island Preserve to the protected area in 1996; some of the exclusion zones were redesignated as caution zones based on findings that the zones were equally effective in protecting seagrass; and additional seagrass areas were afforded protection in 2000. Overall, Stowers et al. (2001) concluded that the most important factor to ensure the success of protective ordinances is a proactive public information campaign. Dunton and Schonberg (2002) made a similar recommendation following their study of seagrass damage in beds on the south Texas coast. Dunton and Schonberg (2002) found that increases in population corresponded to increases in severe damage to seagrass beds, in particular in areas where boaters are unfamiliar with navigation routes and secondary channels are not clearly marked. They recommended that state resource managers make an effort to improve marking, in particular of secondary channels, as well as improving enforcement. However, they noted that these efforts will be unsuccessful unless an education campaign is implemented to inform temporary and permanent residents and visitors of regulations protecting seagrass beds, their importance, and the use of signage and navigational aids to avoid damaging marine habitats.

In Puerto Rico, Law 430 of 2000, the Navigation and Aquatic Safety Law, and its associated Regulation 6979 of 2005, establish measures to protect the marine flora and fauna from recreational and other human activities. For instance, Article 24 of Regulation 6979 prohibits the mooring of any vessel in mangroves, coral reefs, or seagrass beds. The fine for violating this regulation is $250 that can be issued in the form of a ticket by any enforcement official (Article 35). Similarly, Law 147 of 1999 for the protection, conservation, and management of coral reefs prohibits the removal, mutilation, or destruction of coral reefs and associated systems, including mangroves. Violations of this law can result in an administrative fine between $500 and $10,000 per infraction. However, a lack of enforcement and a serious lack of understanding on the part of the general public as well as regulatory and enforcement agencies regarding the importance of seagrass beds has resulted in increases in seagrass damages despite the existence of laws and regulations for their protection.

**Purpose/Objectives**

The purpose of this study was to determine the extent of mechanical damage from boating activity within La Cordillera Reefs Natural Reserve. The objectives of this effort were to:

- Determine the intensity of impact of boat traffic and priorities for management of boat traffic that will permit minimization of propeller scarring and anchor damage;
- Provide a baseline in terms of the level of damage in specific seagrass beds at a point in time for assessment of anchor and propeller scar progression or healing of seagrass communities;
- Estimate anthropogenic disturbance to seagrass beds that can be used by regulatory agencies in support of mitigation efforts;
- Enhance existing GIS coverage and create new maps; and
- Serve as an additional test of the approach used to quantify anthropogenic impacts to seagrass beds and to verify (sea-truth) seagrass extensions previously used in Parguera and Guánica adapted from Sargent et al (1995).

**Study Area**

La Cordillera Reefs Natural Reserve consists of geologic formations oriented in a general northwest-southeast direction. The formations include Las Cucarachas, Los Farallones, Cayo Icacos, Cayo Ratones, Cayo Lobos, La Blanquilla, Cayo Diablo, Arrecife de los Hermanos, Arrecife de los Barriles, Palomino, and Palominito. On January 2, 1980, the third extension to the Puerto Rico Planning Board Resolution JP PU-002 designated the area as a natural reserve. However, the land area above the maritime terrestrial zone of Palomino, Palominito and Cayo Lobos is private. The Reserve is composed of a chain of cays, rock formations, coral reefs, and extensive seagrass beds. Some of the cays have lagoons that provide habitat for organisms such as fiddler crabs and seabirds. Fieldwork for this report was realized at Palomino, Palominito, Icacos, Lobos, Diablo, and La Blanquilla, as these are the cays visited by recreational boaters, divers, and tourists (Figure 1).

Cabezas de San Juan Natural Reserve, which was designated January 29, 1986, through the eighth extension to the Puerto Rico Planning Board Resolution PU-002, is managed by the Puerto Rico Conservation Trust. The Trust acquired the lands in 1975 from the Department of Natural Resources and began managing them as a reserve. In 1998, the limits of the Reserve were extended to 9 nautical miles from the coast. Marine habitats inside the Reserve include coastal lagoons, seagrass beds, salt flats, and coral reefs. Seagrass beds along the coast in Las Cabezas Bay (Ensenada Yegua), in the area from the entrance to the Reserve up to the area of Laguna Grande adjacent to the beach, were also surveyed due to the popularity of this beach and the use of the area by jet skis in the past (Figure 1).

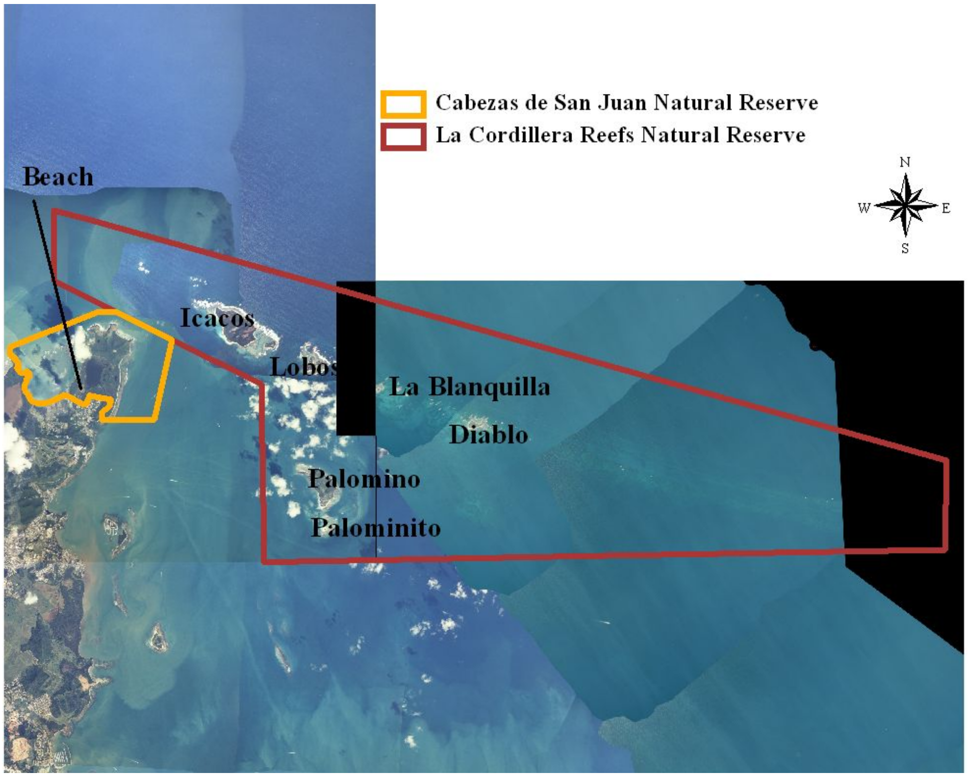


Figure 1. Boundaries of La Cordillera Reefs Natural Reserve indicating areas where seagrass surveys were conducted, as well as surveys for acroporid corals which are discussed in the field report. The boundaries of Las Cabezas de San Juan are also shown, as well as the beach area where seagrasses were surveyed. Note that no aerial photos are available from NOAA or DNER covering the entire reserve area.

## Methods

In general, the work consisted of aerial and field surveys and GIS mapping of impacts of boats on seagrasses. Using the information obtained during field surveys and mapped in the GIS, probable and potential impacted areas were estimated. The description of the aerial and field survey can be found in the Field Report (Appendix A). The description of the final step of this work, estimation of probable and potential impact areas was not reported previously, therefore it is described below. A brief description of how field data were collected is included for the benefit of the reader, but for detailed field methods the reader is referred to Appendix A. In addition to the survey of seagrass damage, the locations of acroporid coral colonies in the area of Cayo Lobos, Cayo Diablo, La Blanquilla, and Palomino/Palominito were marked in the field and later mapped in the GIS. For a detailed description of the coral mapping, see the Field Report (Appendix A).

*Estimation of Probable and Potential Impact Areas*

The positions (latitude/longitude) of propeller and anchor scars and anchor drag were collected in areas shallower than 7 ft (2.3m) at Palomino, Palominito, and Cayo Icacos. All positions were recorded to 5 decimal places of a degree. Anchoring sites in deeper areas were documented when boats were observed at anchor during field surveys (see Field Report in Appendix A). Along propeller scars or anchor drags, GPS positions were collected and these were used to create lines in a GIS corresponding to the marks documented in the field. These lines were used to create a data layer of linear marks for each survey site. The length of the lines was calculated in meters in the GIS. Length was multiplied by 0.25 m, except in cases where the size of the scar was measured in the field, in order to calculate an area to be used in determining the extent of mechanical damage. Individual anchor scars were recorded as individual points and converted to a GIS layer for each survey site. The size of anchor scars was estimated as 1 $ft^2$ (0.09 $m^2$) except in cases where the size of anchor scars was measured in the field. In areas where intense boating impacts prevented the documentation of individual scars, polygons were marked in the field and the positions of these polygons were used to construct polygon layers in the GIS for each cay. The area of the polygons was calculated in the GIS for use in determining the extent of mechanical damage at each survey site. The total area of line, point, and polygon impacts was calculated for Palomino, Palominito, and Icacos in order to provide an estimate of total scar area for each site.

In addition to the line, point, and polygon data layers created in the GIS using survey data, two additional layers, the probable and potential impact areas, were produced in the GIS. The Probable Impact Area (PrIA) was estimated as the polygon or polygons encompassing all documented impacts at a particular survey site where it is highly probable that additional mechanical damages have occurred or will occur. The Potential Impact Area (PoIA) was estimated as the area in shallow waters (7 ft (2.3m) or less) containing seagrass beds or patches where boaters typically transit or anchor (per our observations in the field, the NOAA benthic map for Puerto Rico, and aerial survey photos) at each survey site. NavPak (Global Navigation Software) containing all the nautical charts and corresponding bathymetry for Puerto Rico in IHO S-57 std/NOAA ENC charts was used to determine the position of the PoIA using water depth. PrIA and PoIA were only calculated for La Cordillera Reserve. Finally, the NOAA benthic map plus the seagrass beds that were mapped during the field survey were used to estimate the total seagrass area within the reserve. Large polygons in the NOAA benthic map that extended beyond the Reserve boundaries were divided using the reserve boundary in the GIS. The reserve boundary shapefile used to mark the reserve borders was created by DNER and includes reserves and refuges around Puerto Rico.

## Results

*Aerial Survey*

The aerial survey did not reveal significant impacts to seagrass beds caused by propeller scarring within La Cordillera Reserve. Propeller scar impacts were only observed in shallow areas outside the reserve, for instance the entrance to Las Croabas, during the overflight. Aerial observations indicated the presence of extensive seagrass beds and patches in the zone of Icacos, Palominos and Palominitos, west and southwest of Cayo Diablo, south of La Blanquilla, and within the man-made cove northeast of Cayo Lobos. Figure 2 shows the cays within the Reserve and indicates areas where aerial photos were taken. Figure 3 contains the aerial photos taken during the overflight and numbered in Figure 2.

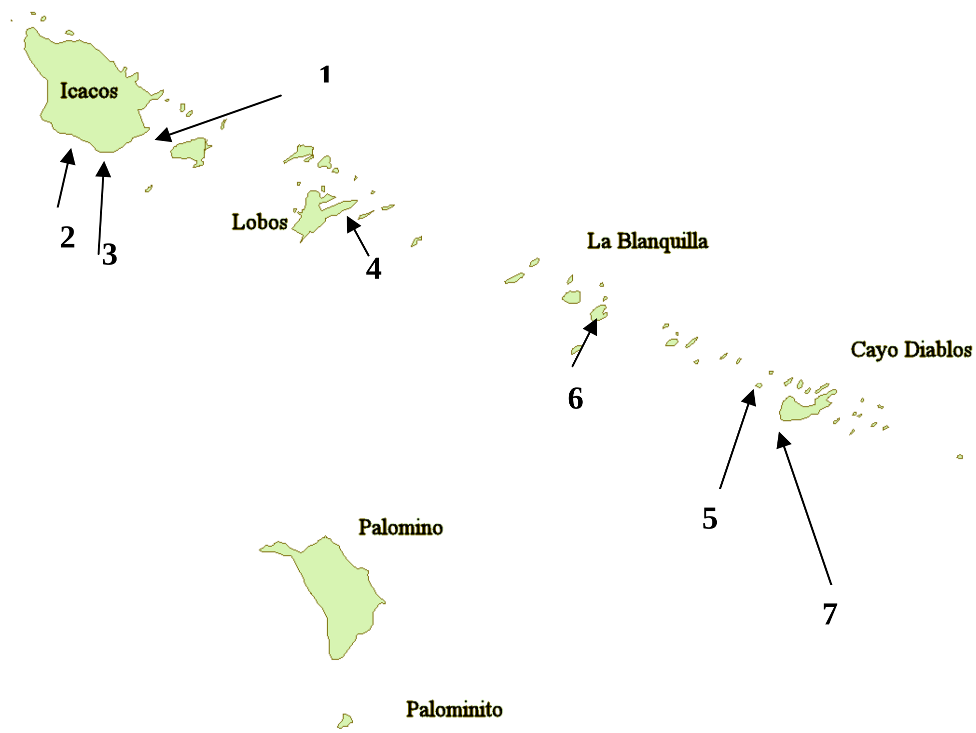


Figure 2. Map of the cays in La Cordillera Reserve with numbers and arrows designating where aerial photos were taken during the overflight.

*Field Survey*

For detailed information regarding survey results, see the field report (Appendix A). Briefly, boat-related impacts were found at Palomino, Palominito, and Cayo Icacos, although impacts of propeller scarring were minimal. Most of the impacts in shallow seagrass beds were in the form of anchor scars or other damage caused by anchoring practices such as propeller wash and anchor drag. The presence of the three most common species of seagrasses in Puerto Rico, *Thalassia testudinum*, *Syringodium filiforme* and *Halodule beaudettei*, was documented in shallow areas within the Reserve. Thick stands of *Halodule* and *Halodule* mixed with *Syringodium* were found in the shallows of western Palominito and to the northwest of Cayo Icacos. Anchor damage was found in each of these areas (Figure 4).

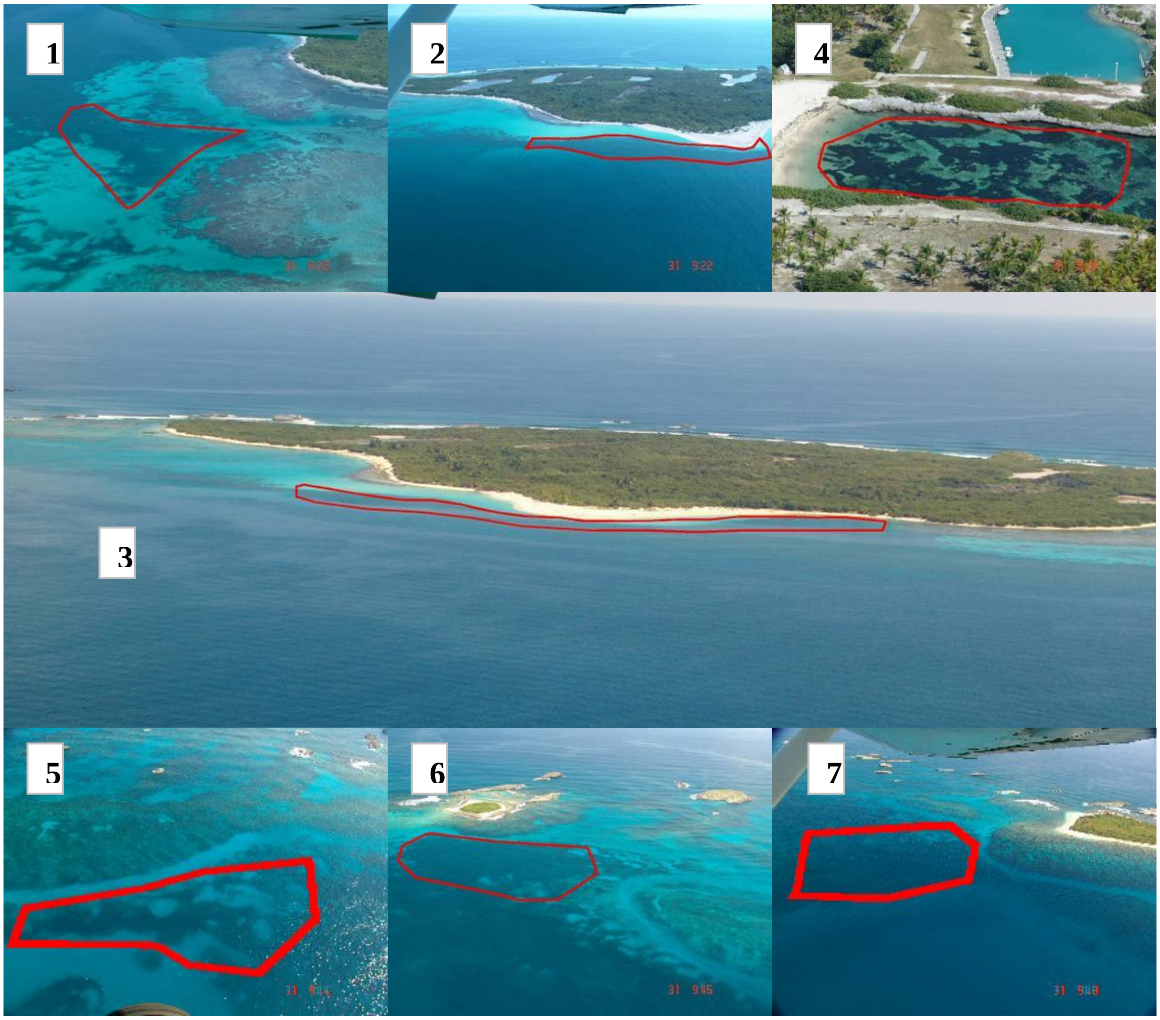


Figure 3. Photos taken during the aerial survey. The numbers correspond to those in Figure 2 indicating where the photos were taken.

*Thalassia* was, as expected, the dominant seagrass in the area. In both Palomino and Cayo Icacos, intense anchoring was determined to be the reason for damages observed in shallow areas during the field survey based on aerial photographs provided by Mr. Hector Horta, the Reserve Manager (DNER). The photographs were taken during overflights of the Reserve at the height of the boating season in the summer of 2006. Seagrass beds, in particular those dominated by *Thalassia*, contained blowouts characteristic of anchor damage adjacent to the sandy bottom area along the beach of Icacos. Damaged areas coincided with places visited by boaters during our field observations and DNER overflight photos. During the field survey of September 7, 2006, we also observed various sailboats anchoring in deeper water southwest of Icacos. A survey of the site corroborated the presence of anchor damage in seagrasses in the area. The unconsolidated nature of the sands at this site made it difficult to assess the number of old anchor scars. It was difficult to distinguish between natural blowouts and boat impacts as the latter may be appear as natural blowouts over time since the area is prone to heavy currents and wave action during storms. However, because only a few hours passed between the departure of the sailboats and our examination, impacts within the seagrass patches could be distinguished as anchor damage. A thorough survey was not performed as the site was deeper than the range of 7 ft (2.3 m) set for our survey.

Figure 4. Upper Left: Juvenile conch in *Halodule*/*Syringodium* bed in Palominito; Upper Right: anchor scar in *Halodule*-dominated seagrass bed in Palominito; Bottom: Giant hermit crab in *Halodule* bed in Icacos.

The greatest impacts to seagrasses were found in the area of Palomino. Apart from the shadow effect of the El Conquistador ferry dock, propeller wash damage in the form of large holes was evident in the area surrounding the dock. The location to which sediment resuspended during ferry operations at the dock was not determined. However, if sediments are not displaced towards adjacent seagrasses, the fine fraction may move towards adjacent reefs. Other impacts to seagrass habitats were observed in the nearshore area north of the El Conquistador dock. A large area of patchy seagrasses is present that contained numerous impacts in the form of anchor damage. During the survey, we observed a boat approach, deploy the bow anchor and drag it on the bottom until it grabbed and held. Based on DNER aerial photos during the summer of 2006 (Figure 5), this area receives dozens of boats of various sizes, which may explain the patchy distribution of seagrasses at this site. A final location where evidence of seagrass habitat disturbance was observed was the area where personal watercraft are trailered and launched at the southern tip of Palomino (Figure 5). Evidence of boat impacts was

Figure 5. (A.) Boats anchored north of the El Conquistador ferry dock, July 2006. (B.) Example of seagrass blowout probably caused by repeated anchoring in the area. (C.) Launching personal watercraft, Palomino. (D.) Blowouts associated with the site where personal watercraft are launched.

observed in seagrass beds of Palominito as well. These impacts were milder than those observed at Palomino but included propeller scars and anchor drags, in particular in an area dominated by *Halodule* (Figure 6) that was not on NOAA´s benthic maps. Few anchor scars were observed at Palominito.  However, in areas dominated by *Thalassia* between Palomino and Palominito, blowouts caused by anchoring were observed. During our survey of Palomino, a chartered sailboat was observed anchoring in deeper waters west of Palominito where *Thalassia* dominates. Although no direct observations were conducted during our survey as the site was outside the established depth limits of 7 ft (2.3 m), it is possible that fragmentation of seagrass beds is occurring if this site is frequently used as an anchorage area.

In addition to the seagrass impact survey, in cays where seagrass beds are found in deeper waters and anchoring of boats is not common, surveys of acroporid coral colonies were conducted in order to map locations of these corals. See the Field Report (Appendix A) for details of the survey as it was not part of the contract and is not reported in this Final Report for the Cordillera project. Briefly, the survey revealed that dense stands of elkhorn, staghorn, and fused staghorn coral once characterized the area from Cayo Lobos

Figure 6. Propeller scar in *Halodule* bed at Palominito (Left); Anchor scar in *Thalassia* bed between Palominito and Palominito (Right).

to Cayo Diablo and elkhorn coral in particular characterized the shallow reef area east and south of Palomino/Palominito. In the area from Cayo Lobos to Cayo Diablo, colonies of acroporid corals appear to be recolonizing and numerous young coral colonies were observed. In the area of Palomino/Palominito, staghorn coral colonies that were observed did not appear to be thriving but there were numerous colonies of elkhorn coral that appeared to be in good condition.

*Estimation of Probable and Potential Impact Areas*

Based on the NOAA benthic maps plus the two shoal grass dominated seagrass beds mapped at Icacos and Palominito during the field survey, the total acreage of seagrass within the Reserve is 3,197.67 acres. Of this, 314.35 acres of seagrass are found around Cayo Icacos and 411.85 acres around Palomino/Palominito, which were the cays where mechanical damage to seagrass beds caused by boating was observed. Based on estimates of the potential impact areas for Icacos and Palomino/Palominito, the percent of <u>all</u> seagrass beds (independent of depth) potentially impacted by boater activity is 2.14% and 12.78%, respectively. Because this does not account for impacts in water depths greater than 7 ft (2.3 m), for instance sailboat anchoring, it is likely that total potentially impacted seagrass beds is greater for both Icacos and Palomino/Palominito.

Calculation of total observed impact area, probable impact area, and potential impact area for Icacos indicates that approximately 0.03 acre of seagrass are impacted, 1.42 acres are probably impacted, and 6.73 acres have the potential to be impacted by boating activity (Table 1, Figure 7). Based on the observed impacts divided by estimated potential impact area, 0.44% of the shallow seagrass beds around Icacos have likely suffered mechanical damage. Using estimated probable impact area and estimated potential impact area, 21.03% of the shallow seagrass beds west and south of Icacos potentially impacted by boating suffered significance disturbance (Table 1). This estimate does not take into consideration mechanical impacts in deeper water, particularly as a result of sailboat anchoring.

Calculation of total observed impact area, probable impact area, and potential impact area for Palomino indicates that approximately 0.34 acre of seagrass are impacted, 3.80 acres are probably impacted, and 26.39 acres have the potential to be impacted by boating activity (Table 1, Figure 8). Portions of the potential impact area north of the ferry dock are areas likely impacted by anchoring based on discussions with the Reserve Manager but, as discussed in the Field Report (Appendix A), it was difficult to distinguish boating impacts in this area due to the chronic, long-term nature of the impacts. Observed impacts versus estimated potential impact area produced estimates indicating that 1.29% of the shallow seagrass beds on the west side of Palomino, where boaters concentrate, are likely to have suffered mechanical damage. Using estimated probable impact area divided by estimated potential impact area, 14.39% of the shallow seagrass beds west of Palomino potentially impacted by boating suffer mechanical damage (Table 1).

Table 1. For the three cays where seagrass impacts were observed, total point, line, and polygon impacts are reported as scar area (SA), PrIA represents the calculation of probable impact area, and PoIA represents the calculation of potential impact area. SA, PrIA, and PoIA are reported in square meters and acres.

| Site | Scar Area | PrIA | PoIA | Scar Area | PrIA | PoIA | Scar/PoIA | PrIA/PoIA |
|---|---|---|---|---|---|---|---|---|
| | m2 | | | Acres | | | Percent | |
| Icacos | 120.52 | 5732.15 | 27253.29 | 0.03 | 1.42 | 6.73 | 0.44 | 21.03 |
| Palomino | 1377.85 | 15369.40 | 106812.90 | 0.34 | 3.80 | 26.39 | 1.29 | 14.39 |
| Palominito | 1805.42 | 7128.80 | 106240.30 | 0.45 | 1.76 | 26.25 | 1.70 | 6.71 |

Calculation of total observed impact area, probable impact area, and potential impact area for Palominito indicates that approximately 0.45 acre of seagrass are impacted, 1.76 acres are probably impacted, and 26.25 acres have the potential to be impacted by boating activity (Table 1, Figure 8). As for Icacos, this estimate does not take into consideration deeper areas, where sailboats were observed anchoring, that likely also exhibit mechanical damage but were not examined as part of this survey. Based on the observed impacts compared to estimated potential impact area, 1.7% of the shallow seagrass beds north and west of Palominito are likely to havesuffered mechanical damage. Based on estimated probable impact area compared to estimated potential impact area, 6.71% of the shallow seagrass beds west and north of Palominito potentially impacted by boating suffered mechanical damage (Table 1). This estimate would likely be greater if the depth limit was increased in order to capture the sailboat anchorage areas.


Figure 7. Probable impact areas in three locations around Icacos where mechanical damages to seagrass were observed during the field survey are shown in the figure. The calculated potential impact area is also shown. Note that the potential impact area was found to be limited due to the rapid increase in water depth around Icacos

Calculation of total observed impact area, probable impact area, and potential impact area for Palomino indicates that approximately 0.34 acre of seagrass are impacted, 3.80 acres are probably impacted, and 26.39 acres have the potential to be impacted by boating activity (Table 1, Figure 8). Portions of the potential impact area north of the ferry dock likely are areas impacted by anchoring based on discussions with the Reserve Manager but, as discussed in the Field Report (Appendix A), it was difficult to distinguish boating impacts in this area due to the chronic, long-term nature of the impacts. Observed impacts versus estimated potential impact area produced estimates indicating that 1.29% of the shallow seagrass beds on the west side of Palomino, where boaters concentrate, are likely to have suffered mechanical damage. Using estimated probable impact area divided by estimated potential impact area, 14.39% of the shallow seagrass beds west of Palomino potentially impacted by boating suffer mechanical damage (Table 1).

Calculation of total observed impact area, probable impact area, and potential impact area for Palominito indicates that approximately 0.45 acre of seagrass are impacted, 1.76 acres are probably impacted, and 26.25 acres have the potential to be impacted by boating activity (Table 1, Figure 8). As for Icacos, this estimate does not take into consideration deeper areas where sailboats were observed anchoring that likely also exhibit mechanical damage but were not examined as part of this survey. Based on the observed impacts compared to estimated potential impact area, 1.7% of the shallow seagrass beds north and west of Palominito are likely to have suffered mechanical damage while 6.71% have of the shallow seagrass beds west and north of Palominito probably being impacted by boating activities (Table 1).

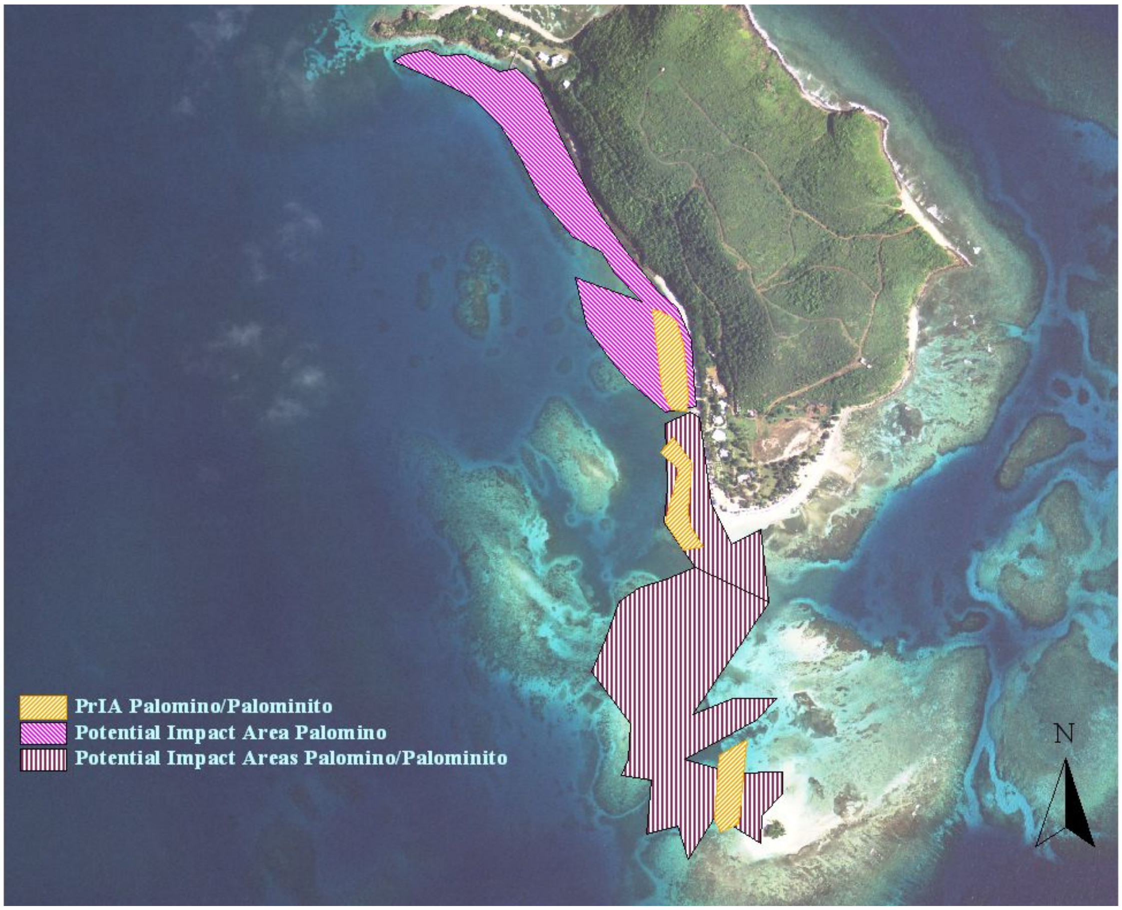


Figure 8. The probable impact areas for Palomino and Palominito are shown in this figure. The potential impact areas for both cays are also shown representing areas with depths of 7 ft (2.3 m) or less where mechanical damage has the potential to occur due to water depths and boating patterns.

Overall, 0.82 acre of mechanical damage to seagrass beds was measured in the Reserve. Probable impacts were estimated as 6.98 acres from a potential impact area of 59.37 acres. Thus, up to 59.37 acres of seagrass beds are at depths of 7 ft (2.3 m) or less and could be potentially impacted by boating in the Reserve. Of these 59.37 acres, approximately 11.7% are probably impacted. Based on estimates of probable and potential impact areas, at least 7, 14 and 21% of the seagrass habitats examined have been impacted in Palominito, Palomino and Icacos, respectively.

**Discussion**

Unlike our previous study in La Parguera Natural Reserve where boating impacts were prevalent in the backreefs of coral cays and in shallow channels inappropriate for heavy transit of vessels and were predominantly related to propeller scarring and propeller wash, impacts in La Cordillera Reserve were concentrated in a few cays where boaters converge in order to access beaches. In addition, the type of mechanical damage to seagrass beds from boats in Cordillera differed greatly than that observed in Parguera. Damages in Cordillera were almost exclusively due to anchoring in seagrass beds. Because boaters in Cordillera often have larger vessels than many of those in La Parguera and moor their vessels using a bow and a stern anchor, anchor damage is extensive in Cordillera in a few concentrated sites where recreational boaters congregate. In addition, because boaters in Cordillera anchor with the stern of their vessel toward the shore in shallow waters, there is evidence indicating that some of the sandy bottom areas adjacent to popular beaches are barren of vegetation due in part to propeller wash. Further, observations during the overflight conducted prior to the field survey in the area of Cordillera indicate that studies such as this cannot focus on the Reserve alone. Instead, the scope should be expanded to marinas along the Fajardo coast from which most of the recreational boaters who visit the Reserve transit because propeller scars were evident in shallow seagrass beds near these marinas during the overflight. Thus, the damages observed in seagrass beds within the Reserve represent only a portion of the impacts of recreational boaters on the seagrass beds that are all part of the east coast coral reef ecosystem.

In summary, it can be concluded that:

- Propeller scarring is not a significant impact within La Cordillera Reefs Natural Reserve.
- Propeller scarring <u>may be</u> a significant impact along the Fajardo coast from which the majority of the recreational boaters utilizing the Reserve transit.
- Anchor damage and other impacts associated with anchoring practices employed within the Reserve are the most significant impacts to seagrass beds.
- Mechanical damage to seagrass beds is concentrated in popular beach areas at Cayo Icacos, Palomino, and Palominito.
- Overflights were useful only in determining locations where boats anchored in the Reserve but could not be used to distinguish mechanical damage (namely anchor scars) in the absence of features such as propeller scars.
- There is a need for continued monitoring of impacted areas and the expansion of survey efforts to deeper water due to the number of sailboats anchoring in certain areas within the Reserve.
- Several areas with numerous acroporid coral colonies were observed that should be protected and monitored.

*Management Recommendations for La Cordillera Reefs Natural Reserve*

Based on observations during the field survey, prior experience in other natural reserves and in public outreach and education, and a literature review of studies in other areas where management practices were implemented to reduce mechanical damage to seagrass beds, we propose the following management measures for implementation within the Cordillera Reserve. We recognize that a management plan for the Reserve is currently under development that may address some of these issues but believe that it is important to stress certain measures based on boating practices observed in the Reserve and the survey of threatened coral colonies.

1. Education and Outreach Program: A comprehensive education and outreach program should be created for the Reserve to educate the public regarding the importance of its marine habitats. In addition, the program should include campaigns targeting resources users such as boaters and divers in order to change attitudes and behaviors regarding transiting in shallow areas near the Fajardo coast, leaving trash on cays and in the water where it becomes a threat to marine life, and anchoring in shallow seagrass beds and coral areas. This portion of the education program should be coordinated with local dive shop owners and marinas. Posters, T-shirts, baseball caps and other promotional materials should be created for users themselves to promote the conservation of resources within the Reserve. Ideally, a program would be created to sell these items and use the proceeds to pay seasonal workers to clean up trash from cays and shallow waters, as well as maintain signs, mooring buoys, and navigational aids. The 30-second public service announcement (PSA) created as part of this project and submitted to DNER, as well as the educational pamphlet, are examples of other materials that can be used to get the message regarding the importance of seagrass beds out to the public of Puerto Rico. The education program should also include the creation of newspaper, radio, and other public service announcements to be aired to announce activities within the Reserve, as well as any new regulations both specific to the Reserve and for the general protection of marine resources in Puerto Rico, including those found within the Reserve. The education program should also include a component for marina owners and operators as a cooperative effort in which those responsible for management and operation of the marinas assist in orienting their clients regarding marine resource conservation, in particular regulations for marine resource protection and specific rules and regulations within the Reserve, as well as other area Reserves such as Las Cabezas de San Juan and Seven Seas in Fajardo and Canal Luis Peña in Culebra. Finally, the education program should include a component for collaboration with the Puerto Rico Ports Authority to orient ferry captains regarding the marine resources along the ferry routes, as well as establish a visitor orientation program such as posters and other announcements within the ferry facilities.

2. No Anchor Zones: In areas around Palomino, Palominito, and Icacos where anchor damage to seagrass beds was observed, no anchor zones should be

established and mooring buoys should be installed to accommodate motorized vessels up to 40 feet and sailboats of various sizes. The numbers and locations of these buoys should be determined based on the results of this survey as well as using overflight photos that indicate heavy use areas during the summer and holidays in order to install mooring fields to accommodate numerous vessels. In areas around Icacos and Palomino where years of anchor damage and propeller wash, coupled with natural sand transport, apparently have resulted in the formation of barren sand areas close to the beach, chains with a series of mooring buoys should be installed at the seaward edge of the sand to allow for mooring of vessels. If this is not possible, then the sand area should be established as an anchorage zone for weighing the bow anchor only and the turning of the vessel to anchor with the stern facing the beach should not be allowed to minimize the impacts of propeller wash and sediment resuspension. In addition, surveys of seagrass beds in deeper areas where sailboats and other vessels were observed anchoring during our survey, as well as anchorage areas in deeper waters visible in photos from overflights of the Reserve, should be realized to quantify the extent of probable damage from sailboat anchoring in these areas and determine whether the installation of mooring buoys in these areas is possible. Where present, areas of bare sand between cays where currents and waves do not allow for the establishment of seagrass beds should be designated anchor areas to accommodate the overflow of vessels once the mooring buoys are used. The areas containing acroporid coral colonies mapped during this survey should also be designated no anchor zones.

3. Idle Zones: Motorized transit within 25 feet (7.6 m) of the beach when approaching to anchor should be prohibited. Instead, vessels should be required to approach the beach in neutral in order to avoid damage to seagrass beds from propeller wash. During heavy seas, this condition would not apply. Instead, during heavy seas, boaters would not be permitted to transit in waters less than 5 ft (1.5 m) to avoid propeller damage to the marine bottom caused by the movement of the vessel with the waves. Likewise, motorized transport in exclusion zones (#6) should be prohibited. Launching of jets skis and other watercrafts in Palominos should be moved from their actual location to one adjacent to the dock facilities. In this way, seagrasses may recover with time. Their present practice of using the engine to propel the craft in and out of the shallows close to the southern tip of Palomino has resulted in damages in the form of large blowouts in seagrass beds.

4. Navigational Aids and Markers: Educational signage should be installed at all beaches frequented by boaters to orient visitors regarding the marine resources and regulations for their protection. Markers should be installed in areas designated as anchorage areas, no anchor areas, idle zones, and exclusion zones to orient boaters and protect shallow seagrass beds and acroporid coral colonies. Similarly, markers and/or special use buoys should be installed in areas containing shallow reefs and seagrass beds to minimize the potential for accidental groundings. Speed limit zone markers should be installed at all cays in

areas frequented by boaters. The type and location of markers should be determined based on wave, current, and wind conditions around each cay as many of the areas within the Reserve are relatively exposed. If used, such markers should be rigged with stainless steel cable equipped with submerged floats attached midway from the bottom to ensure the cable does not scour or shave the bottom, thus avoiding possible impacts to seagrasses.

5. Dive Buoys: Dive buoys should be installed east of Palominito where dive boats always anchor to prevent recurring anchor damage to the coral colonies in this area. These buoys should be of an adequate size to accommodate dive vessels up to 60 ft and have an anchor system that can withstand rough weather conditions without resulting in the frequent loss of the buoy and/or the ripping out of the anchor. One buoy is available at Cayo Diablo. DNER should consider the installation of a buoy at La Blanquilla and one at Cayo Lobo to facilitate mooring of research vessels and eliminate the need for anchorage in these areas.

6. Exclusion Zones: During heavy seas, access to Cayo Icacos and Palomino, except in cases of emergency, would be prohibited to avoid accidental groundings. Access to Palomino may also need to be restricted, although the size and orientation of this cay provides better shelter from certain weather conditions than at other cays. Motorized transit in areas containing coral colonies, including acroporid colonies, with depths of 4 ft (1.2 m) or less should be prohibited to avoid accidental groundings and sediment resuspension. In addition, the areas containing acroporid coral colonies should be designated as no fishing zones. In order to avoid conflicts with fishers who transit through the areas between cays to access the open sea north of the Reserve, navigation channels through the exclusion zones should be designated based on the routes historically used by local fishers. An exception would be transit, anchorage, and sampling by scientific and management personnel with authorization from DNER.

7. Quotas: Quotas, in terms of the number of boats permitted access to a particular site at a particular cay, should be established based on the number of mooring buoys available and the capacity of designated anchorage areas in uncolonized sandy bottoms. Due to geographic location and the physical conditions around the cays, as well as the sensitivity of the marine resources, access to the marine environment of Cayo Lobo, La Blanquilla, and Cayo Diablo should be restricted to use by dive boats, provided the vessel uses the dive mooring, and scientific and management personnel with authorization from DNER.

8. Survey Program: A long-term monitoring program of the areas containing acroporid coral colonies should be established by DNER to study the effectiveness of management strategies and the health of these colonies over time, as well as oceanographic differences (physical, chemical, biological) in the areas where these colonies are found that have enabled them to apparently recover and begin reestablishment. Additional surveys in deeper waters where sailboats and other vessels anchor should be conducted using information from overflights. In

addition, shallow areas from which visitors to the Reserve transit, in particular marinas along the Fajardo coast, up to destination points in the Reserve should be surveyed using overflights and field surveys as the seagrass beds in the Reserve are largely part of a continuous system of seagrasses between the coast and the cays in the Reserve. Shallow coral cays and colonized outcroppings in this area should also be surveyed to determine the impacts of mechanical damage such as propeller scars and accidental groundings. These results should be incorporated in the education campaign (#1), as well as enforcement efforts and Reserve management efforts. Surveys should also be conducted in areas where management measures are established to determine the effectiveness of the measures and any changes that need to be made. Finally, the survey program should include a component to analyze the effectiveness of the education program and make any adjustments necessary to strengthen the program and increase public awareness. Surveys of the education program could range from questionnaires to telephone polls to workshops and independent evaluations.

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Appendix A

Field Report

# Field Report

Contract Number 2006-000951

Characterization of Mechanical Damage to Seagrass Beds in La Cordillera Reefs Natural Reserve

Principal Investigator
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Dr. Lisamarie Carrubba, collaborator

## Introduction

This report describes the fieldwork completed September 5-16, 2006, in La Cordillera Reefs Natural Reserve to characterize mechanical damage to seagrass beds associated with recreational boating activities. Fieldwork in the reserve was realized at Palomino, Palominito, Icacos, Lobos, Diablo, and La Blanquilla. Fieldwork was also completed in the area of Las Cabezas de San Juan.

## Methods

A low level overflight of the reserve and the area of Las Cabezas was completed on August 31, 2006, and the images from the flight, coupled with photos from overflights provided by the Cordillera Reserve Manager, were used to determine where to concentrate field efforts. The areas selected for survey efforts included the southwest coast of Palomino where El Conquistador Resort has its main beach facilities and ferry dock; the west coast of Palominito and between Palomino and Palominito; areas along the west and south coasts of Icacos; and the beach area of Cabezas de San Juan from the beach adjacent to the entrance to the Fideicomiso property up to the eastern point near the lagoon (Figure 1). These are the areas with the greatest recreational use by recreational boaters and beachgoers. Survey efforts were concentrated in areas containing shallow seagrass beds with depths of less than seven feet as the proposal contemplated documenting mechanical impacts to seagrass beds from boat propellers as was done in a previous study in La Parguera and Guánica Natural Reserves. Some surveys were conducted in deeper areas where sailboat anchoring was observed, in particular southeast of Icacos. In addition, in the areas south of Lobos, La Blanquilla, and Diablo (Figure 1) where no impacts to seagrass beds were observed, the locations of areas containing colonies of staghorn and elkhorn coral colonies, which were listed as threatened under the federal Endangered Species Act on May 9, 2006, were documented, as well as colonies of fused staghorn coral.

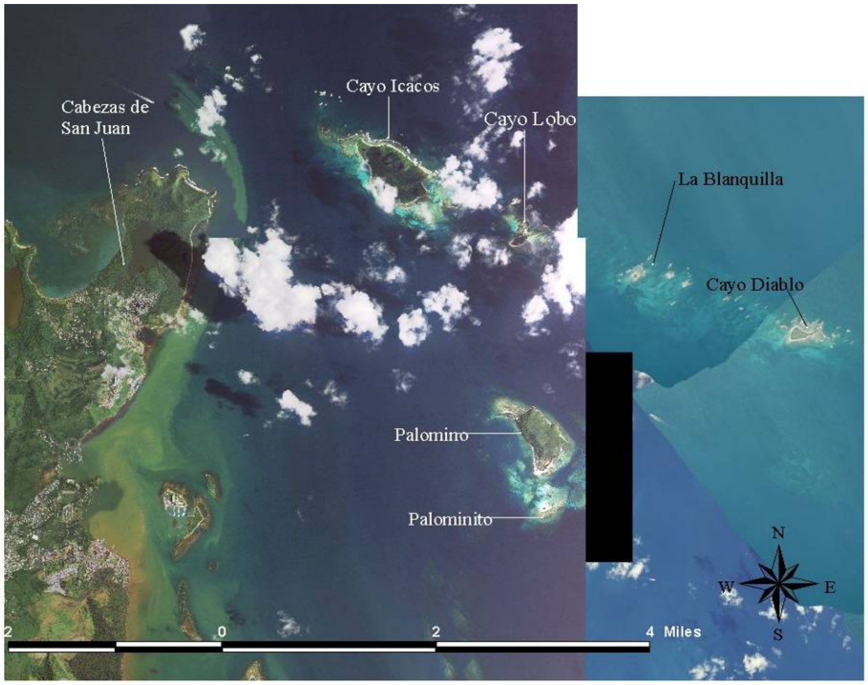


Figure 1. Location of survey sites for seagrass impacts and presence of acroporid corals. Note that neither the 2004 aerial photographs from the Department of Natural and Environmental Resources nor the 2000 aerial photographs taken by NOAA contain coverage of a portion of the area east of Palomino/Palominito, which is why it is black.

*Mapping of Impacted Seagrass Beds*

Originally, the project proposed the documentation only of individual propeller marks but it was determined, based on observations during the overflight; information from the Cordillera Reserve Manager; and observations in the field, that anchor damage rather than propeller scars constituted most of the mechanical disturbance to seagrass beds within the reserve. The distribution and extent of boating impacts to shallow seagrass beds were determined using a swimmer-operated Differential Global Positioning System (dGPS) consisting of a Garmin Map76C handheld unit coupled with a CSI Wireless beacon receiver mounted on a floating platform. At intervals selected by the swimmer, positions were recorded and saved to the GPS unit. Positions were also noted on a piece of PVC tubing used as a notepad by the swimmer during field surveys. The recorded positions documented points in areas with anchor scarring, lines in areas with propeller scarring or anchor drag, and polygons in areas where impacts to seagrass beds were so concentrated that points and/or lines could not be distinguished. Surveyed areas were usually located in 7 feet or less water depth, which was set as a limit based on the draft of motorized vessels. Due to weather conditions during the survey and the location of the reserve relative to the location of the dGPS reference station (Isabela, Puerto Rico, maintained by U.S. Coast Guard Navigation Center), a dGPS signal was not always available or coverage was spotty meaning that the positional accuracy varied between 1 to 4 meters. When dGPS was not available, the instrument was used in Wide Area Augmented Signal mode achieving a level accuracy similar to that indicated above. The most accurate documentation of anchor and propeller impacts possible enables the relocation of impacted areas in future studies to assess changes/recovery of seagrass beds.

Drs. Otero and Carrubba conducted the fieldwork. One person operated the dGPS and stored waypoints marking the location of impacts in the GPS memory while swimming. The swimmer also took notes of the waypoint numbers and field observations, or communicated the information to the other person, who made annotations. One person also took photographs of the survey area. In areas with significant impacts, one person would determine the presence of scars in the area and place small buoys in the impacted area in order for the other person to quickly mark scar locations. This minimized the possibility of missing scars and made survey efforts more efficient. The position data were downloaded into a computer immediately upon return from the field at the end of each day. Positions were recorded in decimal degrees for transferring to a text file where column headings for ID number, latitude, and longitude were added. The facilitated later transfer of the text files to a geographic information system for the creation of maps of impact locations.

Seagrass beds west of Palominitos were mapped on September 5, and additional beds north of Palominitos were mapped September 12; and seagrass beds south and west of Palomino were mapped September 6. Additional seagrass areas northwest of Palomino were surveyed on September 7; seagrass beds around Icacos were mapped on September 7; and seagrass beds in the area of Las Cabezas de San Juan were mapped September 10, 2006 (see Figure 1 for lacations).

*Mapping of Coral Colonies*

When the areas south of Lobos, La Blanquilla, and Diablo were investigated, it was found that areas containing seagrass beds near the cays were limited and occurred in deeper waters. No boating impacts were observed during reconnaissance of the area. However, numerous acroporid coral colonies were observed. It was decided to mark the position of these colonies due to the status of elkhorn and staghorn corals as threatened species under the federal Endangered Species Act as of May 9, 2006. Mapping of elkhorn, staghorn, and fused staghorn coral colonies south of Cayo Lobos was completed September 8, 2006, using the same methods as used for mapping areas of boater impacts to seagrass beds to mark individual colonies and the borders of the reef area where acroporids were present. The areas south of Cayo Diablo and La Blanquilla, as well as the area east and south of Palomino/Palominito, were mapped on September 11, 2006 (see Figure 1), but this survey was done mainly from the boat as these surveys were not in fact part of the project and time was limited. Colonies were observed while navigating transects through the area and marking the location of individual colonies. The type of coral was recorded, as well as the waypoint number and other observations.

## Results

### Impacted Seagrass Beds

Based on conversations with the Reserve Manager, Mr. Hector Horta, and Dr. Alida Ortiz, who assisted in the creation of an educational pamphlet produced as part of this project and who led the development of a management plan for the reserve, areas of boat impacts to seagrass beds were thought to be concentrated in the area of Palomino north of the ferry dock and in front of Las Cabezas de San Juan where jet ski use was prevalent until the use of these motorized vessels was prohibited in the area of the Fideicomiso reserve. However, field observations revealed that there were few mechanical impacts in the Cabezas de San Juan areas while there were additional areas of boater impact north and west of Palominito and in several areas around Icacos within La Cordillera Reefs Natural Reserve.

Results of the survey of seagrass beds to determine the extent of boater impacts around Palomino, Palominito, Icacos, and Las Cabezas de San Juan are detailed below.

<u>Palomino</u>: The areas along the south and west coasts of this cay where the main beach facilities and ferry dock used by El Conquistador Resort are located were found to have the most impacts to seagrass beds, which were dominated by turtle grass (*Thalassia testudinum*) and a mixture of turtle grass and manatee grass (*Syringodium filiforme*) (Figure 2). The area where jet skis are launched from the beach is dominated by turtle grass but the grass has been removed in large patches in this area likely due to the impacts of the water jets from the motors of the jet skis launched by the hotel staff in these shallow areas (Photograph 1). Around the ferry dock, a large area of seagrass has been removed by scouring and the area deepened by propeller wash from the hotel's ferry boat. North of the ferry dock, where recreational boaters commonly anchor, impacts to seagrass beds due to anchor damage are prevalent, as is scour from propeller wash (Photograph 2). An additional area of seagrass scars caused by anchor damage is located south of Palomino between Palomino and Palominito (polygon in Figure 3, Photograph 3). Table 1 contains the geographic position of the impacted areas obtained during the field survey, as well as a description of the type of impact. During the field survey, it was observed that boaters transit toward the beach, drop the bow anchor of the vessel and let the drag of the anchor turn the vessel then drop an additional anchor from the stern. It is the weighing of the front anchor with the related dragging of the vessel that may cause the most damage to seagrass beds, especially because the forward anchor is placed in deeper waters where seagrass is present while the rear anchor is usually placed in sandy bottom or in areas where past anchoring impacts have resulted in the disappearance of seagrass beds. As noted for Cabezas de San Juan, the anchor damage in this area has apparently been ongoing for some time making it difficult to determine whether barren areas are due to boating or due to natural factors, such as wave action. If management measures were implemented in these areas restricting the use of anchors, it would be valuable to continue monitoring the seagrass beds to determine whether natural recovery occurs. The rest of the areas of seagrass beds, including near the home of the person responsible for maintaining the resort's facilities on the cay where a small boat dock is

located, were also surveyed but no impacts were observed, probably due to the greater water depth and the lack of beach in this area.


Figure 2. Location of scars around Palomino

Palominito: In addition to the area noted above in the discussion of Palomino between the two cays, impacts were observed in seagrass beds dominated by shoal grass (*Halodule beaudettei*) in shallow areas adjacent to the western coast of the cay (Photograph 4). This bed grades from shoal grass to a mixture of shoal and manatee grass, to a manatee grass stand, to manatee and turtle grass, and finally to stands dominated by turtle grass in deeper waters (Figure 3, Photograph 5). Table 2 contains the geographic position of impacted areas and information regarding the type of impact. Other probable impacts, likely from anchoring, were observed in the deeper waters dominated by turtle grass west of the cay and sailboats were later observed anchoring in this area. However, this area was not surveyed as it was beyond the depth limit established as part of the study (7 feet, 2 m) being located in waters between 10-15 feet deep (3-4.5 m).

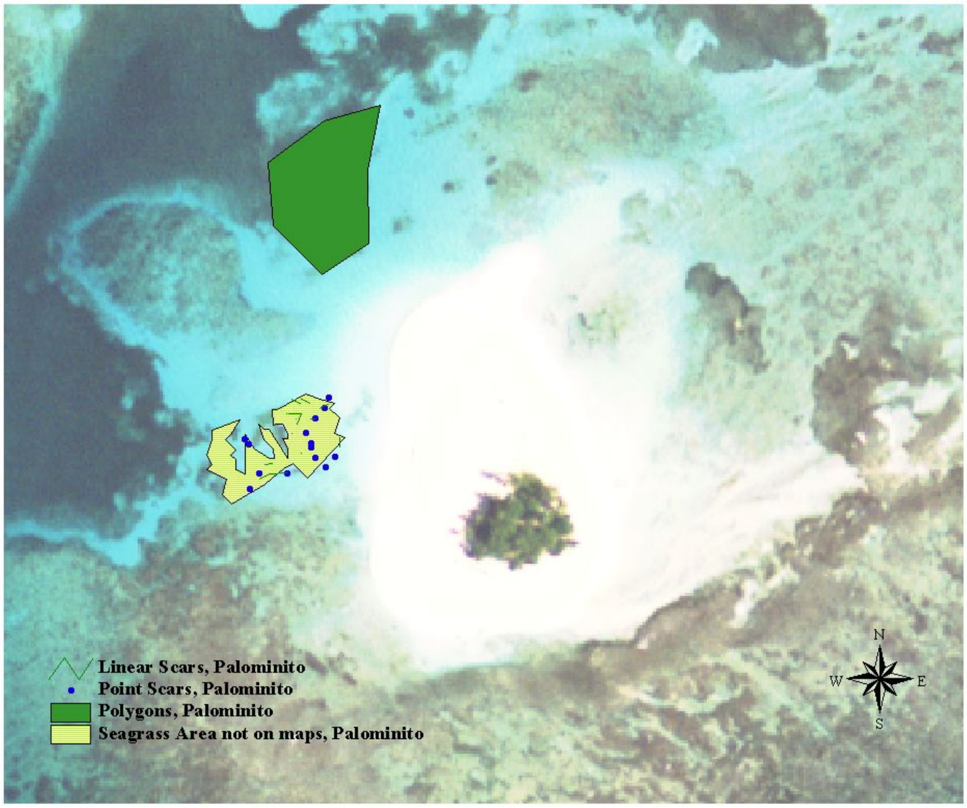


Figure 3. Impacted areas around Palominito and between Palomino and Palominito and shallow seagrass bed found during survey

Icacos: Three main areas of boating impacts to seagrass beds were observed around Icacos, one to the northwest close to an area where sailboat charters anchor to enable clients to snorkel in the adjacent reef, and two to the south of the cay, one adjacent to a heavily-visited beach and the other in an area of deeper water (approximately 10-12 feet, 3-4 m) where sailboats anchor (Figure 4). This last area was only partially surveyed as it was beyond the depth limit established as part of this survey (7 feet, 2 m). It is likely that there are additional anchor scars in the deeper waters in this area. The impact area northwest of the cay contains a shallow seagrass bed dominated by shoal grass that was not on the NOAA benthic map. The impacts appear to be due to anchoring in this area (Photograph 6). The area adjacent to one of the frequented beaches on the south of the island also contained evidence of impacts due mainly to anchoring, including areas adjacent to a rock reef with coral colonization toward the eastern portion of the beach. During our field surveys, we observed charter sailboats weighing anchor off the bow in areas containing seagrass beds, waiting for the anchor to grab and swing the boat, and weighing an anchor from the stern in the sand (Photographs 7 and 8). This practice is also utilized by owners of private motorized vessels and has led to damage to dense seagrass beds similar to that observed at Palomino north of the ferry dock and between Palomino and Palominito. Table 3 contains information regarding the geographic position of the impacted areas surveyed and the type of mechanical damage. Other areas of seagrass beds along the western portion of the cay, including adjacent to the designated swim area, were not surveyed due to the distance of these seagrass beds from the cay. However, photographs provided by the refuge manager indicate that some anchoring may occur in these areas so there may be additional anchoring impacts in these beds.


Figure 4. Impacted areas observed around Icacos and shallow seagrass bed to the northwest. Note that clouds obscure a portion of the southern beach in the aerial photograph.

<u>Cabezas de San Juan</u>: Although several areas were found to be barren of seagrass in front of Las Cabezas de San Juan, it was not possible to determine whether these were due to boaters or beachgoers walking over the grass beds. If these areas were impacted by past jet ski activity, it would be valuable to continue to study them to determine whether or not they recover naturally. Two jet skis were observed in the area using the beach in front of Laguna Madre but the marine bottom in this area was devoid of seagrass (Photograph 9). Again, this may be due to past jet ski activity but, without information regarding the locations of past jet ski damage, it is not possible to make any conclusions. A few areas of obvious boating damage, namely anchor and propeller scars, were observed along the beach (Figure 5, Photograph 10). These areas either extended linearly from the beach into the water or had a round shape indicating anchor damage. Because the forms were similar to those found in other areas devoid of seagrass along the beach, it is likely that other barren areas are due to previous boating impacts. However, it was not possible to definitively identify mechanical damage as the reason for the lack of seagrass in most of these sites as discussed above, so they were not marked during the field

survey.  Table 4 contains information regarding the type of impact and the geographic positions of surveyed impacts.


Figure 5.  Observed impacts in the area of Cabezas de San Juan

*Acroporid Coral Colonies*

The reef system south of Lobos, La Blanquilla, and Diablo cays seems to be a continuous formation that was once dominated by elkhorn coral in shallower waters and mounds formed by staghorn coral colonies in deeper waters.  These corals apparently suffered mass mortality in the past however; there is considerable new growth of both elkhorn and staghorn colonies, as well as the hybrid fused staghorn coral throughout this reef chain.  Additional colonies of these corals may be present between the cays that were not surveyed during this study.  In addition, the recovery of elkhorn colonies in particular was observed to the southeast of Palomino and south of Palominito on the reef platform of which both cays are a part (Figure 6).  Acroporid corals were not observed in the areas surveyed around Icacos, in the area of Cabezas de San Juan, although they may be present on the reef in this area, which was not surveyed as part of the seagrass study, or in areas west of Palomino.

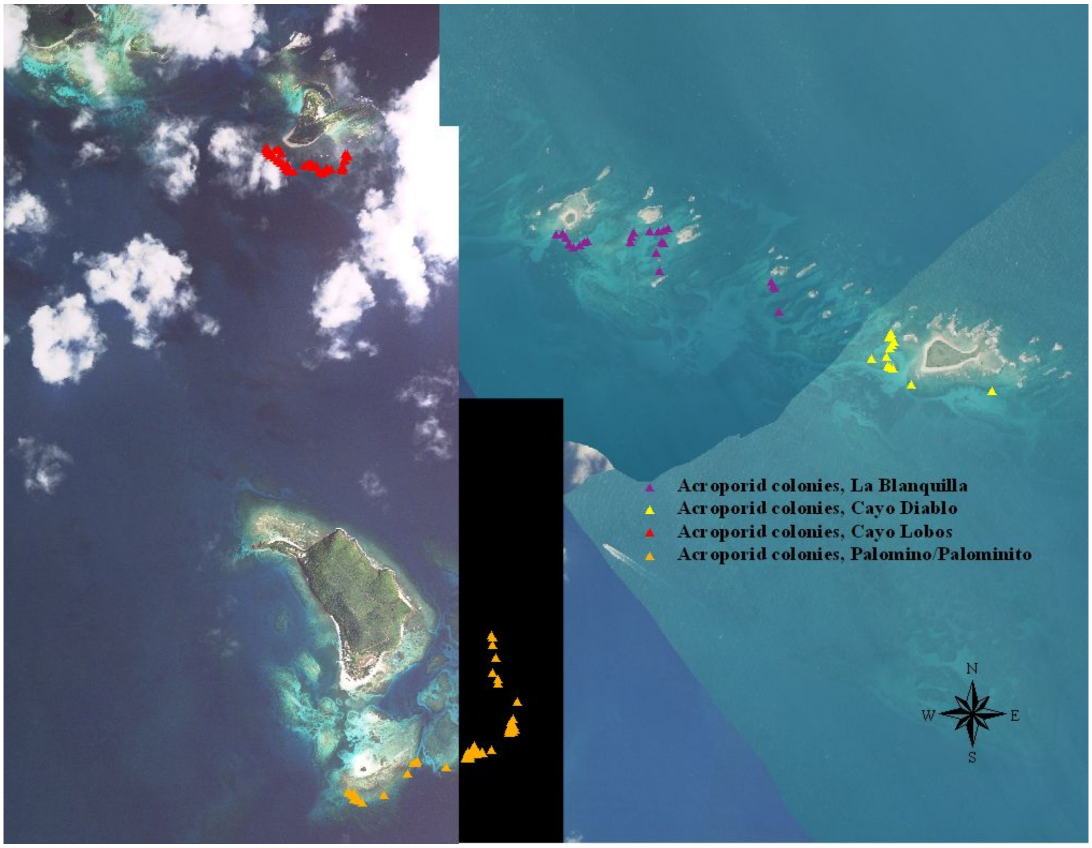


Figure 6. Acroporid colonies mapped around Cayo Lobos, La Blanquilla, Cayo Diablo, and Palomino/Palominito. Note that neither the 2004 aerial photographs from the Department of Natural and Environmental Resources nor the 2000 aerial photographs taken by NOAA contain coverage of a portion of the area east of Palomino/Palominito, which is why it is black.

Results of the survey of acroporid corals around each cay are detailed below.

Lobos: The area south of Cayo Lobos was surveyed using the same methodology as for shallow seagrass beds to survey acroporid coral colonies. A swimmer saved the location of observed colonies as waypoints in the GPS and noted the type of colony and other observations, while another swimmer photographed the area. Mounds of staghorn coral colonies were observed in deeper waters along the southern edge of the reef, as well as extending into shallower waters to the east and west of the reef (Photograph 11). Numerous fragments of dead staghorn coral were also observed in areas of sandy bottom throughout the reef where large mounds of this coral were apparently present in the past, as well as colonies where most of the corals appeared dead (Photograph 12). Elkhorn coral colonies were observed in shallow waters adjacent to the terrestrial portion of the cay extending along the southern border of the cay (Photograph 13). It was not possible to mark the position of all of these colonies due to the water depth and wave action in the area so the map of positions should not be taken to represent the locations of all elkhorn coral colonies. Numerous fused staghorn coral colonies were found between the shallow zone containing elkhorn corals and the deeper zone where staghorn coral colonies were present (Photograph 14). The presence of massive skeletons of elkhorn corals

(Photograph 15) and mounds of staghorn coral skeletons indicate that the reef was previously formed by these corals. Figure 7 shows the locations of surveyed coral colonies and Table 5 provides the geographic location of these colonies, as well as information regarding the type of colony.

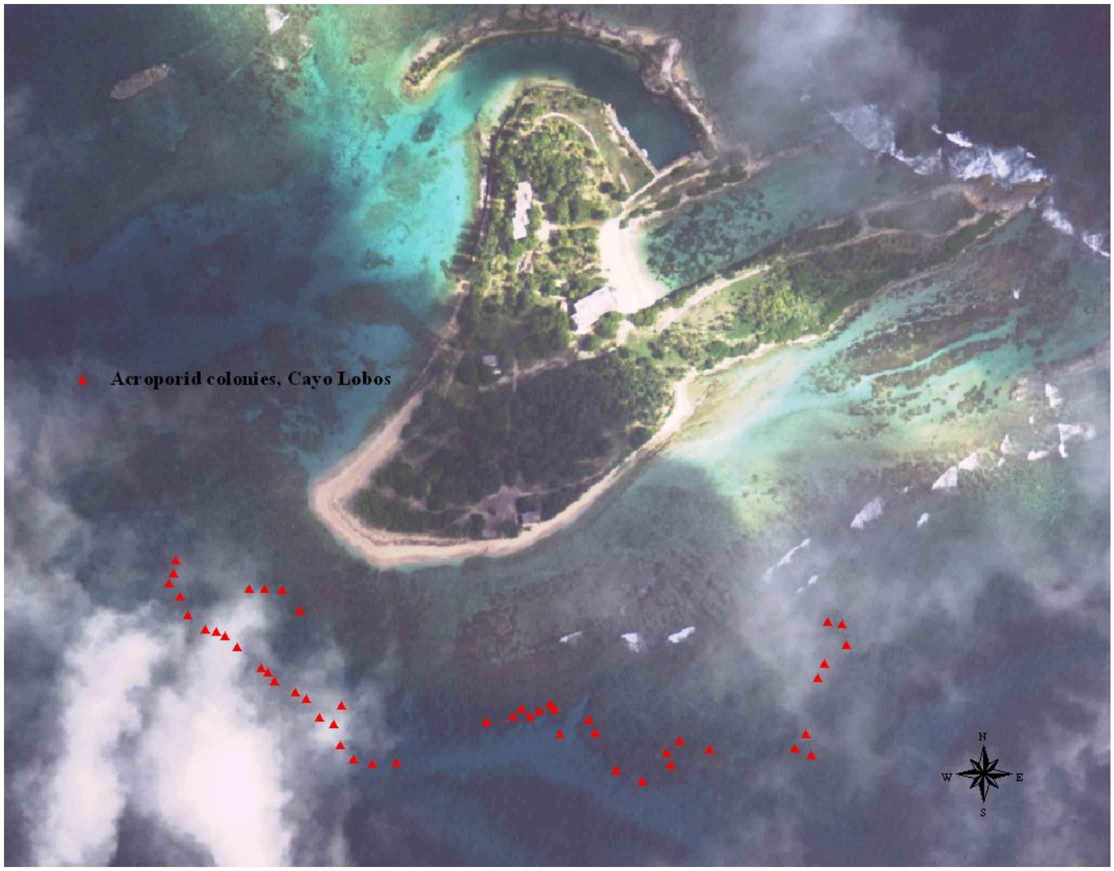


Figure 7. Acroporid colonies around Cayo Lobos

La Blanquilla: Several different areas containing acroporid coral colonies were observed south of La Blanquilla. The western portion of the surveyed area should actually be portrayed as a polygon as acroporid coral colonies were extremely numerous but the depth of the water and the wave action in the area prevented detailed surveying of the entire area. The points taken in this area represent the southern boundary of the zone containing numerous acroporid colonies (Figure 8, Photograph 16). The other areas surveyed contained sparser coverage by acroporid corals, possibly due to the force of the waves passing between the cays. Unlike the area south of Cayo Lobos, the acroporid corals south of La Blanquilla colonized exposed rock, which serves as the base of the reef, rather than being a coral reef with a base of coral skeletons. Staghorn, elkhorn, and fused staghorn colonies were observed, in particular in the southwestern portion of the cay. These areas were surveyed from the boat and the southwestern area was also surveyed while snorkeling. Table 6 lists the locations of surveyed colonies, as well as information regarding the type of coral.

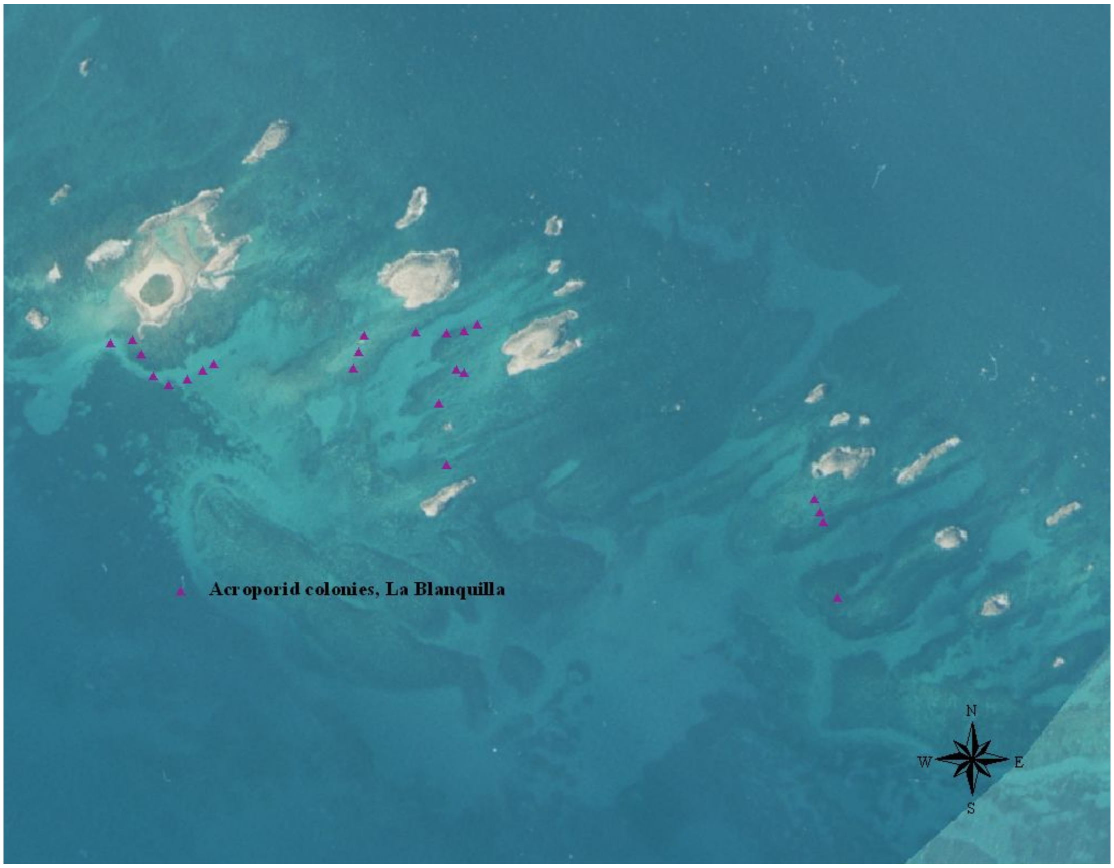

Figure 8. Locations of acroporid colonies south of La Blanquilla

Diablo: Two areas containing acroporid coral colonies were observed around Cayo Diablo, one south of the cay and one west of the cay. The points to the south of the cay actually represent the eastern and western boundaries of the southern edge of the reef, which contains numerous colonies of elkhorn coral that could not be surveyed due to water depth and wave action (Figure 9). This reef is in an area containing a dive buoy, although no boaters were observed at this cay during the project. The area east of the cay appears to be part of the same reef platform that extends south of La Blanquilla and additional acroporid coral colonies are likely present between these two cays. Table 7 contains information regarding the types of acroporid corals observed and their geographic locations. Fewer acroporid colonies were observed in this area than at other cays, possibly indicating that this is the eastern limit of the band of acroporid colonies on the reefs that extend south of the cays in this area or possibly due to the limits of survey methods noting the location of colonies from the boat.


Figure 9. Locations of acroporid coral colonies in area of Cayo Lobos

<u>Palomino/Palominito</u>: Figure 10 shows the areas containing acroporid coral colonies southeast of Palomino and east and south of Palominito. An additional elkhorn colony was observed south of the main beach facilities on Palomino but the location of this colony was not marked due to the difficulty of accessing this portion of the reef. It is likely that other colonies are present throughout this reef but the water depth in the area made extensive surveying from the boat impossible. An additional staghorn coral colony was observed at a depth of 45 feet (13.7 m) during a dive in this area on September 12, 2006, but the location of this colony was not marked. It is likely that other staghorn colonies are present along the borders of the reef in this area. Dive boats were observed weighing anchor along the eastern border of the Palominito reef where damage to the reef was possible but unconfirmed. Overall, the current and wave patterns south of Palominito, as well as the location of this area relative to the ferry routes and other vessel traffic, have led to resuspension of sediments which were observed to disperse to the southwest. Thus, the acroporid coral colonies observed here do not appear to be as healthy as those observed around the other cays. In addition, the shallowness of the southern Palominito reef promotes somewhat higher temperatures, as observed in the field, which might cause stress to the colonies in this area, especially during warmer periods. Table 8 contains details of the type of coral observed and their locations.

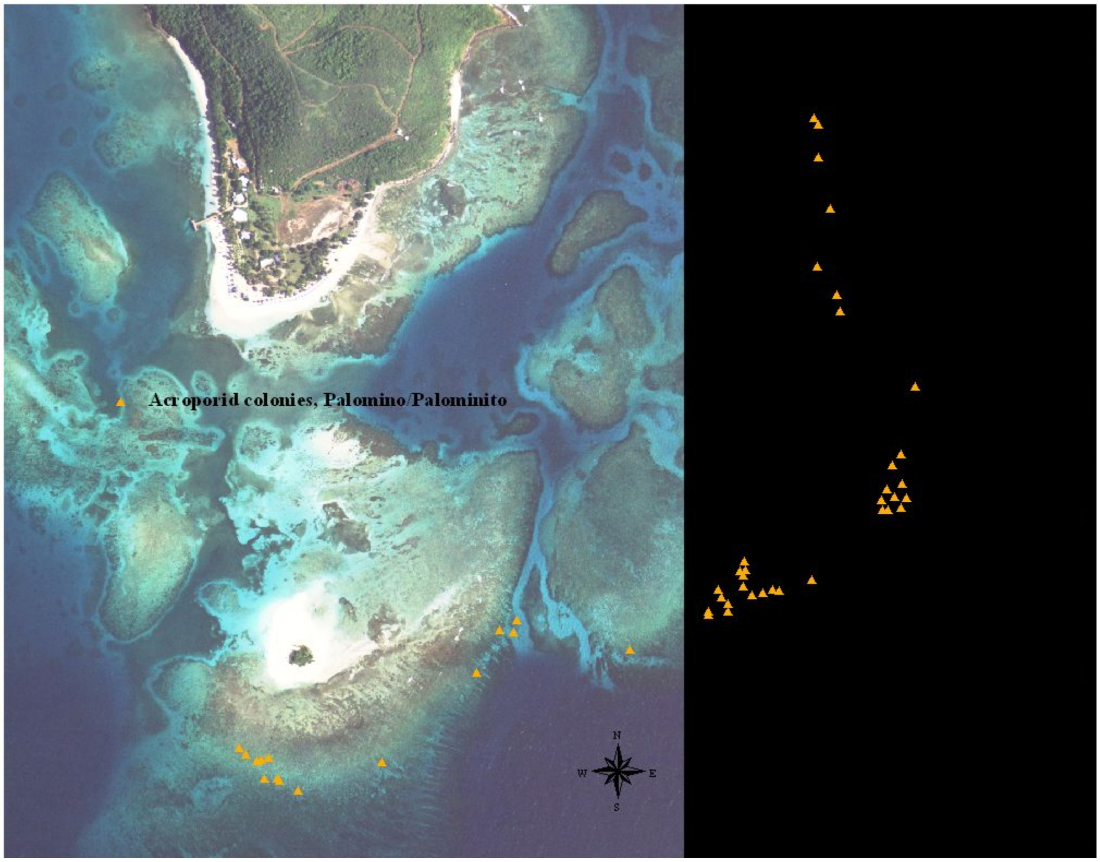

Figure 10. Locations of acroporid coral colonies in the area of Palomino/Palominito. Note that neither the 2004 aerial photographs from the Department of Natural and Environmental Resources nor the 2000 aerial photographs taken by NOAA contain coverage of a portion of the area east of Palomino/Palominito, which is why it is black.

## Conclusions

*Impacted Seagrass Beds*

The launching of jet skis from the beach on Palomino that is part of El Conquistador Resort facilities has led to a decrease in cover in shallow seagrass beds, as has the ferry that services the island as evidenced by the scouring of seagrass beds around the ferry dock. The areas with the most impacts around Palomino and Palominito are in shallow seagrass beds adjacent to beaches and additional areas of impact are likely present in deeper waters east of Palominito due to the anchoring of sailboats. Anchor damage similar to that observed at Palomino/Palominito is present in three areas adjacent to Cayo Icacos. It is necessary to educate boaters regarding proper anchor practices as most boaters were observed using a bow anchor dropped in seagrass beds to turn the boat so that another anchor could be dropped from the stern. Because this practice appears to be widespread in this area, the best way to protect seagrass beds is likely to be through the installation of mooring buoys capable of holding vessels up to 60 feet in length in the area where bow anchors are typically weighed and allowing the use of a stern anchor in sandy bottom. In this way, boaters can continue to access the shallow sandy area adjacent to the beaches directly from the stern of their boat and seagrass beds will be protected. Mooring buoys should also be installed for sailboats in the areas identified as being impacted by sailboats around Icacos and adjacent to Palominito.

In the area of Las Cabezas de San Juan, which was not part of the project but was surveyed to determine the extent of boating impact to seagrass beds, surveys of seagrass beds adjacent to the beach should be continued to determine whether seagrass recolonizes areas that were apparently impacted by past jet ski use. As part of the survey, it would be useful to examine past aerial photographs to determine changes in the extent of seagrass beds, possibly associated with the use of jet skis. In addition, an effort should be made by the Department and Fideicomiso to ensure compliance with regulations regarding the use of jet skis in this area. Although no boats were observed during the survey, two jet skis were observed taking passengers from the area of Seven Seas to the beach adjacent to Laguna Madre on the Fideicomiso property.

*Acroporid Coral Colonies*

While boaters were not observed utilizing the areas around Cayo Lobos, Cayo Diablo, or La Blanquilla where extensive acroporid coral colonies were found, there is a dive buoy in the area of Cayo Diablo where one of the reefs containing numerous acroporid coral colonies was observed. Therefore, there is the possibility of damage to these corals related to anchoring of dive boats. In the area of Palomino/Palominito, numerous boats were observed transiting close to the areas containing extensive acroporid coral colonies and dive boats were observed anchoring east of Palominito in areas where additional staghorn corals are likely present. The reserve manager indicated that the Department has installed buoys in this area in the past but the size of the dive boats exceeds the capacity of the buoys and the buoys are frequently ripped from their moorings. Due to the presence of extensive reefs in this area, not just acroporid corals, it is recommended that the Department install buoys with the capacity to enable mooring of vessels at least up to 60 feet, as well as special use buoys marking the shallow coral reef south of Palominito to avoid damage to corals from vessels navigating in this area. In addition, since the acroporid coral colonies surveyed within the reserve appear to be healthy and growing, it is recommended that the Department protect and preserve these areas by designating them as no fishing and no anchoring zones, as well as prohibiting the transit of vessels in water depths less than four feet, unless the vessels are being used for research activities authorized by the Department. It is unlikely that this designation would significantly impact commercial fishers as they do not appear to frequent any of these cays. The Department should also institute long-term monitoring of these areas to study the effectiveness of management strategies and the health of these colonies over time, as well as oceanographic differences (physical, chemical and biological) in this area that have enabled these colonies to apparently recover and begin reestablishing large colonies.

Table 1. Locations of impacted areas around Cayo Palomino

| Point Scars | | | |
|---|---|---|---|
| ID | LATITUDE | LONGITUDE | INFO |
| 112 | 18.34368 | -65.56958333 | small anchor scar next to bathing area rope |
| 113 | 18.34368 | -65.56960000 | small anchor scar next to bathing area rope |
| 114 | 18.34382 | -65.56965000 | anchor damage 4ft6in by 5ft6in in 5 ft depth |
| 129 | 18.34462 | -65.56943333 | prop wash/blowout from small boat 3ft4in by 3ft |
| 130 | 18.34563 | -65.56956667 | anchor mark |
| 169 | 18.34582 | -65.56961667 | |
| 170 | 18.34592 | -65.56950000 | |
| 221 | 18.34695 | -65.56948333 | old anchor mark algae started growing |
| 224 | 18.34695 | -65.56950000 | old anchor mark algae started growing |
| 149 | 18.34567 | -65.56955000 | two anchor holes |

| Linear Scars | | | | | |
|---|---|---|---|---|---|
| ID | LATITUDE | LONGITUDE | INFO | LENGTH (FT) | METERS |
| 1 | 18.34697 | -65.56951667 | seems to be old damage, algae growing | 0.0000021414 | 0.234869 |

| Polygons | | | | | |
|---|---|---|---|---|---|
| ID | LATITUDE | LONGITUDE | INFO | AREA (SQMETERS) | ACRES |
| 1 | 18.34507 | -65.56956667 | major impact area of prop wash and blowouts around ferry dock | 914.8568826191 | 0.2260021943 |
| | 18.34478 | -65.56943333 | | | |
| | 18.34478 | -65.56946667 | | | |
| | 18.34472 | -65.5695 | | | |
| | 18.34468 | -65.56958333 | | | |
| | 18.34472 | -65.5696833 | | | |
| | 18.34488 | -65.56975 | | | |
| | 18.34493 | -65.56968333 | | | |
| | 18.345 | -65.56966667 | | | |
| 2 | 18.34557 | -65.5694 | anchor damage | 2.9603413448 | 0.0007313096 |
| | 18.3456 | -65.56938333 | | | |
| | 18.34557 | -65.56938333 | | | |
| 3 | 18.34557 | -65.56948333 | anchor damage | 0.0051848017 | 0.0000012808 |
| | 18.34558 | -65.56948333 | | | |
| 4 | 18.34567 | -65.5695 | anchor damage | 8.5525048916 | 0.0021127729 |
| | 18.34565 | -65.56948333 | | | |
| | 18.34562 | -65.56948333 | | | |
| | 18.34562 | -65.5695 | | | |
| 5 | 18.34567 | -65.56946667 | anchor damage | 1.0786192063 | 0.0002664573 |
| | 18.34568 | -65.56946667 | | | |
| | 18.34568 | -65.56948333 | | | |
| 6 | 18.34572 | -65.56941667 | anchor damage | 9.1482759029 | 0.0022599496 |
| | 18.34573 | -65.5694 | | | |
| | 18.34568 | -65.5694 | | | |
| | 18.34568 | -65.56941667 | | | |
| | 18.34575 | -65.5694 | | | |
| 7 | 18.3458 | -65.5694 | anchor damage | 14.3346655581 | 0.0035411723 |
| | 18.34578 | -65.56938333 | | | |
| | 18.34577 | -65.56936667 | | | |
| | 18.34578 | -65.56935 | | | |
| | 18.34582 | -65.56935 | | | |
| | 18.3458 | -65.56936667 | | | |

| | | | | | |
|---|---|---|---|---|---|
| 8 | 18.34572 | -65.56951667 | anchor damage | 4.6149547317 | 0.0011400580 |
| | 18.34575 | -65.56951667 | | | |
| | 18.34577 | -65.56951667 | | | |
| | 18.34575 | -65.56953333 | | | |
| 9 | 18.3459 | -65.56948333 | anchor damage motor block in impact area | 21.7425803554 | 0.0053711908 |
| | 18.34588 | -65.56951667 | | | |
| | 18.34588 | -65.56953333 | | | |
| | 18.34585 | -65.56953333 | | | |
| | 18.34585 | -65.56951667 | | | |
| | 18.34582 | -65.56951667 | | | |
| | 18.34583 | -65.5695 | | | |
| | 18.34585 | -65.5695 | | | |
| 10 | 18.34593 | -65.5697 | anchor damage | 8.1587847617 | 0.0020155101 |
| | 18.34593 | -65.56971667 | | | |
| | 18.34597 | -65.56971667 | | | |
| | 18.34597 | -65.5697 | | | |
| 11 | 18.34592 | -65.56965 | anchor damage | 13.0675890340 | 0.0032281593 |
| | 18.34595 | -65.56965 | | | |
| | 18.34597 | -65.56963333 | | | |
| | 18.34597 | -65.56961667 | | | |
| | 18.34595 | -65.56961667 | | | |
| | 18.34593 | -65.56963333 | | | |
| 12 | 18.34595 | -65.5696 | anchor damage | 12.8249619663 | 0.0031682218 |
| | 18.34595 | -65.56958333 | | | |
| | 18.34593 | -65.56956667 | | | |
| | 18.34593 | -65.56955 | | | |
| | 18.3459 | -65.56955 | | | |
| | 18.3459 | -65.56956667 | | | |
| | 18.34593 | -65.56958333 | | | |

| | | | | | |
|---|---|---|---|---|---|
| 13 | 18.34605 | -65.56945 | not sure whether prop wash or anchor scars | 69.3721780479 | 0.0171373958 |
| | 18.34602 | -65.56946667 | | | |
| | 18.34597 | -65.56945 | | | |
| | 18.34593 | -65.56948333 | | | |
| | 18.34592 | -65.56948333 | | | |
| | 18.34592 | -65.5695 | | | |
| | 18.34593 | -65.56951667 | | | |
| | 18.34595 | -65.5695 | | | |
| | 18.34598 | -65.56951667 | | | |
| | 18.346 | -65.56953333 | | | |
| | 18.34603 | -65.5695 | | | |
| 14 | 18.346 | -65.56968333 | prop wash and anchoring old post apparently for tying boats in past | 91.8286129734 | 0.0226849340 |
| | 18.34603 | -65.56968333 | | | |
| | 18.3461 | -65.56965 | | | |
| | 18.34608 | -65.56963333 | | | |
| | 18.34607 | -65.5696 | | | |
| | 18.34603 | -65.56958333 | | | |
| | 18.34602 | -65.56958333 | | | |
| | 18.34598 | -65.5696 | | | |
| | 18.346 | -65.56965 | | | |
| 15 | 18.34713 | -65.56981667 | anchor damage | 8.7738514157 | 0.0021674534 |
| | 18.34715 | -65.56983333 | | | |
| | 18.34715 | -65.56985 | | | |
| | 18.34717 | -65.56985 | | | |
| | 18.34718 | -65.56983333 | | | |
| 16 | 18.34332 | -65.56941667 | estimate of jet ski launch impact area | 192.4297540952 | 0.0475369946 |

Table 2. Locations of impacted areas around Cayo Palominito

| Point Scars | | | |
|---|---|---|---|
| ID | LATITUDE | LONGITUDE | INFO |
| 72 | 18.33876667 | -65.56863333 | anchor mark |
| 73 | 18.33880000 | -65.56860000 | two round anchor marks |
| 76 | 18.33900000 | -65.56861667 | small scar |
| 79 | 18.33896667 | -65.56863333 | four anchor marks |
| 82 | 18.33893333 | -65.56866667 | two round anchor marks |
| 83 | 18.33883333 | -65.56868333 | anchor mark |
| 84 | 18.33885000 | -65.56868333 | anchor mark |
| 85 | 18.33880000 | -65.56866667 | anchor mark |
| 88 | 18.33888333 | -65.56870000 | two to three round anchor marks |
| 100 | 18.33875000 | -65.56876667 | apparent anchor mark |
| 107 | 18.33870000 | -65.56890000 | anchor drag to dead coral |
| 108 | 18.33875000 | -65.56886667 | three anchor holes |
| 109 | 18.33886667 | -65.56891667 | small anchor drag plus prop wash |
| 110 | 18.33885000 | -65.56890000 | |

Linear Scars

| ID | LATITUDE | LONGITUDE | INFO | LENGTH (FT) | METERS |
|---|---|---|---|---|---|
| 1 | 18.33873333<br>18.33875<br>18.33875 | -65.56886667 -<br>65.56883333 -<br>65.56876667 | long scar 2 depressions possibly anchor | 0.0001042730 | 11.436663 |
| 2 | 18.33878333<br>18.33878333 | -65.56885 -<br>65.56881667 | long scar with depression at one end possible anchor | 0.0000316009 | 3.465987 |
| 3 | 18.33881667 | -65.56871667 | two short scars of anchor drag | 0.0000027703 | 0.303847 |
| 4 | 18.33888333 | -65.56875 | short scar | 0.0000033244 | 0.364620 |
| 5 | 18.3389333 | -65.56873333 | small scar in 6 foot water depth | 0.0000016758 | 0.183802 |
| 6 | 18.33883333<br>18.33886667 | -65.56858333<br>-65.56858333 | scar approximately one foot wide | 0.0000328061 | 3.598173 |
| 7 | 18.33893333<br>18.33893333 | -65.56868333<br>-65.56866667 | linear prop scar | 0.0000171849 | 1.884840 |
| 8 | 18.33895<br>18.33891667 | -65.56871667<br>-65.56873333 | scar left a trench approximately 4 inch deep sidecast | 0.0000363377 | 3.985519 |
| 9 | 18.33895<br>18.33895 | -65.56876667<br>-65.56871667 | small scar in terms of depth | 0.0000487706 | 5.349159 |
| 10 | 18.33898333<br>18.33900 | -65.56871667 -<br>65.56875 | scar | 0.0000380413 | 4.172370 |
| 11 | 18.33900<br>18.33898333 | -65.56871667 -<br>65.56868333 | scar with y form where prop entered bed | 0.0000378170 | 4.147769 |
| 12 | 18.33896667<br>18.33898333 | -65.56865 -<br>65.56861667 | scar in 4 foot depth thin then rounded at one end<br>anchor damage | 0.0000365996 | 4.014244 |
| 13 | 18.33895 | -65.56876667 | small scar | 0.0000024427 | 0.267915 |

Polygons

| ID | LATITUDE | LONGITUDE | INFO | AREA (SQMETERS) | ACRES |
|---|---|---|---|---|---|
| 1 | 18.3398 | -65.56881667 | polygon around area with anchor impacts | 1792.4256576000 | 0.442793 |
| | 18.33958333 | -65.5688 | | | |
| | 18.33941667 | -65.56863333 | | | |
| | 18.33951667 | -65.56846667 | | | |
| | 18.33976667 | -65.56846667 | | | |
| | 18.33998333 | -65.56841667 | | | |
| | 18.33993333 | -65.56841667 | | | |

Table 3. Locations of impacted areas around Cayo Icacos

| Point Scars, Northwest seagrass bed | | | |
|---|---|---|---|
| ID | LATITUDE | LONGITUDE | INFO |
| 262 | 18.38935000 | -65.59376667 | anchor mark |
| 263 | 18.38935000 | -65.59376667 | anchor mark |
| 264 | 18.38931667 | -65.59376667 | anchor mark |
| 265 | 18.38916667 | -65.59376667 | anchor mark |
| 266 | 18.38910000 | -65.59370000 | anchor mark |
| 271 | 18.38940000 | -65.59375000 | anchor mark |
| 272 | 18.38943333 | -65.59376667 | anchor mark |
| 273 | 18.38943333 | -65.59378333 | anchor mark |

| Polygon, Northwest seagrass bed | | | | | |
|---|---|---|---|---|---|
| ID | LATITUDE | LONGITUDE | INFO | AREA (SQMETERS) | ACRES |
| 1 | 18.38930000 | -65.59371667 | impact in area apparently anchor | 10.8267321600 | 0.0026745880 |
| | 18.38925000 | -65.59373330 | | | |
| | 18.38925000 | -65.59370000 | | | |

| Point Scars, Seagrass bed adjacent to southern beach | | | |
|---|---|---|---|
| ID | LATITUDE | LONGITUDE | INFO |
| 274 | 18.38223333 | -65.58971667 | anchor damage |
| 275 | 18.38223333 | -65.58966667 | anchor damage |
| 276 | 18.38223333 | -65.58960000 | anchor damage |
| 277 | 18.38221667 | -65.58956667 | anchor damage |
| 278 | 18.38245000 | -65.58923333 | anchor damage |
| 279 | 18.38246667 | -65.58918333 | anchor damage |
| 280 | 18.38260000 | -65.58906667 | anchor damage |
| 281 | 18.38263333 | -65.58900000 | anchor damage |
| 282 | 18.38263333 | -65.58900000 | anchor damage |
| 283 | 18.38263333 | -65.58896667 | anchor damage |
| 284 | 18.38261667 | -65.58893333 | anchor damage |
| 285 | 18.38260000 | -65.58890000 | anchor damage |
| 286 | 18.38261667 | -65.58883333 | anchor damage |

| | | | |
|---|---|---|---|
| 287 | 18.38253333 | -65.58841667 | anchor damage |
| 316 | 18.38233333 | -65.58835000 | possible blowout |
| 317 | 18.38248333 | -65.58831667 | possible blowout |
| 328 | 18.38253333 | -65.58841667 | anchor damage |

| Point Scars, Seagrass bed to southeast | | | |
|---|---|---|---|
| ID | LATITUDE | LONGITUDE | INFO |
| 341 | 18.38050000 | -65.58675000 | anchor damage, at least 10' deep |
| 342 | 18.38023333 | -65.58690000 | anchor damage, at least 10' deep |
| 343 | 18.38021667 | -65.58690000 | anchor damage, at least 10' deep |
| 344 | 18.38020000 | -65.58688333 | anchor damage, at least 10' deep |
| 345 | 18.38020000 | -65.58686667 | anchor damage, at least 10' deep |
| 346 | 18.38018333 | -65.58686667 | anchor damage, at least 10' deep |
| 347 | 18.38016667 | -65.58685000 | anchor damage, at least 10' deep |
| 348 | 18.38016667 | -65.58685000 | anchor damage, at least 10' deep |
| 349 | 18.38015000 | -65.58686667 | anchor damage, at least 10' deep |
| 350 | 18.38030000 | -65.58675000 | anchor damage, at least 10' deep |
| 351 | 18.38030000 | -65.58673333 | anchor damage, at least 10' deep |
| 352 | 18.38028333 | -65.58678333 | anchor damage, at least 10' deep |
| 353 | 18.38030000 | -65.58680000 | anchor damage, at least 10' deep |
| 354 | 18.38030000 | -65.58683333 | anchor damage, at least 10' deep |
| 355 | 18.38028333 | -65.58683333 | anchor damage, at least 10' deep |
| 356 | 18.38031667 | -65.58680000 | anchor damage, at least 10' deep |
| 357 | 18.38038333 | -65.58671667 | anchor damage, at least 10' deep |
| 358 | 18.38040000 | -65.58661667 | anchor damage, at least 10' deep |
| 359 | 18.38040000 | -65.58660000 | anchor damage, at least 10' deep |
| 360 | 18.38030000 | -65.58656667 | anchor damage, at least 10' deep |
| 361 | 18.38030000 | -65.58656667 | anchor damage, at least 10' deep |
| 362 | 18.38025000 | -65.58650000 | anchor damage, at least 10' deep |
| 363 | 18.38043333 | -65.58641667 | anchor damage, at least 10' deep |
| 364 | 18.38043333 | -65.58641667 | anchor damage, at least 10' deep |
| 365 | 18.38046667 | -65.58618333 | anchor damage, at least 10' deep |
| 366 | 18.38046667 | -65.58620000 | anchor damage, at least 10' deep |
| 367 | 18.38048333 | -65.58618333 | anchor damage, at least 10' deep |

| Polygons, Seagrass bed adjacent to southern beach | | | | | |
|---|---|---|---|---|---|
| ID | LATITUDE | LONGITUDE | INFO | AREA (SQMETERS) | ACRES |
| 1 | 18.38246667 | -65.58830000 | area of anchor damage | 29.9892661525 | 0.0074084156 |
| | 18.38245000 | -65.58828333 | | | |
| | 18.38240000 | -65.58828333 | | | |
| | 18.38240000 | -65.58833333 | | | |
| | 18.38238333 | -65.58831660 | | | |
| | 18.38236667 | -65.58835000 | | | |
| | 18.38241667 | -65.58835000 | | | |
| | 18.38241667 | -65.58830000 | | | |
| 2 | 18.38248333 | -65.58825000 | area of anchor damage | 44.5488269970 | 0.0110051450 |
| | 18.38246667 | -65.58823333 | | | |
| | 18.38243333 | -65.58823333 | | | |
| | 18.38240000 | -65.58825000 | | | |
| | 18.38241667 | -65.58826667 | | | |
| | 18.38241667 | -65.58828333 | | | |
| | 18.38240000 | -65.58830000 | | | |
| | 18.38243333 | -65.58830000 | | | |
| | 18.38246667 | -65.58828333 | | | |
| | 18.38246667 | -65.58826667 | | | |
| 3 | 18.38261667 | -65.58873330 | area of anchor damage | 0.0879611839 | 0.0000217295 |
| | 18.38265000 | -65.58873330 | | | |
| 4 | 18.38265000 | -65.58878333 | area of anchor damage | 9.9155904705 | 0.0024495036 |
| | 18.38265000 | -65.58875000 | | | |
| | 18.38261667 | -65.58875000 | | | |
| | 18.38263333 | -65.58878333 | | | |
| 5 | 18.38265000 | -65.58881667 | area of anchor damage | 3.9481723871 | 0.0009753390 |
| | 18.38266667 | -65.58880000 | | | |
| | 18.38263330 | -65.58880000 | | | |
| 6 | 18.38250000 | -65.58835000 | area of anchor damage | 14.8303735049 | 0.0036636298 |
| | 18.38248333 | -65.58836667 | | | |
| | 18.38245000 | -65.58836667 | | | |
| | 18.38243333 | -65.58835000 | | | |
| | 18.38245000 | -65.58835000 | | | |
| | 18.38246667 | -65.58833333 | | | |

Table 4. Locations of mechanical impacts in area of Cabezas de San Juan

| Point Scars | | | | | |
|---|---|---|---|---|---|
| ID | LATITUDE | LONGITUDE | | | |
| 421 | 18.37266 | -65.63103 | | | |
| 422 | 18.37285 | -65.63073 | | | |
| 423 | 18.37304 | -65.63026 | | | |
| 432 | 18.37395 | -65.62936 | | | |
| 433 | 18.37394 | -65.62935 | | | |
| 503 | 18.37843 | -65.62673 | | | |
| 504 | 18.37838 | -65.62674 | | | |
| Linear Scars | | | | | |
| ID | | | INFO | LENGTH (FT) | METERS |
| 1 | 18.37180<br>18.37181 | -65.63176<br>-65.63175 | propeller scar | 0.0000146171 | 1.6032035280 |
| 2 | 18.37367<br>18.37359 | -65.62977<br>-65.62966 | anchor impact, jet ski, or walking | 0.0001405403 | 15.4144601040 |
| 3 | 18.37379<br>18.37382 | -65.62943<br>-65.62950 | anchor impact, jet ski, or walking | 0.0000831528 | 9.1201991040 |

Table 5. Locations of surveyed acroporid corals in area of Cayo Lobos

| Cayo Lobos | | | |
|---|---|---|---|
| ID | LATITUDE | LONGITUDE | INFO |
| 368 | 18.37478333 | -65.57203333 | cervicornis |
| 369 | 18.37465000 | -65.5721 | cervicornis |
| 370 | 18.37450000 | -65.57205 | more rubble begins, less live cervicornis |
| 371 | 18.37440000 | -65.57195 | end of sand, more sand, deeper, cervicornis |
| 372 | 18.37436667 | -65.57181667 | remains of palmata |
| 373 | 18.37436667 | -65.57163333 | live cervicornis and rubble |
| 374 | 18.37465000 | -65.57095 | live cervicornis and rubble |
| 375 | 18.37468333 | -65.57075 | live cervicornis and rubble |
| 376 | 18.37473333 | -65.57068333 | once dominated by large palmata colonies |
| 377 | 18.37471667 | -65.570-65 | once dominated by large palmata colonies |
| 378 | 18.37468333 | -65.57061667 | once dominated by large palmata colonies |
| 379 | 18.37471667 | -65.57055 | cervicornis |
| 380 | 18.37476667 | -65.57046667 | small, live palmata colonies |
| 381 | 18.37473333 | -65.57043333 | small, live palmata colonies |
| 382 | 18.37455000 | -65.5704 | patch reef, once large palmata colony |
| 383 | 18.37465000 | -65.57018333 | area of enormous dead palmata colonies |
| 384 | 18.37455000 | -65.57013333 | cervicornis |
| 385 | 18.37428333 | -65.56998333 | cervicornis |
| 386 | 18.37420000 | -65.56978333 | cervicornis |
| 387 | 18.37431667 | -65.56956667 | cervicornis |
| 388 | 18.37440000 | -65.5696 | cervicornis and dead palmata |
| 389 | 18.37448333 | -65.5695 | cervicornis |
| 390 | 18.37441667 | -65.56928333 | dense cervicornis thickets |
| 391 | 18.37441667 | -65.56863333 | cervicornis thickets and dead palmata |
| 392 | 18.37436667 | -65.56851667 | cervicornis and areas of palmata colonies |
| 393 | 18.37451667 | -65.56855 | cervicornis and areas of palmata colonies |
| 394 | 18.37491667 | -65.56845 | cervicornis and areas of palmata colonies |
| 395 | 18.37501667 | -65.5684 | dense cervicornis thicket, dead palmata |
| 396 | 18.37515000 | -65.56823333 | areas of cervicornis and palmata |
| 397 | 18.37530000 | -65.56826667 | small, live palmata colony |
| 398 | 18.37531667 | -65.56836667 | areas of cervicornis and palmata |
| 399 | 18.37546667 | -65.57233333 | areas of cervicornis and palmata |
| 400 | 18.37561667 | -65.57246667 | small palmata colony |
| 401 | 18.37563333 | -65.5726 | palmata and cervicornis |
| 402 | 18.37563333 | -65.57271667 | cervicornis |
| 403 | 18.37585000 | -65.57326667 | cervicornis |
| 404 | 18.37575000 | -65.57328333 | cervicornis |
| 405 | 18.37568333 | -65.57331667 | cervicornis |
| 406 | 18.37558333 | -65.57323333 | cervicornis |
| 407 | 18.37545000 | -65.57318333 | some cervicornis colonies but dominated more by gorgonia |
| 408 | 18.37535000 | -65.57305 | some cervicornis colonies but dominated more by gorgonia |
| 409 | 18.37533333 | -65.57296667 | some cervicornis colonies but dominated more by gorgonia |
| 410 | 18.37530000 | -65.5729 | some cervicornis colonies but dominated more by gorgonia |
| 411 | 18.37521667 | -65.57281667 | cervicornis but more rubble than live colonies |
| 412 | 18.37506667 | -65.57263333 | cervicornis but more rubble than live colonies |
| 413 | 18.37503333 | -65.57258333 | cervicornis but more rubble than live colonies |
| 414 | 18.37496667 | -65.57253333 | patches of live cervicornis and rubble of it |
| 415 | 18.37488333 | -65.57238333 | patches of live cervicornis and rubble of it |
| 416 | 18.37483333 | -65.5723 | patches of live cervicornis and rubble of it |
| 417 | 18.37470000 | -65.5722 | cervicornis, end of area and final pt |

Table 6. Locations of surveyed acroporid corals in area of La Blanquilla

| La Blanquilla | | | |
|---|---|---|---|
| ID | LATITUDE | LONGITUDE | INFO |
| 516 | 18.36540 | -65.54158 | palmata |
| 517 | 18.36680 | -65.54182 | varias palmata colonies |
| 518 | 18.36697 | -65.54188 | various palmata colonies |
| 519 | 18.36721 | -65.54198 | various palmata colonies |
| 520 | 18.36796 | -65.54897 | various palmata colonies |
| 521 | 18.36908 | -65.54910 | various palmata colonies |
| 522 | 18.36964 | -65.54861 | various palmata colonies |
| 523 | 18.36970 | -65.54876 | various palmata colonies |
| 524 | 18.37050 | -65.54834 | various palmata colonies |
| 525 | 18.37039 | -65.54859 | various palmata colonies |
| 526 | 18.37035 | -65.54893 | various palmata colonies |
| 527 | 18.37038 | -65.54951 | more than 20 colonies, palmata |
| 528 | 18.37034 | -65.55050 | more than 20 colonies, palmata |
| 529 | 18.37004 | -65.55062 | more than 20 colonies, palmata |
| 530 | 18.36976 | -65.55072 | more than 20 colonies, palmata |
| 531 | 18.36988 | -65.55337 | palmata |
| 532 | 18.36976 | -65.55358 | southern border of Acropora area |
| 533 | 18.36961 | -65.55389 | southern border of Acropora area |
| 534 | 18.36951 | -65.55424 | southern border of Acropora area |
| 535 | 18.36969 | -65.55454 | southern border of Acropora area |
| 536 | 18.37008 | -65.55476 | southern border of Acropora area |
| 537 | 18.37034 | -65.55492 | southern border of Acropora area |
| 538 | 18.37030 | -65.55534 | between keys |

Table 7. Locations of surveyed acroporid corals in area of Cayo Diablo

| Cayo Diablo | | | |
|---|---|---|---|
| ID | LATITUDE | LONGITUDE | INFO |
| 61 | 18.36092 | -65.53337 | palmata with some cervicornis in area |
| 61palm | 18.36043 | -65.52838 | palmata and prolifera |
| 505 | 18.36188 | -65.53449 | mainly palmata |
| 506 | 18.36196 | -65.53473 | mainly palmata |
| 507 | 18.36204 | -65.53486 | mainly palmata |
| 508 | 18.36258 | -65.53488 | mainly palmata |
| 509 | 18.36312 | -65.53466 | mainly palmata |
| 510 | 18.36328 | -65.53454 | mainly palmata |
| 511 | 18.36349 | -65.53440 | mainly palmata |
| 512 | 18.36374 | -65.53463 | mainly palmata |
| 513 | 18.36374 | -65.53471 | mainly palmata |
| 514 | 18.36399 | -65.53459 | mainly palmata |
| 515 | 18.36247 | -65.53583 | mainly palmata |

Table 8.  Locations of surveyed acroporid corals in area of Cayos Palomino and Palominito

| Palomino/Palominito | | | |
|---|---|---|---|
| ID | LATITUDE | LONGITUDE | INFO |
| 540 | 18.34640000 | -65.55981000 | palmata colonies |
| 541 | 18.34630000 | -65.55975000 | palmata colonies |
| 542 | 18.34581000 | -65.55975000 | palmata colonies |
| 543 | 18.34506000 | -65.55959000 | palmata colonies |
| 544 | 18.34419000 | -65.55980000 | palmata colonies |
| 545 | 18.34377000 | -65.55950000 | palmata colonies |
| 546 | 18.34353000 | -65.55947000 | palmata colonies |
| 547 | 18.34239000 | -65.55831000 | palmata colonies |
| 548 | 18.34139000 | -65.55856000 | palmata colonies |
| 549 | 18.34123000 | -65.55870000 | palmata colonies |
| 550 | 18.34076000 | -65.55867000 | palmata colonies |
| 551 | 18.34087000 | -65.55879000 | palmata colonies |
| 552 | 18.34072000 | -65.55887000 | palmata colonies |
| 553 | 18.34057000 | -65.55877000 | palmata colonies |
| 554 | 18.34059000 | -65.55857000 | palmata colonies |
| 555 | 18.34074000 | -65.55849000 | palmata colonies |
| 556 | 18.34095000 | -65.55855000 | palmata colonies |
| 557 | 18.34057000 | -65.55886000 | palmata colonies |
| 558 | 18.33955000 | -65.55999000 | palmata colonies |
| 559 | 18.33940000 | -65.56050000 | palmata colonies |
| 560 | 18.33942000 | -65.56059000 | palmata colonies |
| 561 | 18.33938000 | -65.56075000 | palmata colonies |
| 562 | 18.33935000 | -65.56091000 | palmata colonies |
| 563 | 18.33910000 | -65.56130000 | palmata colonies |
| 564 | 18.33922000 | -65.56130000 | palmata colonies |
| 565 | 18.33932000 | -65.56140000 | palmata colonies |
| 566 | 18.33948000 | -65.56105000 | palmata colonies |
| 567 | 18.33963000 | -65.56104000 | palmata colonies |
| 568 | 18.33972000 | -65.56102000 | palmata colonies |
| 569 | 18.33985000 | -65.56102000 | palmata colonies |
| 570 | 18.33970000 | -65.56110000 | palmata colonies |
| 571 | 18.33944000 | -65.56144000 | palmata colonies |
| 572 | 18.33911000 | -65.56160000 | palmata colonies |
| 573 | 18.33907000 | -65.56161000 | palmata colonies |
| 574 | 18.33857000 | -65.56283000 | palmata colonies |
| 576 | 18.33903000 | -65.56458000 | cervicornis colonies |
| 577 | 18.33886000 | -65.56464000 | cervicornis colonies |
| 578 | 18.33889000 | -65.56486000 | cervicornis colonies |
| 579 | 18.33827000 | -65.56523000 | cervicornis in area with porites many parts of colonies are dead |
| 580 | 18.33697000 | -65.56673000 | palmata colonies various sizes some cervicornis areas some dead |
| 581 | 18.33658000 | -65.56804000 | palmata colonies various sizes some cervicornis areas some dead |
| 582 | 18.33676000 | -65.56836000 | palmata colonies various sizes some cervicornis areas some dead |
| 583 | 18.33672000 | -65.56833000 | palmata colonies various sizes some cervicornis areas some dead |
| 584 | 18.33676000 | -65.56857000 | palmata colonies various sizes some cervicornis areas some dead |
| 585 | 18.33702000 | -65.56868000 | palmata colonies various sizes some cervicornis areas some dead |
| 586 | 18.33704000 | -65.56861000 | palmata colonies various sizes some cervicornis areas some dead |
| 587 | 18.33707000 | -65.56850000 | palmata colonies various sizes some cervicornis areas some dead |
| 588 | 18.33713000 | -65.56884000 | palmata colonies various sizes some cervicornis areas some dead |
| 589 | 18.33722000 | -65.56894000 | palmata colonies various sizes some cervicornis areas some dead |