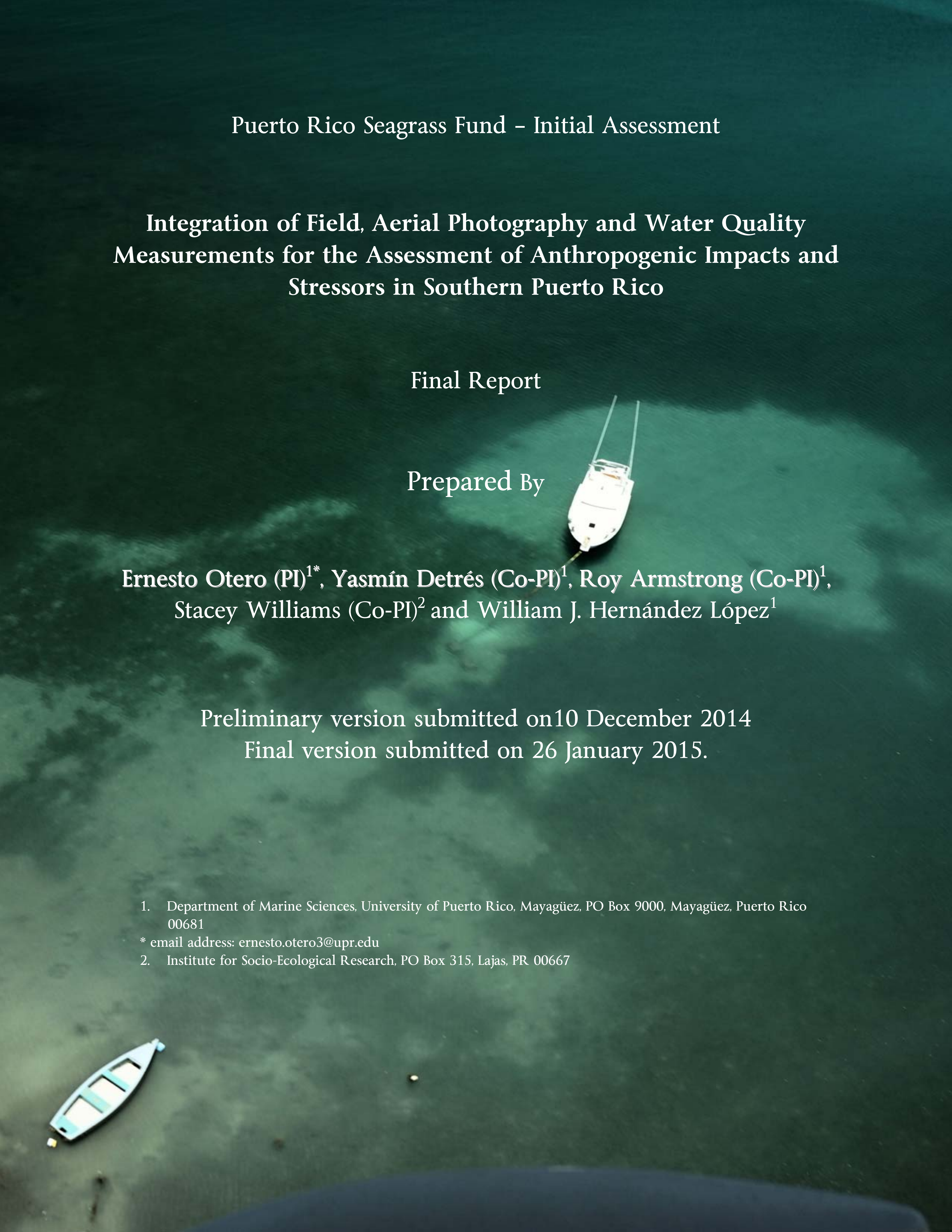

Puerto Rico Seagrass Fund – Initial Assessment

Integration of Field, Aerial Photography and Water Quality Measurements for the Assessment of Anthropogenic Impacts and Stressors in Southern Puerto Rico

Final Report

Prepared By

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Impacts on Seagrasses

Clockwise from the top left: Boats and private piers at San Jacinto, Guánica. Scars can be observed towards the coast while boat mooring effects resemble blowouts; Storm water pumping station at Guánica Bay; Storm water pipe discharge at Playa de Ponce; Turbidity plume at a low human impacted zone; dock and mooring halo effects in Guánica coast.

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Summary

This work presents the results of a unique study conducted in Southern Puerto Rico. A fast and intensive region-wide survey from Punta Jorobado to Punta Petrona was conducted to evaluate the extension and intensity of anthropogenic stressors on shallow seagrass habitats. This task was challenging because it covered a wide variety of ecosystems from estuarine mangroves to coral reefs, coastal to offshore. A series of approaches were used. Aerial surveys and photography as well as on the ground observations were used to detect areas of interest. The products of this work are based on the evaluation of observations of up to 700+ stations. In many of these, depending on field conditions, data on seagrass cover, turbidity, light attenuation, salinity and temperature were collected. Land erosion potential was also addressed at specific stations representative of different land uses. Overall, data on light attenuation and GIS derived metrics (proximity to urban development, recreation facilities, seagrass boating impacts and nutrient sources), and observations of land based sources of pollution and mechanical damages to seagrass beds were used to produce a Vulnerability Index which can serve as a research and management guide. According to the index, the most vulnerable seagrass habitats are associated with coastal areas of Guánica, Peñuelas and Santa Isabel based mainly on mechanical damage and nearness to high nutrient sources. Nearness to urban centers (development) is also an important factor, based on the index. Statistical analysis partially support a relationship between the absence of seagrasses and the distance to urban and recreational activities. A series of recommendations in management, policy, infrastructure, education and outreach, and research in support of management are provided.

Introduction

Seagrass habitats are important features of coastal marine systems in the Caribbean and considered one of the main pillars of coral reef ecosystems. The ecosystem value of seagrass beds has been estimated to be similar or even higher than those of mangroves/saltmarshes and reefs (Constanza et al 1997). The primary productivity of seagrass habitats is equal to or greater than that of cultivated terrestrial systems and similar to that of coral reefs (Duarte and Chiscano, 1999 and Dawes, 1986). This high production potential plays an important role in marine food webs and in carbon sequestration (Hemminga and Duarte, 2000). Overall, seagrasses provide habitat for numerous types of organisms including crustaceans, fishes, echinoderms, mollusks and algae. Seagrass beds also support managed species such as conch, snappers, sea turtles, and manaties (Musick and Limpus, 1997; Bjorndal, 1997; Greenway, 1995; Aguilar-Perera, 2004). The proximity and connectivity of seagrass habitats with reefs and mangroves encourage cross habitat utilization by marine species as well as trophic transfer (Orth, et al. 2007; Musick and Limpus, 1997; Bjorndal, 1997; Greenway, 1995).

The extent of seagrass habitats is sometimes obscured by temporal changes that in part are modulated by wave energy, light penetration and human disturbances (Fonseca et al, 1998). Mechanical impacts, such as propeller scarring, affect structural changes in seagrasses resulting in increased susceptibility of seagrass beds. Previous efforts (http://www.uprm.edu/cima/seagrass%20impacts.html) have reported on mechanical impacts to seagrasses in Puerto Rico. Other impacts of yet unknown spatial consequences include those from elevated nutrient inputs due to human activities (sewage, stormwater) or increases in soil erosion leading to sediment transport to nearshore waters. Most of the countries in the Wider Caribbean Region have reported high levels of sediments on the coastal zones among their major environmental problems (UNEP 1999). Anthropogenic activities such as agriculture and urbanization often impact the processes of erosion and sedimentation. Increased sediment loads and increased sediment-attached nutrients can contribute to reduced water quality in coastal areas and area associated with potential degradation of marine ecosystems.

The present report expands our knowledge of anthropogenic impacts on seagrass habitats and encompasses the first stage of the ***PR Seagrass Fund Initial Assessment*** that is, a summary of the initial findings and a list of future projects and recommendations that will enhance conservation of seagrass habitats in the geographic area from Punta Jorobado, Guánica to Punta Petrona, Santa Isabel and adjacent islands.

Major Work Goals

The major objectives of the work were:

- Identify factors related to anthropogenic seagrass habitat degradation along shallow areas within the study area.
- Evaluate the extension or intensity of the effects of the above factors;
- Enhance existing GIS coverage and create new maps to help prioritize future conservation efforts in hotspots of anthropogenic seagrass impacts (Vulnerability Index)
- Provide guidance to management agencies in the form of a list of prioritized activities that will most effectively promote seagrass conservation within the study area. This list will consider the allocation of resources to assure the best long-term benefits for seagrass conservation.

In order to provide the best information to address the above goals, the team used a stepwise approach where:

1. GIS was used to define the range of seagrass habitats to be examined. NOAA Benthic Habitat maps (http://ccma.nos.noaa.gov/ecosystems/coralreef/usvi_pr_mapping.aspx) and a maximum depth of 4m (as defined in the scope of work) based on digital elevation models (DEM's) data for southern Puerto Rico were used to focus on primary target areas.

2. Field visits and an aerial survey followed. Although most of the locations were visited by boat, others were accessed by swimming, by land or kayaking due to limited water depth or other navigational hazards (i.e. reefs). Underwater photography was used to estimate the presence of seagrass species and seagrass cover (SSSC) at predetermined locations. Water quality (salinity, turbidity, light attenuation) was also estimated to complement SSSC data.

3. Additional stations to those selected during the planning stages were also visited based on reports that came to our attention after the initiation of the project (García, pers. comm.) or based on our overflight observations. These additional visits helped to confirm the presence of seagrasses in areas not indicated in NOAA's Benthic maps.

4. Aerial photography and GIS were used to develop a delineation of land uses and coastal structures potentially impacting seagrass habitats. Field data on propeller scarring and boat anchoring effects were also integrated into the GIS.

5. Soil erosion potential was evaluated using the Revised Universal Soil Loss Equation, Version 2 (RUSLE2; http://fargo.nserl.purdue.edu/rusle2_dataweb/RUSLE2_Index.htm), an empirically based model developed by the USDA-Agricultural Research Service (ARS), the USDA-Natural Resources Conservation Service (NRCS), and the University of

Tennessee, was used to predict average-annual soil loss from erosion caused by rainfall. This model considers effects of climate, soil erodibility, topography, cover management and support practices in a broad range of cropland, pasture, construction, and forestry sites.

Methods

Sampling Sites Selection

Sites were randomly selected within the seagrass polygons identified in the NOAA benthic habitat maps using ARCGIS. Sites were initially selected between depth contours from 0-4m, but later from 1-4m. The position of stations was changed if the location was too deep or shallow for safe navigation. In the latter case, locations were revisited using kayaks or by snorkeling. The number of sites per polygon was dependent on the total area of the polygon and surrounding possible impacts. Areas with anticipated potential impacts (i.e. mechanical, pollution) were identified as priority areas.

Overflights

An aerial recognizance was facilitated by biologists from the Puerto Rico Department of Natural and Environmental Resources (PRDNER) Marine Resources Division, Edwin Rodríguez and Maribel Rodríguez. The low level overflight (ca. 500ft) was conducted on 23 June 2014 and covered the entire sampling region enabling us to identify priority areas where mechanical or other potential anthropogenic impacts could be of significance. A selection of the photographs taken during the overflight were geotagged using RoboGeo (Ver. 6.3.2). These were used to recreate the overflight sequence for later reference by projecting the location of the shots in formats compatible with Google Earth and ArcGIS. These are available in the Electronic File Appendix (EFA) at the end of the report.

In-Water Surveys

Field Work Schedule and Visits to Selected Sampling Sites

Field work was conducted from 11 June -1 August 2014. Site visits were guided using shipboard or hand held WAAS-GPS units (Garmin) for a nominal horizontal accuracy of 2-3m, although due to environmental conditions (higher winds, water currents or waves) <10m offset was considered acceptable for the project goals. Once at the station, the depth was checked using a handheld transducer positioned vertically over the bulwark. Stations deeper than 4m were repositioned to shallower waters or eliminated. Programmed visits were those from 11 June-15 July. Additional visits were conducted to corroborate field observations, information from previous reports, or to collect photographic evidence of coastal structures or other potential sources of anthropogenic inputs. Additional site visits were conducted on 9 October (for water quality assessment within the Guánica region) and on 15 October (to evaluate benthic conditions surrounding shipwrecks in Tallaboa).

Underwater Photography and Determination of Seagrass Cover

Underwater photography was used to estimate seagrass cover in the field. An Aqua-Vu Micro 5 shipboard system wide angle camera was fitted to a weighed frame in a vertical position and videos were collected at two locations within a 10m radius of the station waypoint. Enough scope was given to the camera and frame umbilical line to keep it motionless over the seafloor to record the best possible videos. Due to extreme low light conditions, some of the shots were too dark to analyze. Towards the end of the site visits, an additional camera with better resolution (Go-Pro) was attached to the frame in order to collect photographs which enabled better discrimination of benthic community composition. In addition to shipboard photographic documentation of seagrass cover, snorkelers used handheld cameras and WAAS enabled GPS at shallow or non-navigable sites. Underwater photographs were taken while kayaking by submerging a handheld camera pointing downward on one side.

Estimates of cover were conducted on the basis of 0.25m^2 quadrat (the base of the frame used to take underwater photographs served as quadrat). However, due to the constraint of space and maneuverability while visiting sites using kayaks, no frame was included and thus estimates for the 1 August 2014 visit were qualitative. On other occasions, hand held cameras and a quadrat was used while snorkeling.

Once at the laboratory, photos and videos were visually analyzed by a single person to minimize error. For the video analysis, estimates of cover were made from the portion of the video when the camera frame stayed on the bottom for some seconds. Videos and photos were visually evaluated for the presence of seagrass species and total percent cover seagrass. Coral Point Count (CPCe; Kohler and Gill, 2006) software was used to determine percent cover for 20 quadrants. Those quadrats were then classified on a 0 - 3 scale (Appendix 1) and were used as a guide for the visual analyst during the percent cover determination.

Water Quality

Water quality evaluation included general physical, chemical and optical measurements. Temperature and salinity were determined using a YSI Pro Plus Multimeter (June 11) or a YSI CastAway CTD (rest of the time). A SCUFA II (Turner Designs) was used to collect turbidity data. A Secchi disk was used to evaluate light penetration or light availability at depth. An underwater photosynthetically active radiation (PAR) sensor (Licor) was used to calculate attenuation coefficients (Kd_{PAR}) at different locations. Downwelling irradiance values were collected at surface, and at 1m and 2m depths. The PAR data was used to calculate PAR attenuation coefficients (K_{dPAR}), which could be used to calculate the available light at any depth at different locations during the time of sampling. The Kd_{PAR} at each site was estimated as in Kirk (2011):

$$Kd_{PAR} = [\ln(E_{z1}/E_{z2})] \div (Z2-Z1);$$

where:

$Kd_{PAR\Delta d}$ is the attenuation coefficient of PAR at a specific depth interval,
Z1 and Z2 are the shallower and deeper depths (1 and 2m) and,
E_{Z1} and E_{Z2} are PAR values at the respective depths.

Geographic Information System (GIS)

Coastal and marine features within 1 km of the coastline were evaluated. For marine features, the area evaluated includes the seagrass areas surveyed. The classification was based on the USGS National Land Cover Dataset 1992 classification (NLCD, 1992) for land use (Table 1).

Table 1. Classification categories used during impact analysis.

Major Use	Subcategories
Barren	Industrial, Natural Areas, Urban
Beach	Natural areas
Boardwalk	Recreation, Urban
Coastal lagoon	Natural areas
Community	Urban
Dock	Industrial, Marine Structure, Recreation
Energy production	Industrial
Farm	Farm
Jetty	Marine structure
Marinas	Recreation
Moorings	Marine structure, Recreation
Other	Industrial, Marine Structure, Recreation, Urban
Outfall	Industrial
Parking	Urban
Potable water treatment	Industrial
Ramp	Recreation
Residential	Urban
Streams	Natural areas
Waste water treatment	Industrial
Water front house/condo/hotel	Urban

A high resolution aerial photograph (dated 2010) was used with 1 foot pixel resolution to evaluate the features. The features were delineated using polygons and defined as attributes as depicted in Table 1. An initial survey to a fixed scale of 1:5000 was done to identify large scale feature from the study area. A second analysis of the aerial photography was done at a 1:1000 scale to depict smaller features (ie. docks, ramps, sewer, etc.).

Anthropogenic Impacts

Records of visual confirmation of the presence of different forms of anthropogenic impacts on seagrasses were compiled and used as different layers of information in the GIS. The forms of anthropogenic impacts include:

1. Shoreline structures that may cause degradation of seagrass habitat;
2. Land-use patterns including but not limited to urbanization and agriculture;
3. Boating impacts including propeller scarring, propeller wash, anchoring and groundings;
4. High nutrient inputs, including the presence of sewage or storm water coastal inputs (outfalls), and the presence of filamentous (i.e. *Chaetomorpha*) or species of alage indicative of eutrophication (i.e. *Ulva lactuca*).

In addition, a collection of photographs was geotagged and included in the GIS and in a Google Earth compatible format for later reference (See EFA).

Propeller Scarring and other Boating Related Mechanical Impacts

Swimmer-operated WAAS-GPS units mounted on a floating platform or within an impermeable submersible case were used to trace the orientation of propeller scars at sites identified during the aerial survey following previous work (http://www.uprm.edu/cima/seagrass%20 impacts.html). The horizontal accuracy of these units can reach 3m or less most of the time depending upon satellite coverage. Positions were recorded and saved as waypoints on a GPS at intervals selected by the swimmer. Anchor scarring was represented by punctual positions and propeller scarring and/or anchor drag will be represented as lines or polygons, especially in areas where impacts to seagrass beds are too dense to be mapped as points or lines. Propellers wash estimates were made with available aerial photographs because these impacts are difficult to detect in the field potentially due to spatial scale. Usually, these effects are observed close to docks and anchoring sites and appears as an apparent denudation of bottom aquatic vegetation.

Potential Soil Erosion

The Soil Loss Potential (based on RUSLE 2) was determined for four selected coastal locations with different soil types, climate, topography, land use classification and management (Table 2).

Table 2. Locations selected for the application of RUSLE2.

Location	*Land Use Classification*	*Acres*
Santa Isabel	Annual crops (fruits & vegetables)	364.5
Ponce	Graze pastureland	2685.8
Guayanilla	Hayland from perennial grasses	456.1
Guánica	Forest Land *	318.4

*Guánica site includes forest land dominated by Pitahaya – Limestone soil type and an adjacent area consisting of urban development and Pitahaya – Limestone soil.

The application of RUSLE 2 required collaboration and support of USDA – NRCS, Mayagüez and Juana Díaz Service Center personnel since they have the knowledge, expertise and accessibility to the basic database required to run this model in Puerto Rico. Appendix 2 shows NRCS Conservation Plan Maps for the evaluated sites.

The potential soil input evaluation for individual fields comprised identification of different soil types per location, estimation of *Soil Loss Potential* (Tons/Acre/Yr) for each soil type, determination of the number of acres evaluated per soil unit, and final determination of *On Farm Gross Soil Loss Potential* (Tons/Acre/Yr) using the formula:

A = RKLSCP

where,

A = average erosion potential
R = climate erodibility
K = soil erodibility
L = slope length
S = slope steepness
C = cover management
P = conservation practices

Since management practices on agricultural lands have a significant impact on total sediment pollution in a watershed, potential soil erosion was calculated for two extreme scenarios. The "Bare Ground" scenario represents the conditions yielding maximum sediment loads and the "Conservation System" scenario is the potential soil loss when the most favorable conservation system is adopted to reduce sediment loss. During this work the soil conditions of the area of Juana Díaz approached bare ground conditions (see aerial photography in the EFA section). Soil management of the remaining areas were between both extremes during the sampling period.

Evaluation of Seagrass Cover and Light Attenuation Related Variables

Accuracy of Benthic Habitat Maps

The accuracy of the 2001 NOAA's benthic habitat maps in identifying seagrass habitats for the entire sampling region (Guánica to Santa Isabel) was examined based on our observations. In order to verify the accuracy of NOAAs habitat maps we ran a Wilcoxon Matched Pair Test. The test allowed us to determine if the data collected in the field were similar to that reported by NOAA in their benthic habitat map.

During 2010, the NOAA's Biogeography Branch updated the benthic habitat map off southwest Puerto Rico, extending from Guánica Bay to Cabo Rojo. This was part of a baseline characterization of Guánica Bay in support of an ongoing watershed restoration effort. A qualitative comparison of both map versions was conducted for the Guánica area.

One additional important assessment was that of relationships among variables that allowed the evaluation of light regime in seagrass habitats. Regression analysis was conducted for Kd(PAR) vs. Secchi depth and Turbidity. Data was naturally log transformed for the analysis for Kd(PAR) vs. Secchi and square-root (sqrt) transformed for the Kd(PAR) vs. turbidity analysis.

We used simple linear regressions to assess the relationship between Secchi disk depth (m) and attenuation coefficient (K_d). Secchi depth was the predictor variable and K_d was the response variable, and variables were naturally log transformed before running the regression.

Ordinal regressions were used to assess the associations between the sources of potential impacts measured in this study with seagrass presence/absence since the data was categorical. The potential impacts (see Table 3), were categorized by distance from impact, or by percent light availability (15% surface PAR at depth). Therefore, the predictor variables were formatted as nominal factors. We ran five separate ordinal regression models, in order to examine the influence of the five individual potential impacts and seagrass presence. All ordinal regression tests were run using SPSS 17.0, which uses PLUM (Polytomous Universal Model), an extension of the general linear model that uses ordinal categorical data.

Vulnerability Index

A Vulnerability Index (VI) was developed to evaluate the susceptibility of the seagrass habitat to the different sources of impact. A spatial correlation process was performed based on the geographic layers developed from various field sampling campaigns, digitizing of the coastal uses and impacts, and sources of high nutrients or mechanical impacts. The index is based on proximity to potential sources of impact and environmental conditions in the form of percent PAR availability during sampling. Table 3 shows the final threshold value criteria used for the VI. The data values for the parameters were obtained from the field sampling campaign and through GIS geo-processing to obtain the distance of point location from impact sources.

Table 3. Layers and parameter value criteria used for the vulnerability index.

Index Category	Parameters	Data values	Weight Index	Data Source
Depth	Depth values	0-2m, 2-4m		Field campaign
High Mechanical Damage Potential	Distance	<100m >100m	0-2m depth **(2)** 2-4m depth **<u>(1)</u>** 0-2m depth **(0)** 2-4m depth **<u>(0)</u>**	Impact classification (ocean:recreation; docks, moorings)
High Mechanical Damaged Areas	Distance	<500m >500m	**<u>1</u>** **<u>0</u>**	Field campaign
High Urban Areas	Distance	<500m >500m	**<u>1</u>** **<u>0</u>**	Impact Classification (urban)
High Nutrient Potential	Distance	<250m >250m	**<u>1</u>** **<u>0</u>**	Rivers, streams, and other sources (water treatment plants, etc.)
Percentage of light	% of light(Kd)	<15% >15%	**<u>2</u>** **<u>0</u>**	Field campaign

A binary weight system (mostly 0 or 1) was implemented to assign each parameter an influence in the final index, where zero (0) represents less influence of a specific parameter and one (1) represents more influence of that parameter. The depth ranges were also used in the analysis based on the parameter of Mechanical Damage Potential, where shallower points (0-2 meters) were considered to be more susceptible to these types of impacts than deeper ones (2-4 meters). A threshold value of <15% subsurface PAR was used to indicate the minimum light requirement for sustainable seagrass growth, based on the work of Dixon (2000). A score of 2 was given to sites where estimates of light reaching the bottom were <15% subsurface PAR since this parameter was considered dominant in explaining seagrass distribution. The selected distance for the parameters was based on field campaigns an in-depth analysis of the values of proximity obtained. The application of the above criteria results in a VI range of 0-6 directly proportional to the vulnerability of seagrass habitat at specific sites.

Results

Land/Coastal Classification

The Total Area analyzed for the classification of coastal impacts was 95,342 km2 (23,559 acres) an approximately 127 km shoreline. The municipalities included in the classification were Guánica, Yauco, Peñuelas, Ponce, Juana Díaz, and Santa Isabel. The major uses based on the categories used were: Urban (30%), Agriculture (28%), Industrial (22%), Natural Areas (19%, and Recreational Use (1%) (Figure 1).

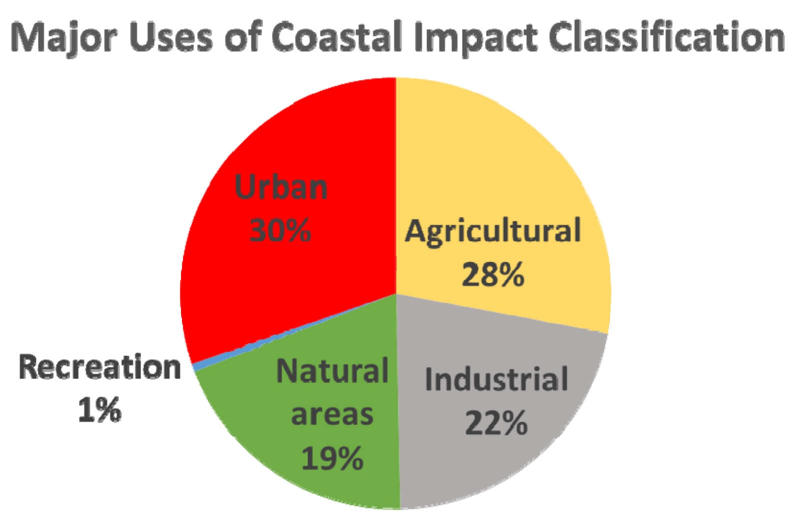


Figure 1. Proportion of major categories used within the impact classification scheme.

Some important findings were:

- The municipalities of Santa Isabel (39.9 %) and Juana Diaz (37.6%) comprised 77.5% of the total area in the Agriculture category.
- For the total Urban area classified, the municipality of Ponce comprised approximately 32.7 %.
- For the Recreation category, the municipality of Guánica (39.3%) and Ponce (27.4%) comprised 66.7% of the total area classified in this category.
- A total of 53 Recreation docks were found and of those 25 were located within the area of the municipality of Guánica.
- The total area of Recreation docks was 54,414.20 m^2, and of that 74% were in the Guánica area.

Extension of Seagrass Habitat

A total of approximately 24 km^2 of seagrass habitat was estimated as present within the 0-4 m contour interval within the study area. Approximately, 700 spot-check stations were visited to evaluate the condition of seagrasses. This information is available in kml format so that it can be accessed using Google Earth and thus increase access to all users. A view of a group of stations displaying some of the collected data is shown in Figure 2. In addition the same data is also available in an ArcGIS compatible format which will facilitate further analysis. All data is available and described in the EFA at the end of the document.

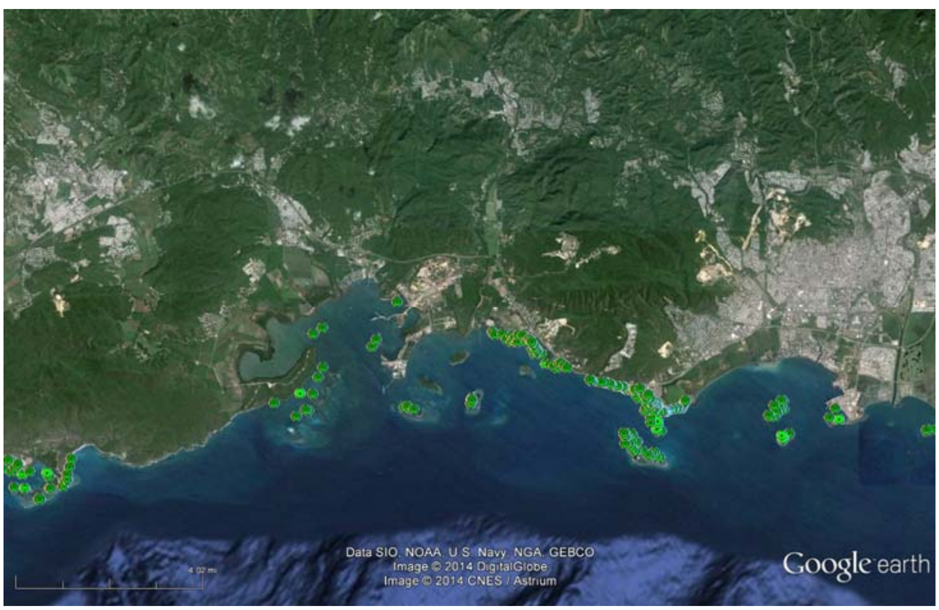


Figure 2. Google Earth screen of station locations throughout the study area

Seagrass Cover Analysis

Seagrass cover analysis was completed. Data was divided in regions using the boundaries of municipalities. Data are summarized in Figure 3 as percent of stations within each of the seagrass cover categories. Fifty to 79% of the sites in each region had >50% seagrass cover while 16-50% had no seagrasses. No data was collected on seagrass cover adjacent to EcoElectrica LNG pier and Cayo Palomas, Peñuelas because PI Otero has been conducting detailed studies on seagrass cover associated with those areas (http://www.ecoelectrica.com/images/Documents_pdf/2012%20Large%20Scale%20Seagrass%20Studies%20Final%2010%20Mar%2014.pdf). Seagrass cover at the LNG pier (17.97481N; 66.75986W) fluctuated from ca. 90% at the NE to none at the NW transects. Cayo Palomas (17.97627N; 66.74864W) seagrass cover was close to 90% to bare sand due to the presence of numerous blowouts.

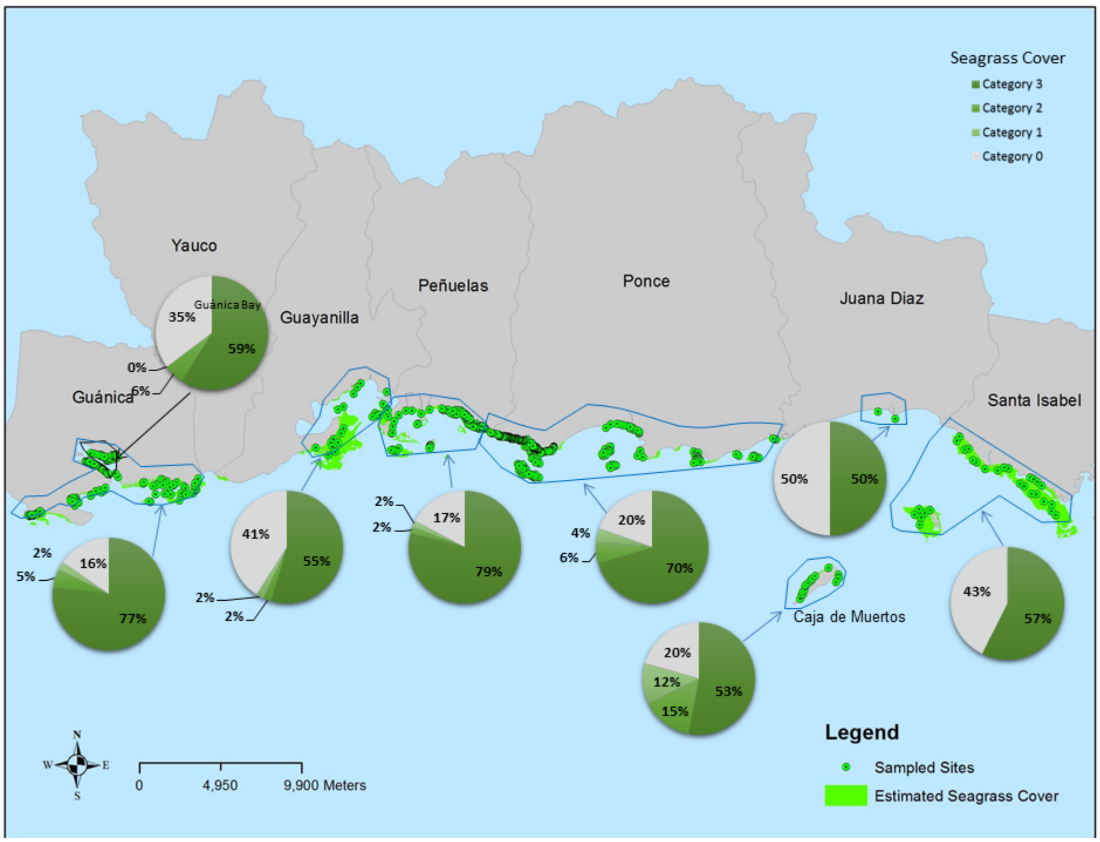


Figure 3. Proportion of seagrass sites at different regions. Polygons define stations within each region.

According to our field observations, Cayo Berbería contained the highest cover while the least cover was found some of the near shore areas of Juana Díaz and Santa Isabel characterized by high exposure to wave action (Juana Diaz) or adjacent to coastal development, boat traffic and some anchorage. Data for the Guánica Bay indicates further decrease of seagrass cover in contrast to the overall data for the region. This could be due to the increased turbidity, high light attenuation and even competition for space with the abundant macroalgae present in the area (Fig. 4)

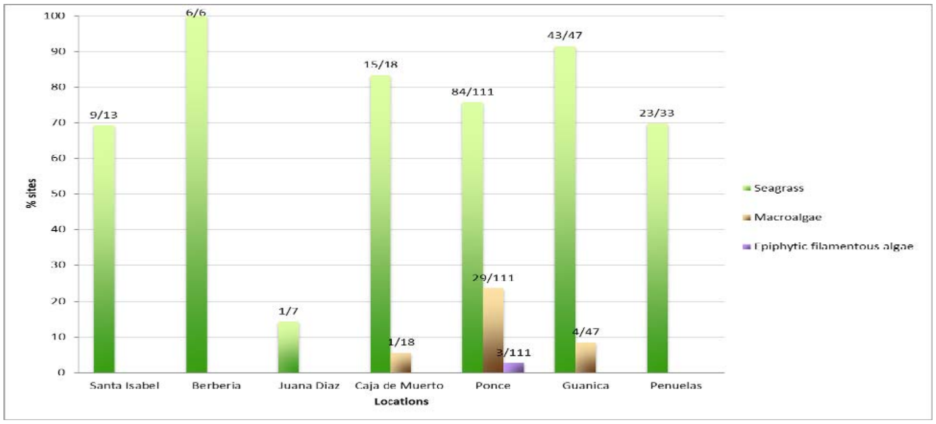


Figure 4. Percent of selected sites with seagrass cover, macroalgae and filamentous epiphytes.

Accuracy of Seagrass Layers from Benthic Maps

The overall accuracy of the NOAA benthic habitat map in identifying areas of seagrass presence was 66%. The areas where the benthic habitats map was the least accurate were Santa Isabel, followed by Guánica (Table 4). We found that our observations of seagrass presence were significantly different from what was reported in NOAA maps (Wilcoxon test, Z=7.97, p<0.0001).

Table 4. Estimates of accuracy of NOAA Benthic Maps in determining seagrass presence. All sites were assumed to contain seagrasses.

Locations	Seagrass (# of sites)	No Seagrass (# of sites)	% Accuracy
Guánica	67	46	59.29
Santa Isabel	16	14	53.33
Caja de Muertos	23	15	60.53
Guayanilla	23	11	67.65
Ponce	74	18	80.43

It is important to note that the coastline of La Pieza, Guánica was not included as seagrass areas in the NOAA benthic habitat map, when in fact, abundant *Halodule* and some *Thalassia* were also found at La Pieza (Fig. 5). Additional surveys in Ponce confirmed previous findings by García (pers comm.; Fig 5) that indicated the presence of seagrass cover along the coast of Playa de Ponce.

Figure 5. Coasts that showed significant growth of seagrasses but were not included in NOAA Benthic Maps are indicated in red.

A comparison of the seagrass habitat extension for the Guánica area, based on benthic habitat maps from 2001 and 2010 indicates a slight increase in seagrass extension during 2010 (Figure 6). This difference is minor and does not include the areas of seagrasses associated with La Pieza observed during this work.

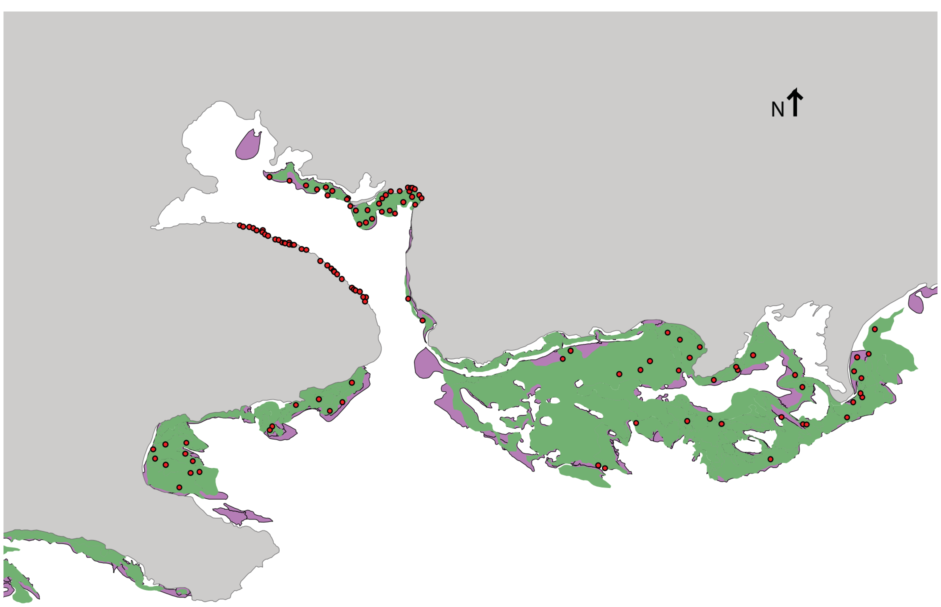


Figure 6. NOAA benthic habitat map of seagrass polygons from 1998 (green) and 2010 (purple) in the area of Guánica, Puerto Rico. Red dots indicate our seagrass sampling stations.

These observations have important management implications because stakeholders, state and federal government (i.e. PRDRNA, USACE) may base their management policies on information given in NOAA benthic habitat maps. Therefore, we feel that the NOAA map needs to be updated and revised.

The accuracy of the DEM was also assessed. Based on the random sites selected, the DEM was 79% accurate because some areas were significantly deeper than expected. These results suggest the need for field work to further validate and increasing the accuracy of these tools.

Boating Impacts

Various types of boating related activities were observed during the aerial survey that may increase human impacts on seagrass habitat. Mechanical effects were associated with anchoring, propeller wash, propeller scarring, ship groundings and docks.

Two zones were preliminarily identified as affected by propeller scarring during the aerial survey, the shallow area south of San Jacinto, Guánica, and the entrance close to the area of El Boquete, Ponce. However, of the two, the San Jacinto area was the most affected. This area is prone to scarring due to the shallow depths and the local boat traffic associated with adjacent

docks or anchoring (Fig. 7).

Figure 7. GPS based maps of boating impacts at San Jacinto, Guanica. Red lines are propeller scars. Green polygons are areas where scars were too many o count or where boats were anchored at the time of sampling.

The total length of the scars was 767.7 meters. The range of scar lengths is 3- 45m. Based on these lengths and using a 0.3 m average scar width, we estimated that 229.44 m^2 of seagrasses were affected by scarring at this site. Based on our preliminary evaluation using aerial photography and GIS, this propeller scar impact estimate is about 3% of the total impacted area (ca. 8,800 m^2) associated with nearby moorings and docks (including those north along the coast towards the Copamarina Hotel. These estimates suggest that propeller scarring at present is a low percentage of the total physical impacts on seagrasses. Other impacts such as propeller wash seem to be of higher significance and were evaluated further. However, the fact that the density of scarring seems to be higher at this site than at others examined (based on aerial observations) indicated that the boating pattern makes this area susceptible to mechanical impacts. Further analysis was conducted during the project as part of the filed work component.

As mentioned above, less prominent propeller scarring was observed at el Boquete. El Boquete, can be characterized as a muddy area where boat traffic is limited by the shallow depths (1-1.5m; Figure 8). Approximately 500m SW from El Boquete lie two grounded ships within the seagrass habitat the footprints of which caused impacts on their surroundings. Another site with some scarring was observed about 800m SE of El Boquete.

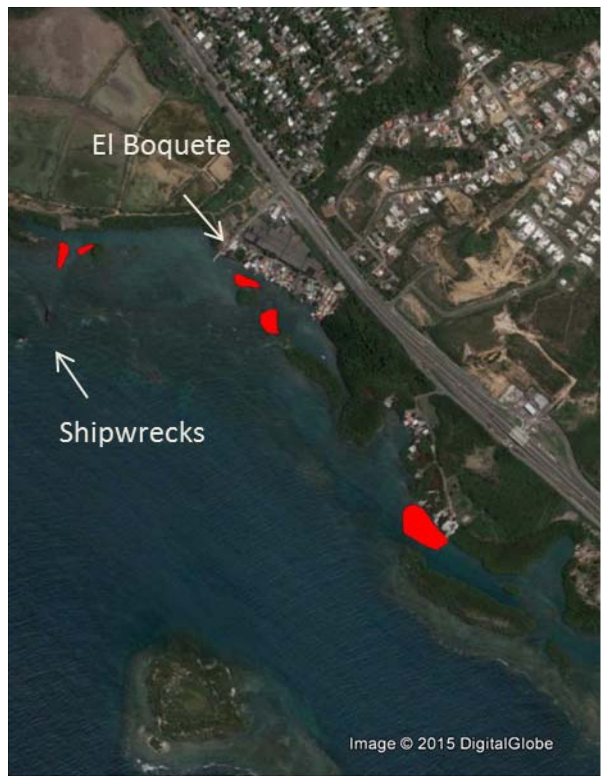


Figure 8. Additional boating impacts near El Boquete, Peñuelas, PR.

Figure 9 shows a closer look at these wrecks during an additional visit to the site during 10/15/2014. This visit was conducted to verify in detail impacts to the seagrass and to preliminarily evaluate in the field the feasibility of removal of these wrecks for later restoration. In summary, the observations corroborated the presence of a halo around each of the ships of about 7-10 m where little or no seagrass cover was observed. Also debris from the wreck was observed surrounding the area. No reef formation was observed in the periphery of the ships. Only shallow seagrass colonized sand banks were observed towards the NW. These banks display blowout patterns which culd be consistent with wave exposure. Some encrusting forms of corals (*Orbicella, Colpophyllia* and *Micetophyllia* spp.) were found growing on the protected surface of the ships. Pieces of these corals may be transplanted to other sites according to

Figure 9. Shipwrecks located in seagrass beds close to El Boquete.

agencies recommendations prior to any operation. Octocorals were found mostly on the hulls exposed to wave action. Georeferenced photographs collected during the visit to the shipwrecks can be viewed as ArcGIS or Google Earth compatible formats (see EFA).

As in the case of San Jacinto, the effects of docks and anchorages at these sites could be significant, however during our visits limited *Halodule* and *Thalassia* growth could be confirmed in this site. However, *Halophila* was observed in the shallows to the west of El Boquete, suggesting that this species may be found in the surrounding areas. However, no *Halophila* could be observed in the immediate channels.

Water Quality

<u>Of a total of 274 secchi</u> readings 22% were shallower than the depth at its corresponding location. These turbid conditions were found at all depths but dominated between 2-3m deep (Fig. 10).

<u>Salinity and Temperature</u> were uniform throughout the study area being 36.4 ±0.8 (mean±2SD) and 29.7±1.8 °C, respectively. Both salinity and temperature are within the reported tolerable range of seagrasses (optimal growth conditions for Thalassia sp have been reported as 23-31 °C and 25-35 PSU; van Tussenbroek, et al., 2007). The lack of evidence of significant inputs of fresh water even in Guánica and Guayanilla Bay indicate the severity of draught that characterized the sampling period.

Turbidity ranged from below detection at Caja de Muertos to > 8 NTU's (Fig. 11). The higher values dominated towards the coast and were most often observed within Guánica Bay. Turbidity higher than 2 NTU is not conducive to good availability of light for the development of dense seagrass stands at depths >5m based on recent data collected in Guayanilla Bay (Large Scale Seagrass Work).

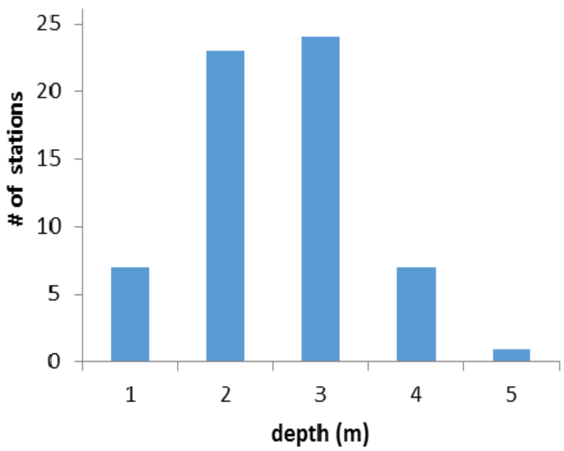


Figure 10. Frequency distribution of stations depth where Secchi readings were less than bottom depth.

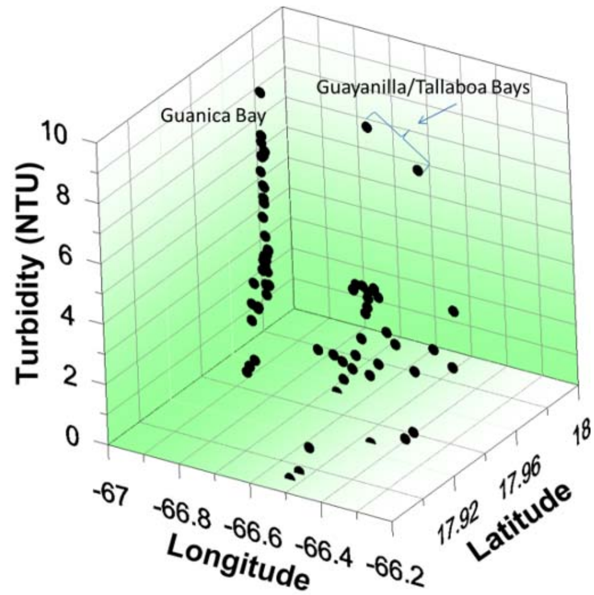


Figure 11. Turbidity estimates throughout the study area.

Photosynthetic light attenuation as represented by Kd_{PAR} ranged from <0.1 to >2 m-1, but 80 % of the measurements were <1 (Fig. 12). The depth at which seagrass growth might be limited by PAR availability for *Thalassia* has been estimated as that where ca. 15% of surface irradiance reaches (Dixon, 1999). This is in agreement with previous research by Lee and Dunton (1997).

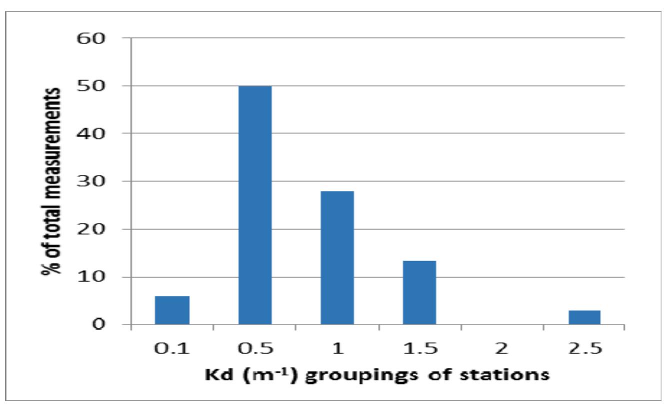


Figure 12. Frequency distribution of K_dPAR (m-1) at sampling locations.

Based on this threshold value and Kd(PAR), the range of depth at which light limitation is expected in the study fluctuates between <1m [in the most extreme situations (Guánica Bay) to ca. 22 m in the clearest waters sampled (Caja de Muertos]. However, based on the frequency distribution shown in Fig. 12, the most likely light limitation occurs at 4-15m followed by the 2-4m depth range.

The site specific potential for light limitation was evaluated using the actual depth at each site and calculated PAR levels at depth [Light availability=100*(EXP(-K_d*Z); Z= depth; Duarte (1991)]. However, since PAR was not measured in a significant number of stations and Secchi depths were collected more frequently, the regression of Kd(PAR) vs Secchi [***ln(Kd(PAR) = 0.0832-1.0571*ln(Secchi depth); r^2=0.7]*** was used to calculate the Kd's and thus expand the geographical extension of light limitation estimates. Figure 13 shows the results of light availability at depth based on these estimates and indicates that the overall maximum available light was >30% in all sites, and that the PAR levels estimates <15% can be found at Guánica Bay, Tallaboa and Santa Isabel (this last one being ca. 1% surface PAR).

We tested the covariation of turbidity and Kd(PAR) using the data collected from June –August

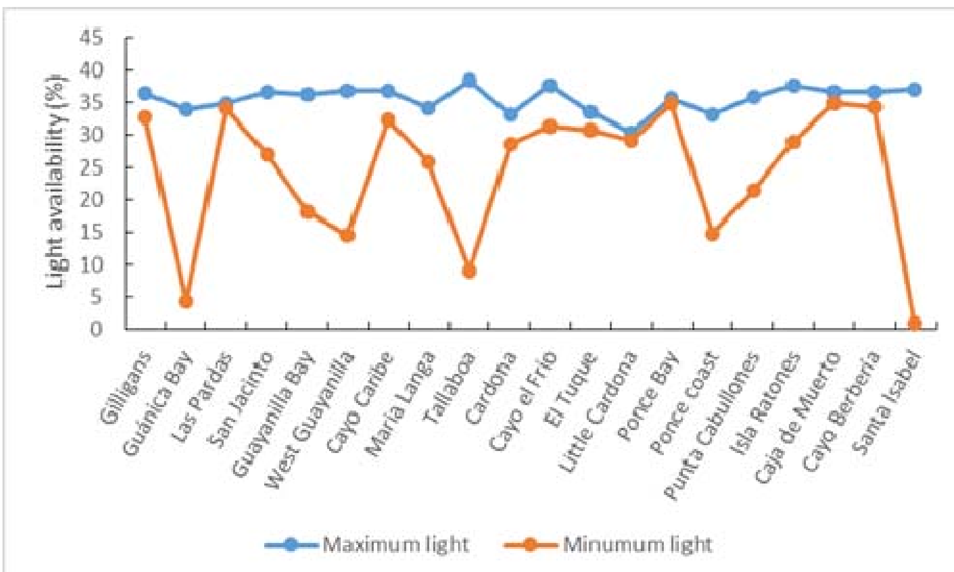


Figure 13. Maximum and minimum Surface PAR availability (%) at general locations within the study area.

2014 since turbidity is an important factor modulating light attenuation. The results indicated that square root transformed data of both variables covaried linearly [***sqrt(Kd(PAR)=0.326(sqrtTurb)+ 0.349; r^2= 0.69***]. This result is important since at times environmental conditions make difficult or impossible the collection of precise measurements of light attenuation while turbidimeters are sturdy and relatively easier to use during those conditions. Further analysis is needed to evaluate if changing environmental conditions (i.e. water stratification) changes the usefulness of turbidity as a light attenuation proxy.

Although no nutrient measurements were conducted, high nutrient indicator species of alga were observed infrequently according to underwater photography. However, sites such as Manglillo (close to the western boundary of the study area) Guánica Bay and sites along the coast of Ponce (Las Cucharas) offered evidence of the entrance of significant inputs of nutrients, most probably related to discharges due to lack of management or potential illegal discharges (Fig. 14). The prevalence of both *Ulva* and *Chaetomorpha* were recorded at multiple locations. Large stands of *Chaetomorpha* characterized the area of Manglillo (Fig 14A) close to urban development as well as in the shallow area close to the shore of the town of Guánica (Fig. 14B). Significant growth of *Ulva* was, not surprisingly, observed close to a coastal sewage outfall related to a sewage treatment plant at Guánica. Also at Guánica, storm waters (probably mixed with an undetermined proportion of sewage) are pumped directly into the bay after being accumulated on a near coastal pumping station (see picture at the beginning of the report). At el Tuque, *Ulva* growth was evident in the residual mangroves along the coast close to house constructed along the shoreline (Figure 14C). These observations are included as GIS layers and in Google Earth format (See EFA below).

Figure 14. Large masses of *Chaetomorpha* are found at Manglillo (A) and Guánica Bay (B). *Ulva* can be observed in mangrove roots at El Tuque.

Sediment Erosion Potential

Agricultural lands represents 28% (2,402.95 Acres) of the major uses of coastal areas within the study area. These agricultural lands are within three major categories including: cropland, pastureland and fallow land.

Cropland is the land used for the production of vegetables (i.e. tomatoes, peppers), orchards (fruit trees) and hayland. Pastureland is suitable for the production of introduced forage plants for livestock grazing and fallow land is the land left unseeded (uncultivated) for a season or more.

Farmlands in the study area are concentrated in Guayanilla, Ponce and the Juana Díaz/Santa Isabel regions (Figure 15).

Figure 15. Farmlands within the study area.

The average potential soil loss for the Bare Ground scenario ranged from 383.3 Tons/Acre/Yr in the Santa Isabel annual crop site to 2624.3 Tons/Acre/Yr in the Ponce grazing pasture land (Table 5). Overgrazing caused by poorly managed agricultural applications is usually associated with increased soil erosion from grazed pastureland. Soil loss at the Guánica forest land is associated to the dominance of the Pitahaya-Limestone soil type.

Table 5. RUSLE 2 Soil Loss Estimates (Tons/Acre/Yr) for the selected locations. Data include range values and average potential soil loss per location and for the Bare Ground and Conservation System scenarios.

	Soil loss potential (range)		Soil Loss Potential (Avg)	
Location	Bare Ground	+ Conservation Practice	Bare Ground	+ Conservation Practice
Ponce	112.9-4767.5	3-100.4	2624.3	56
Guayanilla	185.5-861	1.4-10.5	479.5	5.7
Santa Isabel	11-796.4	3.5-234.8	383.3	99.2
Guánica	999.9	13.6	999.9	13.6

This soil is represented by soil deposits on outcrop that result in limited infiltration and increases in water velocity and flow rate, thus promoting erosion. There is a considerable reduction in soil loss (74 to 99%) at all sites when the most favorable conservation practices are adopted (Table 5, Figure 16). These improvements would benefit soil productivity and the coastal environment.

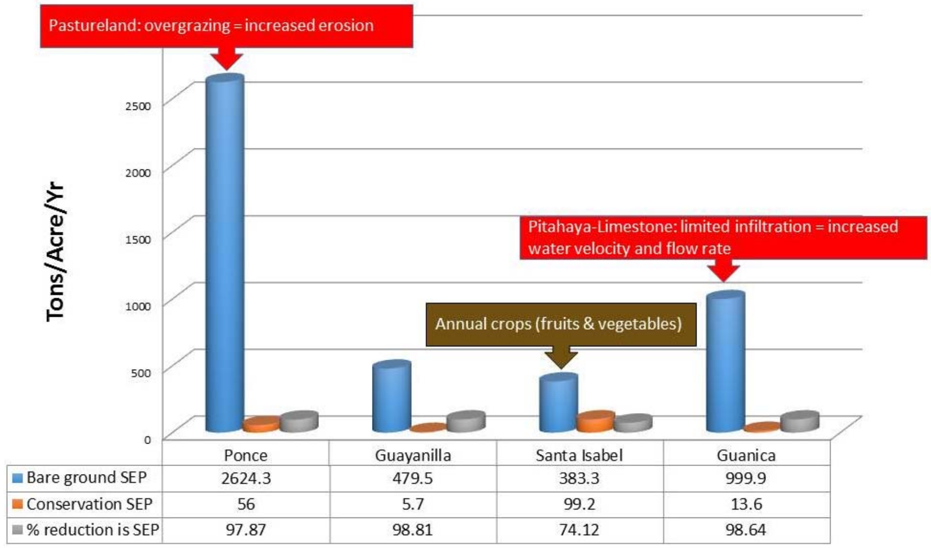


Figure 16. Soil Erosion Potential

Farmland practices in coastal areas can determine the load of sediments, nutrients and contaminants reaching shallow habitats. However, a more extensive soil erosion assessment is needed in those areas under intense agricultural activity such as Santa Isabel. Based on the USDA 2012 census, this municipality has a total of 9,376 Acres classified as farms (114 farms), thus further evaluations must consider alternative soil erosion models such as the Water Erosion Prediction Project (WEPP) and the Soil and Water Assessment Tool (SWAT), to determine erosion potential at a watershed scale (Figure 17).

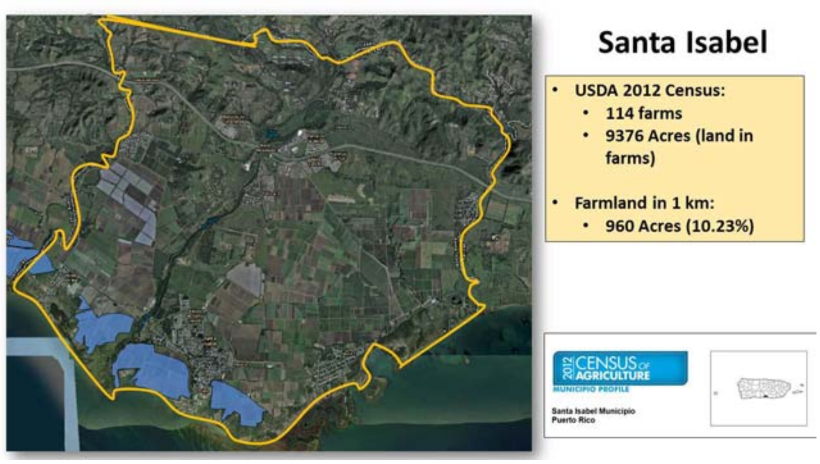


Figure 17. Watershed view of farmland land use at Santa Isabel.

Vulnerability Index

The vulnerability index was calculated only for stations where all variables could be determined. Of the total number of stations visited (704) data on light attenuation was collected only for 269. The range of VI was 0-5 units. Of all stations ca. 1, 4, 7% reached index values of 5, 4, and 3 respectively (Figure 18). The stations associated with VI > 3 were associated to stations located close to the coast in zones of Guánica, Penuelas and Santa Isabel (Table 6). The most vulnerable stations according to the index (VI=5) were located close to the area of el Boquete in Peñuelas. Stations close to inner Guánica Bay and Santa Isabel (close to the developed zone), had VI=4 (See EFA for a map of the results). The most vulnerable stations were not related to %PAR vulnerability based on the 15% PAR selected here but to mechanical Impacts and or high nutrients. However, the most pervasive factor was distance to Urban development (Table 6).

VI values	#of stations per VI	% per VI
0	132	49.1%
1	78	29.0%
2	29	10.8%
3	18	6.7%
4	10	3.7%
5	2	0.7%
6	0	0.00%

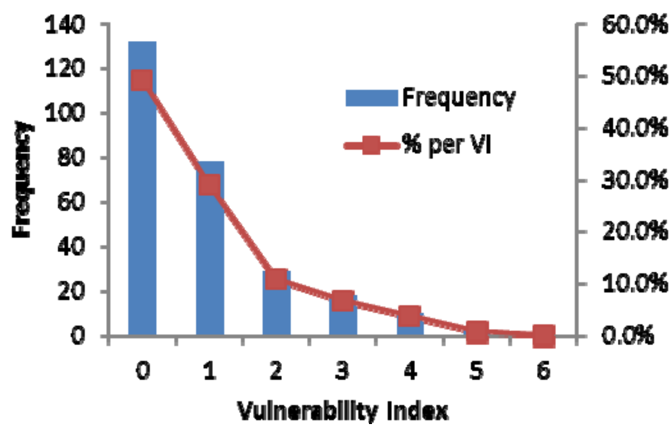


Figure 18. Frequency distribution of Vulnerability Index Estimates.

Table 6. Summary of Vulnerability Fac tors and Index for stations with VI ≥ 3.

				Vulnerability Metrics					
OBJECTID	LAT (dec Deg)	LON (dec Deg)	Location	Urban	Ocean Recreation	Mechanical Impact	High Nutrients	%PAR	Index
78	17.98939	66.71679	Tallaboa	1	1	2	1	0	5
80	17.98942	66.71759	Tallaboa	1	1	2	1	0	5

				Vulnerability Metrics					
OBJECTID	LAT (dec Deg)	LON (dec Deg)	Location	Urban	Ocean Recreation	Mechanical Impact	High Nutrients	%PAR	Index
79	17.98688	66.71356	Tallaboa	1	0	2	1	0	4
81	17.98755	66.71629	Tallaboa	1	0	2	1	0	4
76	17.98302	66.7112	Tallaboa	1	1	2	0	0	4
43	17.94843	66.87457	San Jacinto	1	1	2	0	0	4
41	17.95052	66.87827	San Jacinto	1	1	2	0	0	4
77	17.98524	66.71204	Tallaboa	1	1	2	0	0	4
26	17.95051	66.40007	Santa Isabel	1	1	0	1	1	4
557	17.95264	66.40408	Santa Isabel	1	0	0	1	2	4
551	17.96575	66.91826	Guanica Bay	1	0	0	1	2	4
550	17.96277	66.90799	Guanica Bay	1	0	0	1	2	4
7	17.96358	66.90603	Guanica Bay	1	1	0	1	0	3
25	17.9519	66.40215	Santa Isabel	1	1	0	1	0	3
8	17.96432	66.90634	Guanica Bay	1	1	0	1	0	3
9	17.96448	66.90562	Guanica Bay	1	1	0	1	0	3
637	17.98629	66.71441	Tallaboa	1	0	1	1	0	3
87	17.98729	66.71945	Tallaboa	1	0	2	0	0	3
84	17.9881	66.72067	Tallaboa	1	0	2	0	0	3
88	17.98749	66.71901	Tallaboa	1	0	2	0	0	3
75	17.98232	66.70826	Tallaboa	1	0	2	0	0	3
40	17.95186	66.8814	San Jacinto	1	0	2	0	0	3

				Vulnerability Metrics					
OBJECTID	LAT (dec Deg)	LON (dec Deg)	Location	Urban	Ocean Recreation	Mechanical Impact	High Nutrients	%PAR	Index
83	17.98982	66.71979	Tallaboa	1	0	2	0	0	3
85	17.98867	66.72013	Tallaboa	1	0	2	0	0	3
74	17.98007	66.70761	Tallaboa	1	0	2	0	0	3
82	17.98958	66.71892	Tallaboa	1	0	2	0	0	3
549	17.95491	66.90667	Guanica Bay	1	0	0	0	2	3
548	17.95291	66.90529	Guanica Bay	1	0	0	0	2	3
622	17.97184	66.78838	W Guayanilla Bay	1	0	0	0	2	3
639	17.98915	66.72114	Tallaboa	0	0	1	0	2	3

The GIS product displaying the results of the Vulnerability Index for the area of Guánica is shown in Figure 19). Other factors may be important to consider in the future such as water currents and waves as these may change the cover of seagrasses in exposed areas (Patriquin, 1975; Tewfik, Guichard and McCann, 2007).

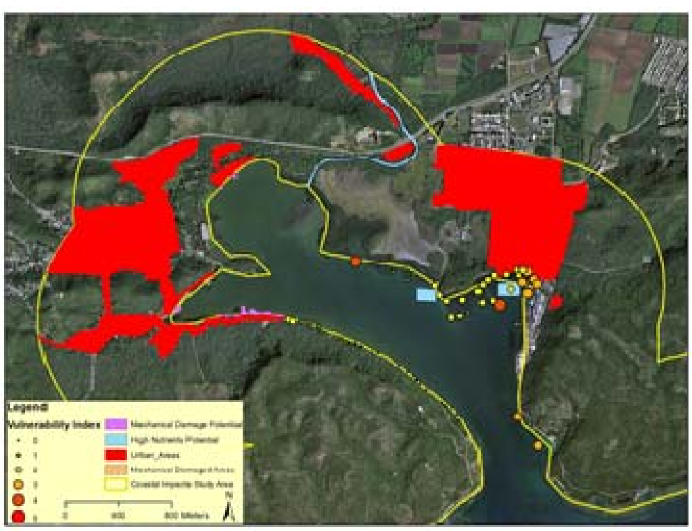


Figure 19. The vulnerability for an area of Guánica bay where the values of the index were scaled by color and symbol size (green to red, low to high) from least to more vulnerable.

Impacts and Seagrass presence and cover

Impacts on seagrass presence

Ordinal regressions suggest the potential impact included in VI were significantly associated with seagrass presence (Table 7). The coefficients (estimates) of the predictor variables, their standard errors, the Wald test

(square of the ration of the coefficient to its standard error) and associated p-values, along with 95% confidence interval of the coefficients are given in the parameter estimate table. The parameter estimate table (Table 8) shows the relationship between the predictor variable and response variable. The estimates labeled *Threshold* are the intercept equivalent term, and in this case the reference variable is seagrass presence. When we include all predictor variables into one model, the predictor variables that were significantly associated with seagrass habitats between 0-4m were availability of light, followed by nutrient input and potential mechanical damage (Table 8). As shown in Table 8 the coefficient for availability of light was positive, therefore we can conclude that seagrass was more likely to be absent at sites with a higher light availability. This tendency was unexpected but is most likely due to the sampling design because most of the sites (98% of sites) had a light availability greater than 15%, the threshold value used for the analysis.. Coefficient for high nutrient potential was positive, signifying that seagrass was more likely to be present when there was a higher potential for nutrient inputs. This supports other studies which have found seagrass to be bioindicators of increasing nutrient levels (Mumby et al. 2014). The reef lagoon of Puerto Morelos, Mexico has been strongly affected by development, with increasing sewage output and land-based runoff. Seagrass meadows closest to the town of Puerto Morelos had either a greater biomass of seagrass or fleshy macroalgae. We also observed that sites closer to nutrient inputs were positively associated with fleshy macroalgal presence (Ordinal regression, Chi-square= 39.19, $p<0.0001$). Therefore, algae may outcompete seagrass in areas of increasing nutrient input, eventually having a negative impact on seagrass presence. Lastly, seagrass was more likely to be absent in areas with increasing potential of mechanical damage.

Table 7. Results from an ordinal regression analysis assessing the relationship between seagrass presence and all potential impacts (5 in total). This includes seagrass habitats between 0 to 4 meters.

Model Fitting Information

Model	-2 Log Likelihood	Chi-Square	df	Sig.
Intercept Only	75.295			
Final	58.856	16.439	6	.012

Link function: Logit.

Table 8. Parameter estimates for the ordinal regression analysis in Table 2. Parameter estimates were determined for the first model in which all impacts were assessed.

Parameter Estimates

		Estimate	Std. Error	Wald	df	Sig.	95% Confidence Interval Lower Bound	95% Confidence Interval Upper Bound
Threshold	[presence = .00]	2.346	.895	6.864	1	.009	.591	4.101
Location	[urban=.00]	-.061	.196	.098	1	.754	-.445	.322
	[urban=1.00]	0[a]	.	.	0	.	.	.
	[recreation=.00]	.408	.294	1.928	1	.165	-.168	.985
	[recreation=1.00]	0[a]	.	.	0	.	.	.
	[mechanical=.00]	.469	.273	2.942	1	.086	-.067	1.005
	[mechanical=1.00]	1.027	.597	2.958	1	.085	-.143	2.197
	[mechanical=2.00]	0[a]	.	.	0	.	.	.
	[nutrient=.00]	.332	.188	3.107	1	.078	-.037	.701
	[nutrient=1.00]	0[a]	.	.	0	.	.	.
	[light=.00]	1.846	.816	5.111	1	.024	.246	3.446
	[light=1.00]	0[a]	.	.	0	.	.	.

a. Seagrass presence is set to zero because it is redundant

Impacts on seagrass cover

Seagrass cover was classified into three categories, low (<25% cover), medium (25%-50%) and high (>50%). We ran nominal regressions in order to assess which of the impacts influenced seagrass cover. As seen in the regression model results (Table 9), there were no impacts influencing the seagrass cover in shallow- and deep-water habitats. This could indicate that either seagrass presence is a better indicator of human impacts and/or the sampling effort in this study was not sufficient for identifying the impacts affecting seagrass cover. For example, areas with low and medium cover were under sampled in both shallow and deep water when compared to areas of high cover.

Table 9. Results from the nominal regression analysis, (*) indicates which impacts were significantly associated with seagrass cover in depths between 0 to 4 m.

Source	Source	Log likelihood	Chi-square	df	p
Cover	Urban areas	14.85	0.05	2	0.97
	Recreational areas	11.21	1.42	2	0.49
	Mechanical damage	14.13	1.75	2	0.42
	Nutrient inputs	13.62	1.92	2	0.38
	Light availability	11.01	2.09	2	0.35

Recommendations

The following recommendations are based on the above results and visual observations. Recommendations were organized by topic and category (Table 10).

Recommendations are classified in 5 different categories:

- Management (M): strategies to reduce environmental impacts
- Policy (P): recommendations that require multi-agency coordination
- Infrastructure (I): activities that involve structures and facilities
- Education & Outreach (E/O): activities to educate and raise awareness
- Research for Management: applied research to increase effectiveness of environmental management through the increase of science based knowledge.

There is significant overlap among the different categories. Priority levels (High (H), Medium (M) and Low (L) were established based on the recommendation importance, impact and implementability as discussed in the working group.

Table 10. List of recommendations organized by Topic, Categories and Priority. Specific examples of sites are provided in the Description of Recommendations section.

Topic	Recommendation	Category	Priority	Source of Info
Erosion & Pollution	Divert storm water from pumping station located in the NE corner of Guánica Bay to the mud flat and explore the possibility of using this effluent as part of a wetland mitigation project.	M & P	H	Photos and video

Topic	Recommendation	Category	Priority	Source of Info
Erosion & Pollution	Search for alternatives to decrease the nutrient and microbiological loads from the effluent of the Guánica Bay (West) sewage treatment plant.	M & P	H	Surveys and photos
Erosion & Pollution	Build or improve ramps and erosion control systems in high traffic areas, such as San Jacinto, where existing improvised ramps are a constant source of sediments to nearby seagrass beds.	MP&I	M	Surveys and photos
Erosion & Pollution	Remove private or improvised ramps, in areas such as San Jacinto, once new public ramp facilities are available.	M & P	M	Surveys and photos
Erosion & Pollution	Install storm drain traps to minimize the entrance of debris into coastal waters and the resulting physical damage to seagrasses at Guanica Bay.	MP&I	M	Surveys and photos
Erosion & Pollution	Promote the use of salt tolerant species in coastal landscapes in areas sensitive to erosion or to restore areas that have been impacted by either natural (i.e. hurricanes) or anthropogenic (i.e. urbanization) factors.	E/O & M	M	Observations and surveys
Erosion & Pollution	Determine if the community situated at the southwestern rim of Guanica Bay is discharging sewage directly into the bay. If so, take corrective actions.	M & P	L	Surveys and photos
Erosion & Pollution	Evaluate erosion control alternatives to minimize impacts of unpaved roads in Guánica Bay and adjacent areas.	MP&I	L	Observations and surveys
Coastal structures	Removal of old unused structures in bad conditions (old docks, piers, pilings, pieces of riprap, old unused sewage infrastructure) along the coast. These are commonly found in densely populated areas such as Las Cucharas and El Boquete in Ponce and Guayanilla and the Santa Isabel waterfront.	M & P	H	Surveys and photos

Topic	Recommendation	Category	Priority	Source of Info
Coastal structures	Study the feasibility of removal of shipwrecks in the vicinity of El Boquete, Ponce. Removal should be conditioned to a replanting and monitoring program as well as an analysis of indirect impacts of the influence of the removal of the wrecks on nearby seagrasses.	M & P	M	Surveys and photos
Coastal structures	Removal and/or substitution of refuse material (i.e. construction rubble) used for wave erosion control. An alternative practice that combines the use of native coastal vegetation (i.e. mangroves) is preferable as it provides better ecological connectivity and species habitat.	M & P	L	Surveys and photos
Effects of Docks	Include the use of different materials (e.g. gratings) to reduce docks shadowing effects as a requirement in the permitting process.	M & P	L	Field Observations
Effects of Docks	Minimize the impact of propeller wash and scars, and boat halo effect on shallow seagrass beds by evaluating exclusion zones, type of vessel/engine type that can be used in these areas and modifications to dock designs.	M & P	H	Surveys and photos, GIS map
Moorings	Evaluate mooring buoys design and anchoring hardware to avoid scouring around the site.	M & P	M	Photos
Education & Outreach	Increase awareness on the importance of seagrasses and associated organisms using a multipronged approach (e.g. talks and the installation of signage at marinas, boat ramps and areas vulnerable to boating impacts).	E/O & M	H	Aerial and field surveys, photos
Education & Outreach	The installation of signage at different locations identified as vulnerable to mechanical damage can potentially help diminish the vulnerability of these habitats by providing navigational cues to mariners (E/O M).	E/O & M	H	Surveys
Research	Update NOAA Benthic Habitat Maps utilizing	R	M-H	Surveys

Topic	Recommendation	Category	Priority	Source of Info
	satellite remote sensing technology and in situ platforms validated by field surveys.			
Research	Quantify the effects of chronic vs. acute turbidity on seagrass cover.	R	H	Field observations
Research	Survey seagrass habitats in insular shelf areas deeper than 4 m in vulnerable areas. Some of these areas include Ponce Playa.	R	H	Field observations, surveys and vulnerability index
Research	Evaluate the physical effects of high-energy conditions on shallow (<4 m depth) seagrasses.	R	H	Field observations
Research	Develop a more robust vulnerability index based on annual average water optical properties and other parameters to model seagrass ecosystem parameters such as maximum distribution depth, species composition, and percent cover.	R	H	Field data and vulnerability index
Research	Study the cause of macroalgal blooms observed in Manglillo, Guanica Bay and some areas in Ponce (anthropogenic vs. natural sources).	R	M	Surveys and photos
Research	Assess the role of seagrass and macroalgae as community bioindicators (biomass, primary productivity, diversity, etc.).	R	M	Field observations
Research	Evaluate the use of extant seagrass biomass and production as sentinels for coastal water quality trends.	R	M	Field observations
Research	Determine the impact of land-use patterns (e.g. agricultural activities) for estimates of potential soil erosion at watershed scales by using WEPP (USDA ARS), SWAT (USDA), BASINS (EPA) and/or other models.	R	M	Case studies
Research	Evaluate the impact of episodic events (storm surge, rainfall events) on seagrass resilience	R	M	Field observations

Topic	Recommendation	Category	Priority	Source of Info
	and mortality.			, aerial photography
Research	Determine the status of seagrasses in areas impacted by river runoff and other high turbidity areas.	R	M	Field observations
Research	Use historical imagery and aerial photography to assess long-term trends and changes in seagrass cover at selected sites (e.g. HAPC).	R	M	Reports from the literature
Research	Expand geographical areas in future surveys to include habitat areas of particular concern (HAPC) and the important reserves of JOBANERR and La Parguera.	R	L	Observations and reports

Description of Recommendations

Topic: Erosion and Pollution

1. ***Divert storm water from pumping station located in the NE corner of Guánica Bay to the mud flat and explore the possibility of using this effluent as part of a wetland mitigation project (MP).*** A storm water (probably combined with sewage) pumping station in the NE corner of Guánica Bay empties its content intermittently to the bay close to the coast. The quality of that water is unknown therefore its impact on benthic flora, including seagrasses is also unknown. This type of disposal should be eliminated or diverted.

2. ***Search for alternatives to decrease the nutrient and microbiological loads from the effluent of the Guanica Bay (West) sewage treatment plant (MP).*** Sewage from the Guanica treatment plant is discharged directly to the Bay (west of town). The input of nutrients and microorganisms is significant based on the presence of green macroalgae (e.g. *Ulva lactuca*) surrounding the impacted zone. Complete or significant reduction of these nutrients and microbiological loads should produce a significant increase in water quality and thus a positive impact on seagrass habitat and other species.

3. ***Build or improve ramps and erosion control systems in high traffic areas, such as San Jacinto, where existing improvised ramps are a constant source of sediments to nearby seagrass beds (MP & I).*** Areas where boats are trailered into the water with minimal or no ramp facilities can become a source of sediments to nearby seagrasses whereas via

resuspension or from erosion effects during rain events. These areas should be fitted with proper ramps and erosion control systems to minimize the impact foot print of the activity. An example of this is found in the coast north of Punta San Jacinto. Other site where in installation of erosion control may be of importance is the area of Manglillo. The access are to the coast is steep and may enhance erosion closer to the coast.

4. ***Remove private or improvised ramps, in areas such as San Jacinto, once new public ramp facilities are available (MP).*** If improvements to the site of San Jacinto are made (see #3), management priorities should be to decrease or eliminate other neighboring private or improvised ramps These other ramps or access points to the watyer can be observed towards the eastern portion of San Jacinto among coastal residences.

5. ***Install storm drain traps to minimize the entrance of debris into coastal waters and the resulting physical damage to seagrasses at Guanica Bay (MP & I).*** Entrance of debris into coastal waters could physically preclude vegetative growth of seagrasses. Roads draining directly to coastal areas should be a primary target of this type of conservation measurement. Storm water drains from the town of Guánica into the Bay are good examples where these traps could be installed. Other sites that may benefit from this type of control are drains in Playa de Ponce, and the water front in Juana diaz and Santa Isabel.

6. ***Promote the use of salt tolerant species in coastal landscapes in areas sensitive to erosion or to restore areas that have been impacted by either natural (i.e. hurricanes) or anthropogenic (i.e. urbanization) factors (E/O & M).*** The combination of mangrove transplants and halophytic (salt tolerant) coastal vegetation in certain areas can be beneficial to mitigate sediment transport and as erosion control along the coast. The coast along playa de Ponce can be a good site in which planting of these species may stabilize coastal erosion (See EFA Playa de Ponce.kmz). In addition there are numerous small scale sites where mangroves have been eliminated to provide access to the coast. These accesses should be replanted. Areas where these type of activity may be practiced include Guanica Bay, San Jacinto and Santa Isabel Water front.

7. ***Determine if the community situated at the southwestern rim of Guanica Bay is discharging sewage directly into the bay. If so, take corrective actions (MP).*** It is unclear how sewage from the community at the southern rim of western Guánica Bay is disposed. If not connected, agencies should coordinate to provide connection to the treatment plant nearby treatment plant.

8. ***Evaluate erosion control alternatives to minimize impacts of unpaved roads in Guánica Bay and adjacent areas (MP & I).*** Unpaved roads along the coast of Guánica Bay (to the south) show significant signs of erosion (gullies). Sediments most probably enter the Bay via this route during rain events. Specific sites that should be evaluated include the roads along the southern rim of central/western Guanica Bay where gullies were observed.

Topic: Old Coastal Structures, Debris and Grounded Ships

1. ***Removal of old unused structures in bad conditions (old docks, piers, pilings, pieces of riprap, old unused sewage infrastructure) along the coast. These are commonly found in densely populated areas such as Las Cucharas and El Boquete in Ponce and Guayanilla and the Santa Isabel waterfront (MP).*** Numerous old unused structures in bad structural conditions were observed along the coast of the most densely populated urban areas. Many of the smaller of these structures may be removed; however their removal should avoid the use of heavy equipment whenever possible to minimize impacts during the operations. Old crumbling houses should be removed in order to avoid debris falling into the sea. (See EFA: Laguna Salinas to Boquete).

2. ***Study the feasibility of removal of shipwrecks in the vicinity of El Boquete, Ponce. Removal should be coupled with a replanting and monitoring program as well as an analysis of indirect impacts of the influence of the removal of the wrecks on nearby seagrasses (MP).*** Ship wrecks related to a former coastal aquaculture operation that went bankrupt decades ago are located in the vicinity of El Boquete, Ponce. Other than impacts within the footprint of these ships, wave pattern changes and shading caused by the ships' structures have probably extended the area of impact. If these ships are to be removed, additional impacts during the operation should be factored in when considering the alternatives. In general, impacts could be minimized by avoiding the use of large barges or machinery. Also removal should be conditioned to a replanting and monitoring programand analysis of indirect impacts of the influence of the removal of the wrecks on nearby seagrasses due to a possible increase of boat traffic once these navigation hazards are eliminated (See EFA: Shipwrecks at Boquete). Other aspects to be considered include an analysis of impacts and management alternatives related to the corals colonizing the wrecks and to the disposal of materials extracted.

3. ***Removal and/or substitution of refuse material (i.e. construction rubble) used for wave erosion control. An alternative practice that combines the use of native coastal vegetation (i.e. mangroves) is preferable as it provides better ecological connectivity and species habitat (MP).*** The practice of using refuse material for erosion control should be

eliminated. Removal of such material and/or substitution by other type of more durable and appropriate ones should be evaluated. An alternative that combines the use of native coastal vegetation (i.e. mangroves) will be the best as it provides better ecological connectivity and species habitat. Areas where this recommendations can be applied are Playa de Ponce (See EFA: Playa de Ponce) and along the coast of el Tuque (See EFA: Laguna Salinas to Boquete).

Effects of Docks

1. ***Include the use of different materials (e.g. gratings) to reduce docks shading effects as a requirement in the permitting process (MP).***

2. ***Minimize the impact of propeller wash and scars, and boat halo effect on shallow seagrass beds by evaluating exclusion zones, type of vessel/engine type that can be used in these areas and modifications to dock designs (MP)***

The effects of docks are directly related to their footprint and design. Indirectly, the orientation or positioning of these represents in many occasions a larger proportion of impact than the direct effect of the dock structure itself. Propeller wash and propeller scarring can be significant in many places according to the boat sizes and depth where the docks are constructed. It is recommended that docks are designed with materials that minimize shadowing effects (grating) and that the docks are extended to depths according to the type and size of boat that is intended to use the facility to decrease boat halo effect caused by propeller wash. In terms of propeller scars, this study and other has found that navigation to and from points of interest (including docks) is related to the pattern of scarring. Thus minimizing the number of scars will depend not only on the number of dock but their design and boating practices. These recommendations are in agreement with that of Shafer, Karazsia, Carrubba and Martin (2008). Most of the areas. These recommendations are inherent to the areas of San Jacinto since most mechanical impacts were observed in this location. One dock that of FURA in Ponce is roofed. It is unclear what is the shading effect on adjacent seagrasses. This could be evaluated for future occasions where application of permits for such structures are considered by the agencies.

Moorings

Evaluate mooring buoys design and anchoring hardware to avoid scouring around the anchor point (MP). Proper installation of mooring buoys and related hardware is recommended. The main effects of moorings on seagrasses are related to the type of anchoring and line used. In many occasions, moorings are made of heavy masses (i.e. car blocks) and chains or ropes that lie over the bottom where seagrasses are present. This type of practice induces changes in water turbulence and chafing that results in the appearance of "halos" within the seagrasses. Simple mooring designs are available that eliminate the above effects. However, location of moorings in areas too shallow or the permanent use of should be avoided since boats using moorings may, depending of the boat size, exceed the depth limitations and increase scouring around the mooring buoy site. The use of anchoring buoys should be encouraged in the area of San Jacinto, El Boquete and Santa Isabel, where most of the improvised anchorages were observed.

Topic: Education and Outreach

1. ***Increase awareness on the importance of seagrasses and associated organisms using a multipronged approach (e.g. talks and the installation of signage at marinas, boat ramps and areas vulnerable to boating impacts) (E/O & M).*** A multipronged approach should be applied to increase effectiveness and increase awareness of related managed habitats and special resources.

2. ***The installation of signage at different locations identified as vulnerable to mechanical damage can potentially help diminish the vulnerability of these habitats by providing navigational cues to mariners (E/O M).*** Shallow areas should be clearly marked. Special markers can be placed to help minimize the frequency of scarring and grounding at sites as well as increase the awareness for the need for good conservation practices (san Jacinto, el Boquete, Santa Isabel)This approach should be coordinated with other educational initiatives to obtain better results. In addition, the installation of signs at different sites (San Jacinto, El Boquete, Club Nautico Ponce, Santa Isabel, Juana Díaz) can serve as complementary means by which more detailed information may be provided to boaters and the general public.

Topic: Research Oriented to Management

1. ***Update NOAA Benthic Habitat Maps utilizing satellite remote sensing technology and in situ platforms validated by field surveys (R).*** Focus should be given to all areas at a closer scale. The benthic maps used a minimum mapping unit of one acre and imagery of limited spatial resolution. This may explain the disagreement between results observed during this study. In addition, the combination of turbidity, depth, species composition and cloud cover may have influenced the evaluation of seagrass habitats using aerial interpretation. For instance the presence *of Halodule sp*.and *Halophila sp*. stands were more than likely missed using photointerpretation.

2. ***Develop a more robust year-long study of environmental conditions associated with seagrass habitats within the geographical area of interest (R).*** The limited time allotted for this study only allowed the evaluation of environmental conditions related to seagrass habitats during an atypically extended dry period. Wet conditions were sampled a final trip in October 9, 2014. Because the distribution of seagrasses is defined through long-term processes, a year-long study (at a minimum) is recommended to include temporal differences in pluviosity, turbidity and turbulence patterns as part of the evaluation of seagrass cover. This study type will provide information on the resilience of the various seagrass species and temporal patterns of ephemeral ones (*Halophila* sp). The study should consider the available information and probably adopt a random stratified design. It is also recommended that in situ instrumentation be used as much as possible as the environmental regime in the area is highly variable due to weather patterns. These study should consider areas deeper than 4m because of the large diversity of light penetration and the capacity of some species to grow at greater depths (10-15m). Evaluating deeper areas may provide evidence for an increased coverage of seagrass habitat as well as the temporal patterns.

3. ***Evaluate the impact of episodic events (storm surge, rainfall events) on seagrass resilience and mortality (R).*** Seagrass habitats, especially shallow ones, are subjected to the influence of water currents and waves which can modify their cover (Patriquin, 1975; Tewfik, A. F. Guichard and K.S. McCann, 2007). During the present work, the presence of sand ripples at different locations suggested that wave action could be an important factor modifying seagrass distribution. These factor may contribute to the extant seagrass distribution and should provide a better refinement to the preliminary Vulnerability Index described. Overall, this recommendation could be evaluated separately or in conjunction with #5, below.

4. ***Study the cause of macroalgal blooms observed in Manglillo, Guanica Bay and sitesin El Tuque, Ponce (anthropogenic vs. natural sources) (R).*** Shifts in benthic community composition due to increments in nutrient loadings (nutrification) could be important at certain locations within the study area. It is important to evaluate if anthropogenic sources, rather than natural ones, explain the macroalgal blooms observed in Manglillo, Guánica Bay and some areas along the coast of El Tuque, Ponce. Blooms can be responsible in part to changes in seagrass cover (i. e. shading, competing for space). The area of Manglillo showed a significant indication of excessive nutrient inputs to the coast due to the presence of large masses of *Chaetomorpha*, a tough filamentous algae with the potential for smothering seagrasses or other benthic species. The role of urban

development upland from this site as well as the intensive use for recreation of adjacent beach facilities on the development of macroalgal blooms should be studied in order to design possible alternatives for managing algal blooms and protecting sensitive habitats like seagrass. Different approaches can be used to derive information on this topic including microbiological monitoring, chemical tracing and the evaluation of leaks from sewage pipes or tanks.

5. ***Assess the role of seagrass and macroalgae as community bioindicators (biomass, primary productivity, diversity, etc.) (R).*** Field observations suggest the presence of macrolgal blooms within the study area. These blooms were located mainly in coastal areas adjacent to anthropogenic nutrification. The presence of these conditions provides an ideal opportunity to examine how the abundance and growth of macroalgae and seagrasses at these sites are related to the increased availability of nutrients. These species, their growth and nutrient utilization patterns may be used as sentinels or indicators of coastal environmental (quality) trends (i.e. degradation). Overall, an ecosystem level analysis should be emphasized when conducting these studies so that results may be applicable to other sites.

6. ***Determine the impact of land-use patterns (e.g. agricultural activities) for estimates of potential soil erosion at watershed scales by using SWAT (USDA), WEPP (USDA-ARS), BASINS (EPA) and/or other tools (R).*** Estimates of potential soil erosion must be expanded to watershed scales using available models. The examination of the effects of forest fires, common in the area of Santa Isabel, and subsequent changes of the chemical and structure of soils (in addition of the vegetation cover) must be considered. Also in addition soil erosion potential, studies of non-point source pollutants should also be considered.

7. ***Determine the status of seagrasses in areas impacted by river runoff and other high turbidity areas (R).*** River inputs into the coastal sea may provide nutrients, increased sediment loads and higher turbidity to the coastal area. The magnitude of riverine transport can modulate the distribution of seagrass species. High sediment loading may restrict the growth of seagrass species by scouring or burial. However, these effects may be pervasive for seagrass colonizing seagrass species as *Halodule* sp. In Playa de Ponce, near the river mouth of Río Matilde, dense stands of *Halodule* were observed, suggesting that the effects of rivers may not universally negative or at least influence the diversity of seagrass species in an area. Apart from Río Matilde, other areas where rivers may impact seagrass distribution should be examined including Rio Portugués and Bucaná, Rio Loco, Río Descalabrado and Río Coamo.

8. ***Use historical imagery and aerial photography to assess long-term trends and changes in seagrass cover at selected sites (R).*** Identify habitat areas of particular concern (HAPC) for seagrasses for their protection and management. Of particular interest are ecological corridors encompassing mangroves, seagrasses and coral reefs. Historical images can be used to evaluate long term trends in seagrass habitat cover. Many of the seagrass habitats within the study are closely related to reefs and mangroves. However priorities could be given to areas of special interest. The area of Caja de Muertos and Berbería is classified as habitat area of particular concern by NOAA (http://www.habitat.noaa.gov/protection/efh/efhmapper/index.html). Seagrasses in this area may serve as an important link between coastal and offshore reef communities due to their widespread distribution. These could be studied to establish long term trends in seagrass cover along with other aspects of ecological connectivity. Anthropogenic mechanical impacts on seagrasses should also be targeted during long term studies. Areas in San Jacinto were identified during this work as vulnerable by boating related activities. These areas should be monitored using available imagery in order to establish the progression, regression or stability of this type of impacts.

9. ***Expand geographical areas in future surveys to include other habitat areas of particular concern (HAPC) and the important reserves of JOBANERR and La Parguera Natural Reserve (R).*** Studies outside this range can also contribute to the conservation of seagrass habitat within the target area (Punta Jorobado to Punta Petrona). Expansion of the geographical areas surveyed here to other adjacent can expand the applicability of the results obtained. For instance, a similar study could be conducted JOBANERR and La Parguera Natural Reserve and the results of these additional studies would expand management applications within the geographic scope of the present work and at an island-wide scale.

References

Aguilar-Perera, J.A. 2004. Coastal habitat connectivity of reef fishes from southwestern Puerto Rico. Doctoral Dissertation. Department of Marine Science, University of Puerto Rico, Mayagüez, Puerto Rico. 143 pp.

Burfiend, D.D., and G.W. Stunz. 2005. The effects of boat propeller scarring intensity on nekton abundance in subtropical seagrass meadows. Mar. Biol. 48: 953-962.

Costanza et al. 1997. The value of the world's ecosystem services and natural capital. Nature 387: 253-260

Dawes, C. J. 1986. Botánica Marina. Editorial Limusa. México. 673pp.

Dixon, L.K. 2000. Establishing light requirements for the seagrass *Thalassia testudinum*: An example from Tampa Bay, Florida. In: S.A. Bortone (Ed). Seagrasses: Monitoring, Ecology, Physiology and Management. Pp. 9-32.CRC Press.

Duarte, C. 1991. Seagrass depth limits. Aquat. Bot. 40 :363-377

Duarte, C.M., and C.L. Chiscano. 1999. Seagrass biomass and production: A reassessment. Aquat. Bot. 65: 159-174.

Greenway, M. 1995. Trophic relationships of macrofauna within a Jamaican seagrass meadow and the role of the echinoid *Lythechinus variegatus* (Lamarck). Bull. Mar. Sci. 56: 719-736.

Hemminga, M and C. Duarte. 2000. Seagrass Ecology. Cambridge University Press. Cambridge, U.K. 298pp.

Kirk, JTO. 2011. Light and Photosynthesis in Aquatic Ecosystems. 3rd ed. 649pp.

Kohler, K.E. and S.M. Gill, 2006. Coral Point Count with Excel extensions (CPCe): A Visual Basic program for the determination of coral and substrate coverage using random point count methodology. Comput. Geosci., Vol. 32, No. 9, pp. 1259-1269, DOI:10.1016/j.cageo.2005.11.009.

Lee, K.S. and AND K. H. Dunton. 1997. Production and carbon reserve dynamics of the seagrass *Thalassia testudinum* in Corpus Christi Bay, Texas, USA. Mar. Ecol. Prog. Ser. 143: 201–210.

Mumby PJ, Flower J, Chollett I, Box SJ, Bozec Y, Fitzsimmons C, Forster J, Gill D, Griffith Mumby R, Oxenford HA, Peterson AM, Stead SM, Turner RA, Townsley P, van Beukering PJ, Booker F, Brocke HJ, Cabañillas-Terán, Canty SWJ, Carricart-Ganivet JP, Charlery J, Dryden C, van Duyl FC, Enríquez S, den Haan J, Igelsias-Prieto R, KennedyEV, Mahon R, Mueller B, Newman SP, Nugues MM, Cortés Núñez J, Nurse L, Osinga R, Paris CB, Petersen D, Polunin NVC, Sánchez C, Schep Stijn, Stevens JR, Vallés H, Vermeij MJA, Visser PM, Whittingham E, Williams SM (2014) Towards Reef Resilience and Sustainable Livelihoods: A Handbook for Caribbean Coral Reef Managers. University of Exeter, Exeter. 40 p

Musick, J.A., and C.J. Limpus. 1997. Habitat utilization and migration in juvenile sea turtles. In P.L. Lutz and J.A. Musick (eds), The Biology of Sea Turtles, CRC Press, Boca Raton, Florida, pgs. 137-163.

Orth, R.J., et al. 2007. A global crisis for seagrass ecosystems. Bioscience 56(12): 987-996.

Patriquin DG , 1975. ‘Migration’ of blowouts in seagrass beds at Barbados and Carriacou, West Indies, and its ecologicalc and geological implications. Aquat. Bot. 1:163–189.

van Tussenbroeck, B.I., J.IA. Vonk, J. Stapel, P.L.A. Ertmeijer, J.J. Middleburg and J.C. Zieman, 2007. The Biology of Thalassia: Paradigms and Recent Advances. In: A.W.D. Larkum, R.J. Orth and C.M. Duarte (Eds). Seagrasses: Biology, Ecology and Conservation. Springer.

Tewfik, A. F. Guichard and K.S. McCann. 2007. Influence of Acute and chronic disturbance on macrophyte landscape zonation. Mar. Ecol. Prog. Ser. 335: 111-121.

UNEP, 1999, Assessment of Land-based Sources and Activities Affecting the Marine, Coastal and Associated Freshwater Environment in the Wider Caribbean Region, UNEP Regional Seas Reports and Studies 172. UNEP/GPA Coordination Office and Caribbean Environment Programme.

Appendices

Appendix 1: Seagrass Cover Classification Scheme with Photograph Examples.

Seagrass cover categories used in this analysis and their percent cover range.

Seagrass Cover Category	Cover Range (%)
0	0
1	1-25
2	26-50
3	>51

Coral Point Count results for four reference quadrants, their equivalent in Braun Blanquet categories and the categories used for this study.

Quadrant	CPCe Percent	Braun Blanquet Category	Category used for analysis
	0	0	0
	17	1,2	1
	31	3	2
	89	4,5	3

Appendix 2. NRCS Conservation Plan Maps for sites considered in the Potential Soil Loss evaluation using RUSLE 2 model: Santa Isabel, Ponce, Guayanilla, Guánica.

Conservation Plan Map

Date: 11/23/2011

Customer(s):

District: CARIBE SOIL & WATER CONSERVATION DISTRICT

Approximate Acres: 364.5

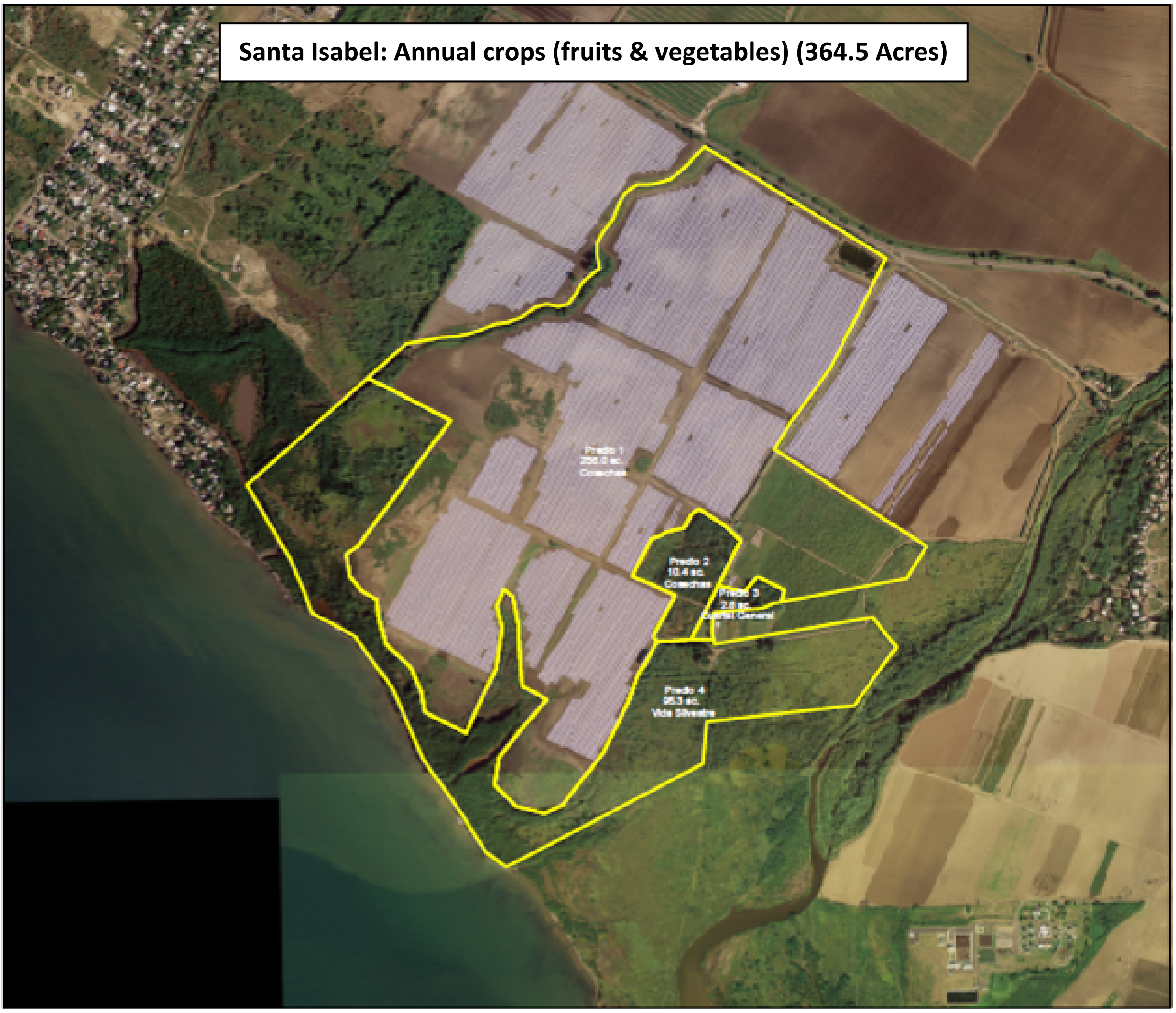
Legal Description: PR #1 bo. Boca Velazquez, Santa Isabel

Field Office: JUANA DIAZ SERVICE CENTER

Agency: USDA-NRCS

Assisted By: ANIBAL VELAZQUEZ

Scale 1:14000



Legend

Santalsabel2012

625 0 625 1,250 1,875 2,500 Feet

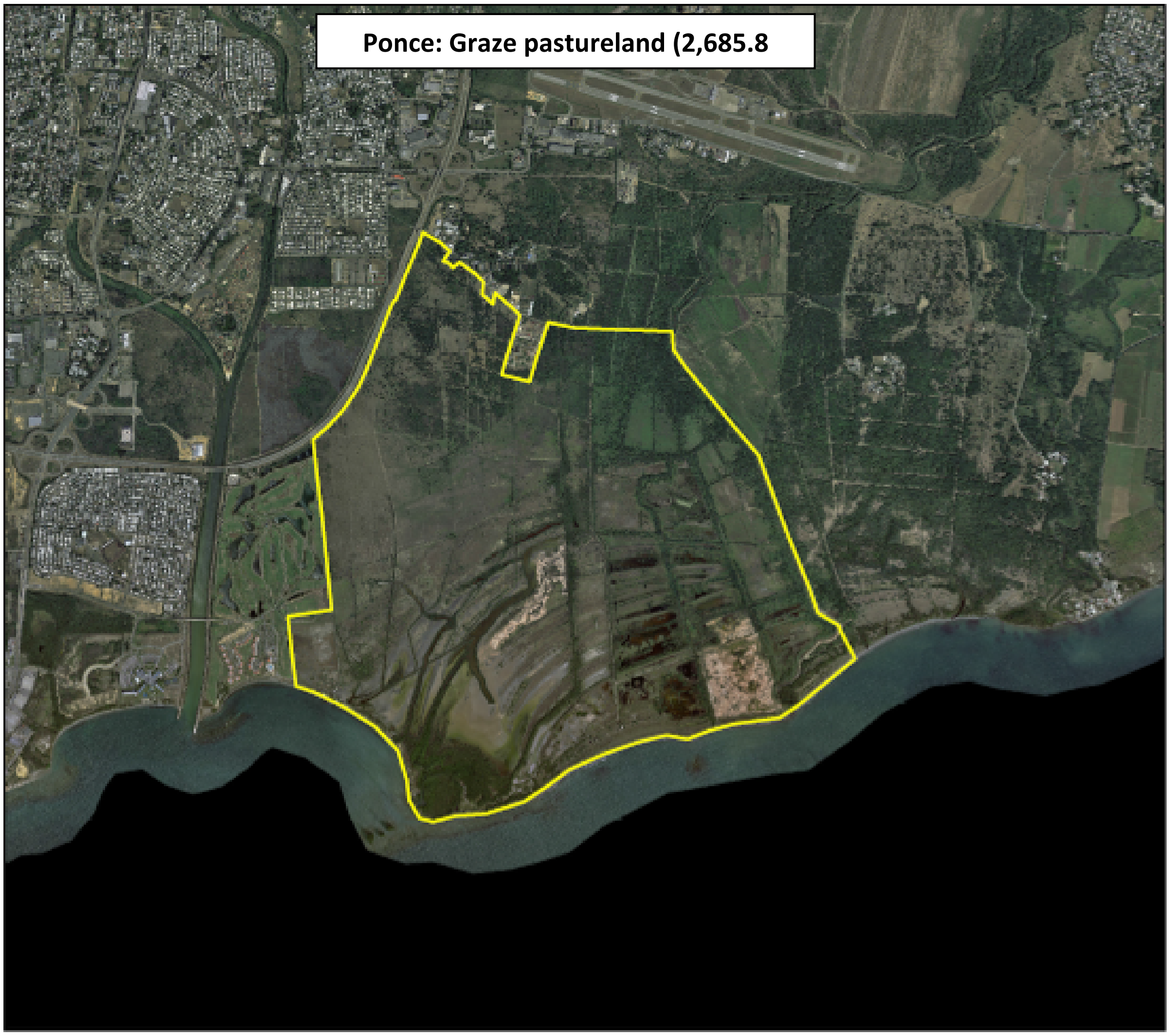
N

Mapa del Plan de Conservación

Date: 8/18/2014

Field Office: JUANA DIAZ SERVICE CENTER
Agency: USDA-NRCS
Assisted By: ANIBAL VELAZQUEZ

District: SUR SOIL & WATER CONSERVATION DISTRICT
Approximate Acres: 0

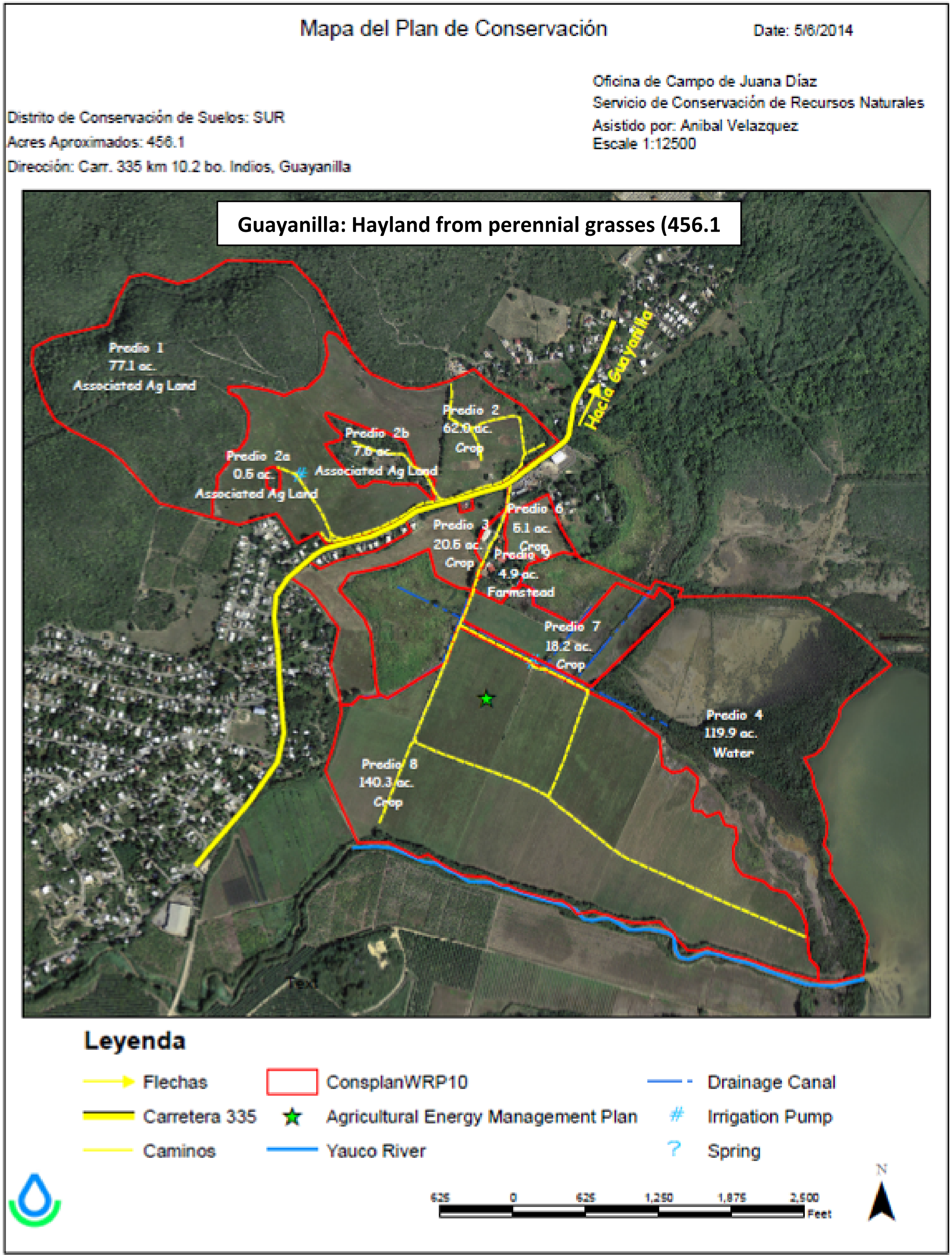


Legend

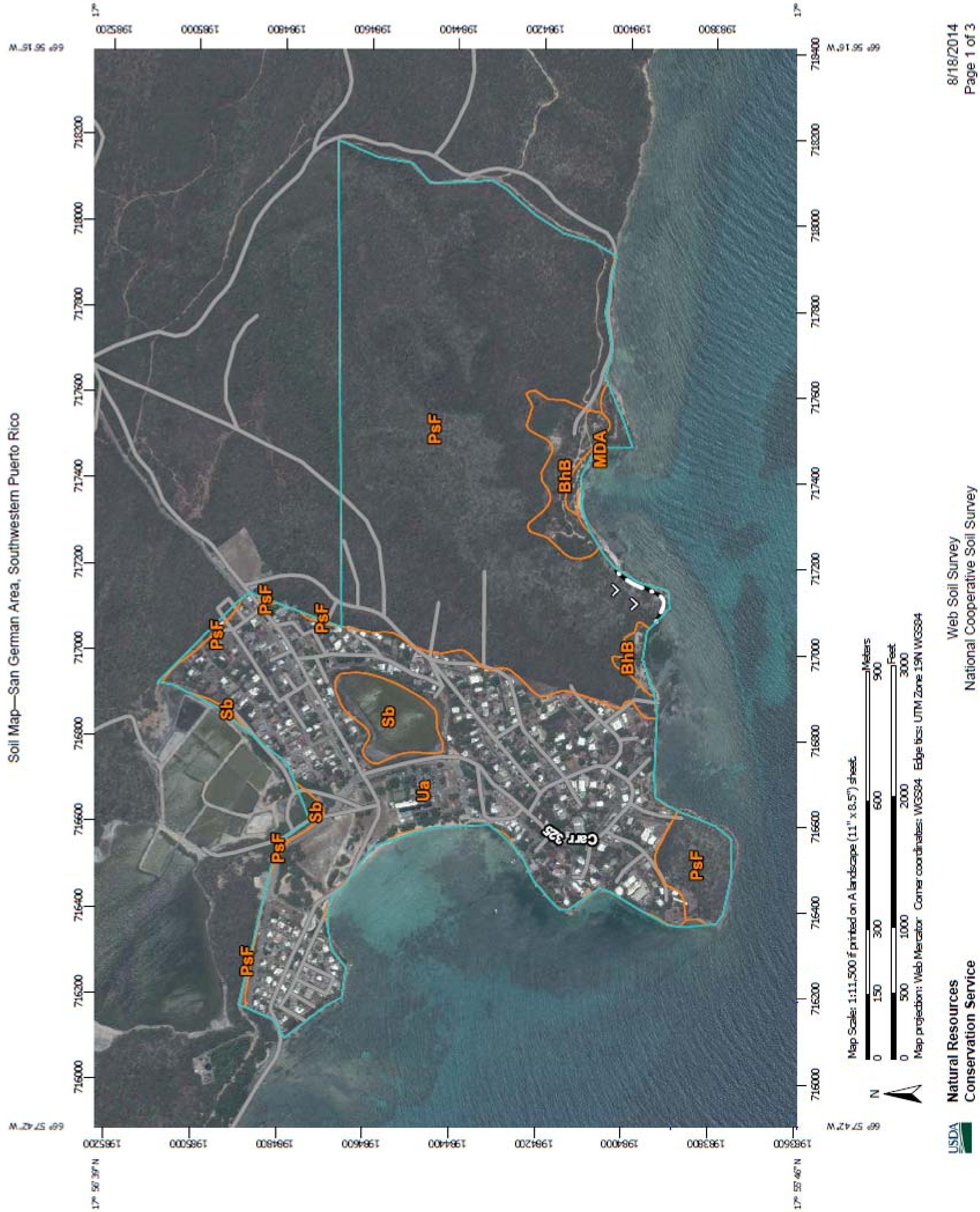
Consplan1

2,100 0 2,100 4,200 6,300 8,400 Feet

N



Mapa del Plan de Conservación
Date: 5/6/2014
Oficina de Campo de Juana Díaz
Servicio de Conservación de Recursos Naturales
Asistido por: Anibal Velazquez
Escale 1:12500
Distrito de Conservación de Suelos: SUR
Acres Aproximados: 456.1
Dirección: Carr. 335 km 10.2 bo. Indios, Guayanilla
Guayanilla: Hayland from perennial grasses (456.1
Predio 1
77.1 ac.
Associated Ag Land
Predio 2
62.0 ac.
Crop
Predio 2b
7.6 ac.
Associated Ag Land
Predio 2a
0.5 ac.
Associated Ag Land
Hacia Guayanilla
Predio 3
20.6 ac.
Crop
Predio 6
6.1 ac.
Crop
Predio 9
4.9 ac.
Farmstead
Predio 7
18.2 ac.
Crop
Predio 4
119.9 ac.
Water
Predio 8
140.3 ac.
Crop
Leyenda
Flechas
Carretera 335
Caminos
ConsplanWRP10
Agricultural Energy Management Plan
Yauco River
Drainage Canal
Irrigation Pump
Spring
625 0 625 1,250 1,875 2,500
Feet
N


Soil Map—San German Area, Southwestern Puerto Rico
PsF
Sb
Ua
BhB
MDA
Carr 325
Map Scale: 1:11,500 if printed on A landscape (11" x 8.5") sheet.
Meters
0 150 300 600 900
Feet
0 500 1000 2000 3000
Map projection: Web Mercator Corner coordinates: WGS84 Edge tics: UTM Zone 19N WGS84
USDA
Natural Resources
Conservation Service
Web Soil Survey
National Cooperative Soil Survey
8/18/2014
Page 1 of 3

Electronic File Appendices (EFA's)

This type of information complementary to the main text of the report and is too long to be included at the end of the manuscript. Examples of the files that can be found in these appendices include worksheets, GIS data sets and other mapping and other graphical documentation (photo files). For the convenience of the reader/user, files are distributed in three separate folders, named worksheets, Google Earth files and GIS files in which Excel, kml/kmz and ARCGIS files can be found respectively. Following is a description of files included in the respective folders. The information in these folders has to be accessed independently to the report and the user will need to provide the proper software to access the data (MS Excel or compatible, Google Earth or recent version of ArcGIS)

Worksheet Folder

Vulnerability_Index_AllData_Simplified: Data Sheet showing data used for the calculation of the Vulnerability Index

20141205 Final Table Environmental: Summary of all Environmental Data

Final Biological Data: Summary of all data related to biological determinations, including the seagrass cover data derived from video or photo analysis.

Google Earth Data files (KMZ)

Salinas Lagoon to El Boquete.kmz: Coastal Survey of Shallow sites using Kayaks. Crew was Yasmin Detrés and Stacey Williams, Mariana Careli and Duane Ponce de Leon and Ernesto Otero.

Playa de Ponce: views of coastal conditions and some associated structures

Shipwrecks: Photos of conditions associated with shipwrecks located close to el Boquete, Penuelas, PR.

Aerial Photos Seagrass Initial Assessment: Photo collection showing views during the low level overflight of the study area.

Santa Isabel Juana Diaz On Land: Views of filed conditions in coastal and inland areas of Sanat Isabel and Juana Diaz

Seagrass_GIS_Data: Summary of GIS all GIS layers and classifications.

Seagrass Coverage: Presents a summary of data including Water quality, Seagrass cover and species composition.

Vulnerability_Index: includes the results of the vulnerability Index for for stations for which data was available to comply with all criteria. Data is derived fom the appropriate worksheet file.

GIS:

All files related to vulnerability index water quality and seagrass cover in format compatible with ARCGIS