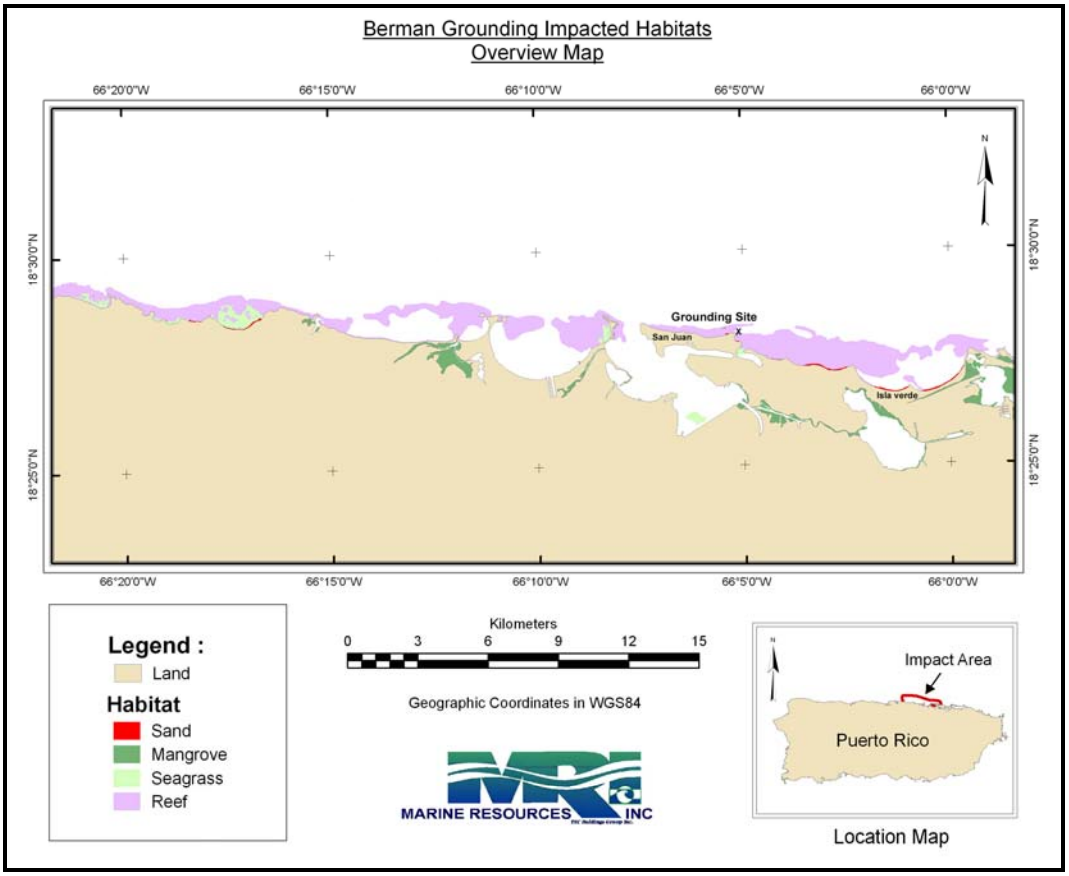
Habitat Suitability Analysis: Compensation for Injured Reef in Support of Restoration Planning for the Berman Oil Spill, San Juan, Puerto Rico

August 2005



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1.0 INTRODUCTION

1.1 Background

On the morning of 7 January 1994, the towline from the tug *Emily S.* broke allowing the fuel tank barge, *Morris J. Berman*, to drift with the wind and current for approximately one hour before it came aground. The barge, loaded with 35,000 bbl. of No. 6 fuel oil, grounded on a hard bottom eolianite reef approximately 274 m (300 yards) offshore of Escambron Beach in San Juan, Puerto Rico (**Figure 1**). The grounding of the barge on the eolianite reef caused seven of the barge's nine holding tanks to rupture, resulting in the discharge of approximately 17,000 bbl. of fuel oil onto the reef and surrounding nearshore areas (Applied Science Associates, 1994). The barge remained aground for over one week and was refloated and towed to a scuttling site 15 January 1994. The discharged oil was reported to impact more than 30 miles of shoreline along the north coast of Puerto Rico (Applied Science Associates, 1994). The weight of the grounded barge scarified the eolianite reef and dislodged rock substrate creating loose boulders and rubble debris (Hudson and Goodwin, 1995); the impact area was estimated to cover an area of 1,009 m^2.

1.2 Objective

A settlement agreement between the U. S. Federal Government, the Commonwealth of Puerto Rico, and the responsible parties concerning the *Morris J. Berman* grounding event resolved claims for the resultant natural resource damages. The National Oceanic and Atmospheric Administration (NOAA), the U.S. Department of Commerce, the National Park Service, a Bureau of the U.S. Department of the Interior, and the Puerto Rico Department of Natural and Environmental Resources, as trustees of the natural resources, have the responsibility to assess the extent of resource damages, plan for appropriate restoration projects, prepare a restoration plan, and implement restoration. On-site restoration of the injured reef is not considered feasible due to the shallow water and associated high-energy sea conditions. The Trustees will compensate for the lost services of the impacted area by conducting off site compensatory restoration, since on-site restoration is not an option. Under Task Order 8 of contract number WC133F-04-CQ0003 to NOAA and in support of the Trustee Council, Tetra Tech EM, Inc. subcontracted Marine Resources, Inc. (MRI) to conduct a Habitat Suitability Analysis (HSA) to identify local marine habitats that could be utilized for compensatory restoration. The objective of the HSA is to evaluate and rank various marine habitats on a service-to-service basis to determine suitability for providing ecological compensation for lost resources associated with the *Morris J. Berman* grounding along the north coast of Puerto Rico.

A total of 183 organisms, documented from the project literature search, occur within the eolianite reef habitat and are considered to have been either directly or indirectly injured by the *Morris J. Berman* grounding. The species documented to occur in the eolianite habitat can be described by the principal functional service that they provide to the environment: 1) primary producers, 2) structural animals, 3) herbivores (invertebrates and vertebrates), and 4) predators (invertebrates and vertebrates). Of the 183 species documented on eolianite reef habitats, 8% are primary producers, 29% are structural animals, 11% are herbivores, and 52% are predators. A thorough description of the organisms and the services that they provide within each service category is provided in **Section 3.3**.

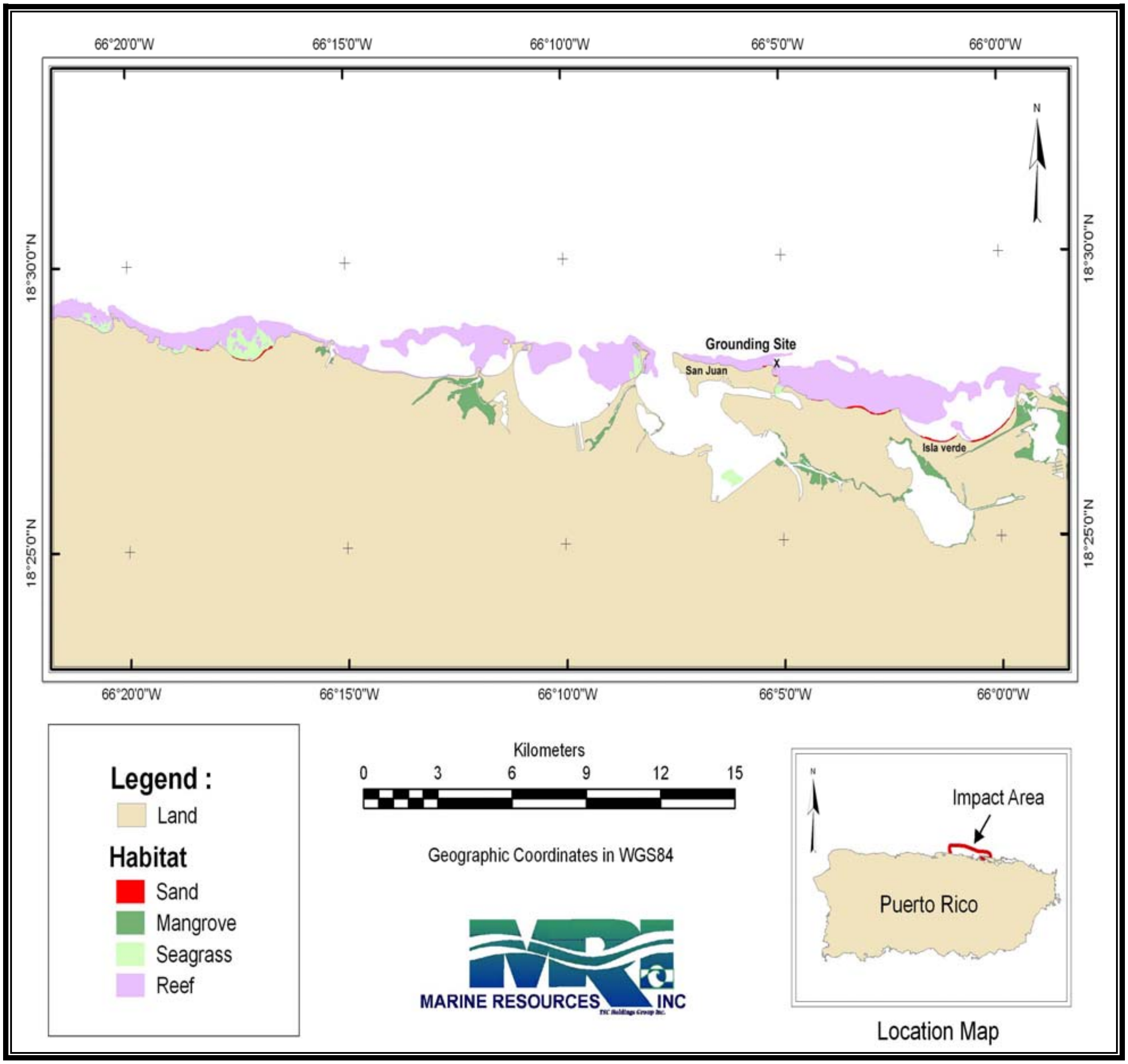

Figure 1. Location of the *Morris J. Berman* grounding site relative to San Juan

2.0 METHODS

Evaluation of the potential ecological benefits associated with compensatory habitat restoration was conducted through the analysis of published articles and technical documents. The principal goal of this evaluation was to compare the ecological services that provided by the eolianite reef habitat to those ecological services likely to accrue from creation (Powers et al., 2003), restoration (Peterson et al., 2003), and/or protection (Sperduto et al., 2003) of alternative habitats. As specified in the Statement of Work (SOW), habitats evaluated on a service-to-service basis included the following:

1) *eolianite reef* - feature of lithified substrate located in 0 – 5 m water depth, characteristic of the nearshore coastline of San Juan with its geomorphology closely related to the erodibility of the rock formation;
2) *shallow hard bottom* - consolidated substrate which supports a biological community dominated by attached sessile organisms located in 5 - 10 m water depth;
3) *deep hard bottom* - consolidated substrate which supports a biological community dominated by attached sessile organisms located in water depths greater than 10 m;
4) *mangroves* - submerged prop-root system of the red mangrove (*Rhizophora mangle*) and adjacent muddy substrate in a water depth of 0 to 2 m; and
5) *seagrass beds* - multi-species seagrass assemblage, often dominated by turtle grass (*Thalassia testudinum*) occurring in protected embayments in a water depth of 0 to 5 m.

Data on the biological community supported by artificial reef habitat was not available for the region of interest; consequently, artificial reef was not included as a specific habitat in the HSA. However, creation of artificial reef habitats may be the preferred alternative of compensatory restoration for the shallow hard bottom and deep hard bottom habitats. Although no specific information from the northern coast of Puerto Rico was available concerning artificial reef habitat, a substantial literature base exists that compares biological community structure between natural and artificial reefs. The majority of this literature focuses on predatory species (fish and mobile invertebrates). The consensus that emerges from this literature is that artificial reefs designed to maximize structural complexity and relief can support diverse fish and epibenthic assemblages (Sherman, et. al., 2002; Hixon and Beets, 1989; Hudson, et. al., 1989; Gorham and Alevizon, 1989). Artificial reefs designed to provide refuge by including small holes in the concrete material may enhance survival of recreationally and commercially important finfish (Hixon and Beets, 1989; Beets and Hixon, 1994). Rilov and Benayahu (2002) reported designing and monitoring artificial reef structures in the Eilat, Red Sea that supported a more diverse fish assemblage than the surrounding natural hard bottom habitats. Results indicating similar fish communities between natural and artificial reefs have been reported for artificial reefs constructed in coastal waters of the United States (see Ambrose and Swarbrick, 1989). Studies examining fish diet and growth have also demonstrated a high degree of similarity between artificial and natural reef habitats (Donaldson and Clavijo, 1994; Vose and Nelson, 1994; Lindquist et al., 1994). Based on our review of the literature, it is assumed that an artificial reef system placed within the target biotope and designed to mimic the local natural hard bottom habitat would function similar to the natural hard bottom it was designed to mimic after a brief period of succession (~5 years).

The HSA compares the ecological services provided by the aforementioned habitats with the eolianite reef in terms of four functional groups: 1) primary producers, 2) structural animals, 3) herbivores (invertebrates and vertebrates), and 4) predators (invertebrates and vertebrates). Biogenic and hard bottom habitats provide a range of ecological services to nearshore environments. The structural complexity characteristic of hard bottom habitats provides attachment area for primary producers (e.g., algae and seagrass) that in turn provide structure and food for a variety of herbivorous animals (Heck et al., 2003). The addition of primary producers from the fouling algae community or those characteristic of the habitat created (e.g., seagrass and mangrove) also serves to process inorganic and organic nutrients. Although a fraction of these nutrients are assimilated in plant tissue, a large percentage of these nutrients are transferred to higher trophic levels through grazing by herbivorous animals. In addition to the primary producer community that develops on the structure provided by these habitats, sessile invertebrates (e.g., corals and sponges) also colonize the habitat and provide additional biogenic structure. Predatory species are attracted to the refuge provided by the structured habitat and/or the increased number of herbivorous animals, which may serve as prey. Thus, the compensatory restoration of structured habitats is expected to modify at least four functional groups (primary producers, herbivores, structural animals, and predators) and these four levels serve as the basis for our service by service comparison.

A schematic diagram for the approach used during the HSA is presented as **Figure 2**. A search and compilation of available literature concerning the floral and faunal communities associated with the eolianite habitat and the four potential compensatory habitats was utilized to identify ecological services. After the literature review was completed, lists of documented species were compiled for each habitat. These documented species were then assigned to one of the four ecological services. Although we recognize that a species may overlap service categories (e.g., an algae species is a primary producer that also provides structure), we assign them to one category. Available information on life-history stage was included in the listing of documented species (i.e., juvenile, adult, and spawner). New data collection or reanalysis of previously collected databases is beyond the scope of this contract; therefore the level of evaluation (qualitative to quantitative) was based on the nature of site-specific information found in the published literature. It was anticipated that there would be a greater availability of quantitative data to evaluate relative abundances of species in the selected habitat comparisons (**Figure 2**). Unfortunately, this level of analysis could not be performed with the limited availability of quantitative data. Consequently, the HSA that we present here is based to a large extent on resemblance analysis between the eolianite reef habitat and the four potential compensatory habitats.

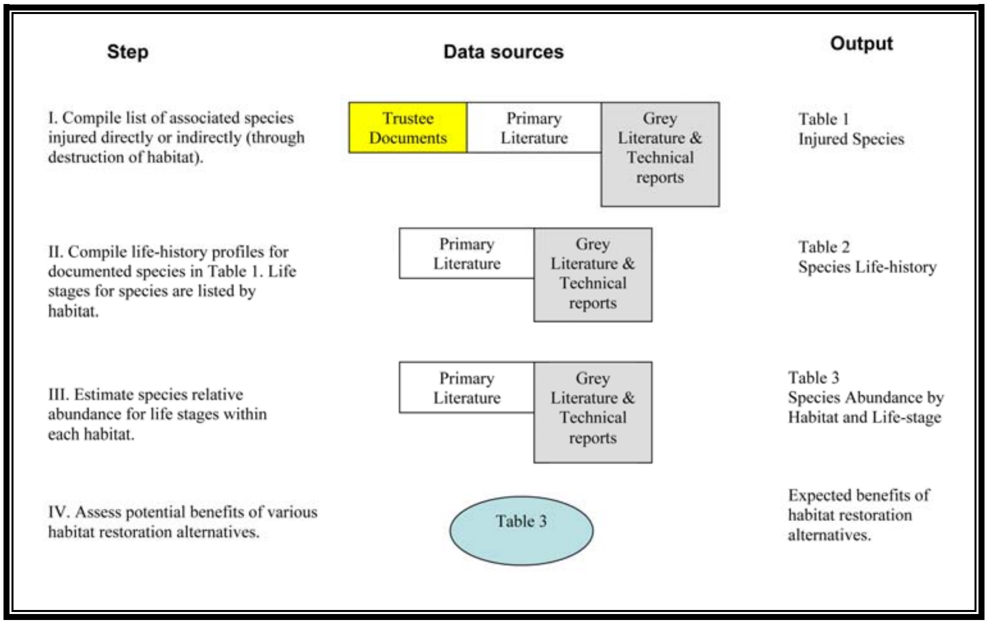

Figure 2. Schematic diagram for the approach used during the Habitat Suitability Analysis.

2.1 Literature Search

Literature sources included: 1) primary literature that included refereed journal articles, Masters Theses, and Ph.D. Dissertations and 2) grey literature that included technical documents pertaining directly to the *Morris J. Berman* grounding which were provided by the Trustees, technical reports and internet searches. Information pertinent to the flora and fauna potentially injured either directly or indirectly by the *Morris J. Berman* grounding were found by conducting a broad literature search utilizing a key word list. Additional government publications were collected by conducting a search of the NOAA document depository at the Rosenstiel School of Marine and Atmospheric Science in Miami, Florida. In addition, personal communications via telephone and email were also used to gather relevant information. A list of the evaluated literature sources is presented as **Appendix A**.

Internet databases used for the literature search included 1) Science Direct (SD), 2) Academic Search Premier (EBSCO), 3) Cambridge Scientific Abstracts (CSA), 4) ProQuest Digital Dissertations (PDD), and 5) ISI Web of Knowledge (ISI). SD is the world's largest electronic database for scientific, technical, and medical full text and bibliographic information. EBSCO is a general interest database with more than 3,000 journals indexed covering a wide variety of topics including social sciences, business, humanities, general science, and education. CSA provides access to more than 100 subject-oriented databases published by CSA and its publishing partners. PDD lists more that 1.6 million thesis and dissertation titles, citations, and abstracts. ISI is a web page for key word searches to access several refereed scientific journals.

2.2 Habitat Suitability Analysis

Using the data gathered from the literature review, a regional list was compiled of species common to the north coast of Puerto Rico. Species within the regional list that were documented to utilize the eolianite reef habitat were identified from Trustee provided injury assessment documents and habitat assessment studies conducted in similar nearby habitats. The species that were documented to utilize the eolianite reef habitat were considered to be species either directly or indirectly injured by the grounding incident. The utilization of the four potential compensatory habitats by the eolianite reef species was then determined from the literature search. Next, species were assigned to one of four service categories for analysis (i.e., primary producers, structural animals, herbivores, and predators). Small pelagic zooplankton predators that are predominantly pelagic in nature and lack a strong affinity for benthic habitats, were placed in a separate category (planktivore) and excluded from the analysis of predators in keeping with previous HSAs involving restoration of benthic habitats (Peterson et al., 2003). A complete regional list of the species reported to occur off the north coast of Puerto Rico with their associated service category, biological descriptor, and presence/absence by habitat is presented as **Appendix B.**

A data matrix of the species documented to occur in the eolianite reef habitat was created from the regional list of species from the north coast of Puerto Rico. This data matrix of eolianite reef species and their presence/absence within compensatory habitat type served as the basis for analysis of resemblance among the eolianite reef habitat and the four possible compensatory habitats. Consequently, our similarity analysis is based only on those 183 species that occurred in the eolianite reef. Ordination of the resemblance data among the habitat types (i.e., eolianite reef, shallow hard bottom, deep hard bottom, seagrass and mangrove) was performed using nonmetric multidimensional scaling (nMDS) with PRIMER® 6 software package (Clarke and Warwick, 2001). An ordination is a map of the samples (i.e., habitats), usually in two or three dimensions, in which the placement of the samples reflects the similarity of their biological communities. Nearby points have a very similar biological community, whereas more distant points have dissimilar communities. The first step in the nMDS method is to construct a similarity matrix among the samples (habitats). The similarity matrix was based on Bray-Curtis similarity distances, a widely used method for calculating similarity among samples, using presence/absence data for marine species reported to occur in the eolianite reef habitat located off the north coast of Puerto Rico. Bray-Curtis distances express how similar two habitats are to each other based on a scale of 0-100 with a value of 100 indicating greatest similarity. The nMDS method then uses the ranks of the similarities among the 5 habitat types (not the actual distance measurements) to construct the ordination plot. NMDS uses relative ranks in the visualization of plots, therefore the axes have no specified units. Four separate nMDS analyses were performed, one for each ecological service (i.e., primary producers, structural animals, herbivores, and predators). Visual comparisons of plots generated for each ecological service were used to characterize differences in community structure among the five habitat types. The plots are presented and described in **Section 3.4**.

Additional qualitative evaluation of the eolianite reef habitat and the four possible compensatory habitats was conducted by summarizing the life history information (where available) for the organisms that were either directly or indirectly injured by the habitat degradation/loss (**Appendix B**). These data, primarily focusing on predatory species, provided the basis for a limited evaluation of habitat utilization by life history stage (i.e., juvenile, adult, and spawner). No formal analysis was conducted by life-history stage due to limited data; life history data were used as qualitative factors in the discussion of potential benefits to the predatory community.

3.0 RESULTS

3.1 Synopsis of Literature Search

Injury assessment reports and other documents pertaining to the *Morris J. Berman* grounding were provided by the Trustees and reviewed prior to conducting the literature search. Grounding-specific documents and habitat assessments from similar habitats were utilized to create a list of species that occur in the eolianite reef habitat and to describe the injured reef resource. The species list, site description, and potential compensatory habitat descriptions were used to create a key word list that was utilized for the literature search. Results from the literature search and from internet databases utilizing selected key words are presented as **Table 1**. The literature search initially focused primarily on relevant literature from Puerto Rican marine habitats, but was later expanded to include the Caribbean and southern Florida due to lack of information from the north coast of Puerto Rico. A total of 362 references were collected and examined during the HSA program (**Table 1**).

References collected during the literature search were assigned to general subject categories and functional groups within a category. Number of references for each functional group within categories is presented in **Table 2**. The majority of references provided information on life history and basic biology of species potentially found in Puerto Rico. Although a relatively large number of site-specific studies concerning life histories and/or ecological field research were identified from Puerto Rico, the majority of these studies were conducted in coral reef habitats along the southwestern coast and were not applicable to the eolianite reef habitat injured during the grounding event (Lisa Carruba, 2005, personal communication, Puerto Rico National Marine Fisheries Service). The few studies conducted in areas near the grounding site were primarily qualitative reporting only presence/absence information. Similarly, few studies of mangrove and seagrass habitats were found for the north coast of Puerto Rico.

Table 1. Key words and databases utilized for the Habitat Suitability Analysis (HSA). Potential sources and selected HSA literature (in parentheses) are presented for each database. Hyphens (--) indicate no search for the given key word.

Key Words			Database				
			SD	**EBSCO**	**CSA**	**PDD**	**ISI**
Puerto Rico			620	4,732	195(6)	--	2,465
Puerto Rico	&	Fisheries	2(0)	9(1)	2(0)	6(3)	10(1)
	&	Reef	19(3)	20(10)	4(0)	22(13)	78(20)
	&	Seagrass	7(1)	2(0)	2(0)	10(6)	18(5)
	&	Mangrove	11(3)	9(1)	1(0)	1(1)	25(8)
	&	Near Shore Habitat	2(1)	0	0	0	1(1)
	&	Fish Production	0	1(0)	1(0)	--	0
	&	Fish	17(3)	4(4)	8(2)	32(9)	90(17)
	&	Ichthyofauna	0	0	0	--	0
	&	Sea Turtles	1(1)	1(1)	1(0)	--	6(1)
	&	Benthic	8(0)	12(2)	2(0)	8(3)	38(3)
	&	Sea Horse	0	0	0	--	0
	&	Hard Bottom Habitat	0	0	0	0	2(0)
Caribbean	&	Fisheries	38(2)	74(13)	14(2)	18(1)	94(4)
	&	Reef	154(10)	234(27)	20(10)	101(9)	897(35)
	&	Seagrass	38(7)	15(8)	18(0)	18(7)	124(11)
	&	Mangrove	34(4)	44(8)	82(8)	18	153(19)
	&	Near Shore Habitat	1(1)	1(1)	0	--	1(0)
	&	Fish Production	7(1)	0	0	--	0
	&	Fish	103(11)	125(0)	689(25)	62(10)	448(18)
	&	Ichthyofauna	0	0	0	--	0
	&	Sea Turtles	1(1)	31(2)	39(1)	--	22(0)
	&	Benthic	45(0)	31(2)	216(9)	31(5)	222(5)
	&	Hard Bottom Habitat	2(0)	0	1(0)	1(0)	5(0)
	&	Sea Urchin	13(6)	2(0)	0	6(2)	46(3)
	&	Habitat	84(8)	118(23)	12(0)	--	347(21)
Life History	&	Corals	42(5)	10(1)	82(3)	--	94(4)
	&	Sponges	12(0)	1(0)	25(0)	--	27(0)
	&	Sea Urchin	9(0)	7(0)	25(0)	--	69(0)
Reproduction	&	Corals	0	40(1)	124(3)	--	239(3)
	&	Sponges	0	50(0)	81(2)	--	111(0)
Growth Rate	&	Corals	207(8)	37(1)	134(3)	--	195(2)

Table 2. Number of references is listed for each functional group within general subject categories. A reference may appear in more than one category.

Category	Group	Total
Life History		
	Algae	6
	Sessile Invertebrates	30
	Mobile Invertebrates	35
	Turtles	7
	Fish/Sharks	88
Site Specific		
	Puerto Rico (P.R.)	71
	Grounding Location	12
	P.R. North Coast	9
General Habitat		
	Seagrass	24
	Shallow Reef: 5-10 m	17
	Deep Reef: >10 m	5
	Mangrove	38
Conceptual		45
Other		14

3.2 *Morris J. Berman* Grounding Site Characterization

Puerto Rico, situated on the leading edge of the Caribbean plate, has a complex northern coastline formed predominantly of limestone formations and alluvial plains which supported the development of beaches and dunes (Krushensky and Schellekens, 2001). The insular shelf along the north coast of Puerto Rico is less than one mile wide and experiences intense wave action and longshore currents (Glauco A. Rivera & Associates, 2003). Wave heights along the Puerto Rican north coast predominantly generated by the east Trade Winds range from 1 to 3 m (Morelock, 1978). These physical conditions, in conjunction with disproportional erosion of the limestone substrate, create topographically variable localized reef formations. Lithified beach rock and fossil sand dunes (i.e., eolianite) are nearshore features characteristic of the San Juan area. Eolianite reefs are submerged hard bottom structures composed of sand deposits cemented together with calcium carbonate. Along the northern coastline of Puerto Rico, these reefs are oriented west to northwest following a slightly sinuous course (Kaye, 1959).

The *Morris J. Berman* barge impacted the seaward edge of a high-energy eolianite reef in a water depth of 2.4 to 4.6 m (8 to 15 ft) that runs parallel to the coastline. The injured eolianite reef, strongly influenced by high wave energy and large influxes of river sediment, was characterized by Hudson and Goodwin (1995) as structurally complex due to erosional processes from land and sea which have created a microkarst topography of small pits, holes, and crevices within randomly distributed, erosion resistant rocky outcrops, shallow caves and trenches. The impacted eolianite reef habitat lacks any evidence of long-term coral reef accretion or relict coral reef deposits.

The habitat impacted by the *Morris J. Berman* grounding event is part of a continuous nearshore reef feature which extends the length of the San Juan coastline as shown in **Figure 1** (Kendall et al., 2001). Vicente (1994), Entrix (1995), and Hudson and Goodwin (1995) characterized the biological resources of the impacted eolianite reef habitat as well as unimpacted reference areas following the grounding event. These documents provided qualitative information such as lists of species within the injury area, lists of species in unimpacted eolianite habitats, and general habitat descriptions. Other surveys providing qualitative and limited quantitative descriptions of the eolianite reef habitat along the northern coast included pipeline corridor characterizations offshore of Isla Verde, Puerto Rico conducted by Vicente & Associates (2000) and Glauco A. Rivera & Associates (2003). Dial Cordy & Associates (2000) conducted an assessment of similar habitat offshore Arecibo, Puerto Rico, approximately 60 km west of the grounding site. CSA Architects and Engineers, et al. (2004) conducted a habitat assessment for the Puerto Rico Aqueducts and Sewer Authority (PRASA) within similar hard bottom habitats east of Puerto Rico which provided limited quantitative fish and coral community data. Mignucci-Giannoni (1999) listed over 152 species and 15 taxon groupings of marine organisms affected by the *Morris J. Berman* oil spill, as documented from specimens gathered along the shoreline after the incident by the Caribbean Stranding Network. Mignucci-Giannoni (1999) found that the most commonly affected biota from the grounding event and subsequent oil spill were echinoderms, mollusks, and crustaceans, respectively comprising 58, 25, and 10 percent. Vertebrates, primarily fish, accounted for approximately 6% of the marine organisms affected by the *Morris J. Berman* grounding event (Mignucci-Giannoni, 1999). The eolianite reef injured by the *Morris J. Berman* was visually dominated by soft corals, sponges and macroalgae.

3.3 Reef Habitat Species Composition

A complete listing of the species reported to occur off the north coast of Puerto Rico with associated service category, biological descriptor, and presence/absence by habitat was compiled by review of the collected literature and is presented as **Appendix B**. Life-history stage (juvenile, adult, or spawning) is presented for some of the documented species; life history data was unavailable for most species. Of the 478 marine species documented along the north coast of Puerto Rico, 183 were documented as occurring within the eolianite reef habitat. Faunal groups with the most species either directly or indirectly injured by the loss of habitat due to the grounding event were fish, sponges, and corals (both hard and soft) with 108, 24, and 25, respectively (**Appendix B**).

3.3.1 Primary Producers

Primary producers are organisms, most often plants, which convert carbon dioxide into chemical energy by photosynthesis. Primary producers are important components of the reef community because they provide both food and structure for higher trophic levels. Algae are the most diverse macrobenthos along the north coast of Puerto Rico and included 113 species of red algae, 59 species of green algae, and 33 species of brown algae (**Appendix B**).

Fourteen species of algae were documented from the eolianite reef habitat (**Appendix B**). Mixed algal assemblages of red articulated coralline algae, fleshy red, green and brown algae are visually dominant in the area of the grounding site (Vicente & Associates, 2000). Green and brown algae such as *Halimeda discoidea, Udotea flabellum,* and *Dictyota* spp. are important primary producers that form loose clumps or dense mats on shallow rocky substrates. *Halimeda* spp., calcareous green algae, are also an important source of reef sediments. Coralline algae are beneficial to reef habitats by binding the reef substrates and increasing the structural integrity of the habitat. Consolidation of reef substrate by coralline algae creates microhabitats for several invertebrates such as juvenile sea urchins, chitons, and limpets. Fleshy red algae, such as *Bryothamnion triquetum, Gracilaria dominguensis,* and *Amansia multifida,* are bushy and provide structurally complex habitats for many small fish and invertebrates. Regional checklists of benthic alga have been compiled by Almodovar and Ballantine, (1983); Ballantine and Norris, (1989); Ballantine and Aponte, (1997); and Ballantine et al., (2004).

3.3.2 Structural Animals

Structural animals are sessile organisms that attach to the substrate and subsequently increase its structural complexity. Although many plant and algal species increase the structural complexity of their environment, as discussed above, their primary service to their environment is to provide food for higher trophic levels and therefore were described and analyzed as primary producers. The most common organisms documented along the north coast of Puerto Rico that increase the structural complexity of the environment in which they inhabit are soft and hard corals and sponges.

Soft corals are a conspicuous component of marine communities worldwide. Soft corals typically have branching or fan morphologies which allows for minimal exploitation of hard substrate while utilizing a large volume of the water column (Barnes, 1980). Soft corals by virtue of their common arborescent colonial morphs, provide structural complexity and vertical relief to the physical habitat. Soft corals provide refuge for various symbiotic and epizoic plants and animals that either attach to or crawl on the surface. Some of the symbionts take on the color of their soft coral host (Barnes, 1980). Common soft corals found along the northern coast of Puerto Rico include sea fans (*Gorgonia* sp.), yellow sea whips (*Pterogorgia citrina*), and sea rods (*Eunicea* spp.) (Vicente & Associates, 2000). Thirteen of the fifteen soft coral species found along the northern coast were documented in the eolianite reef habitat (**Appendix B**).

Scleractinian corals, or hard corals, are the most important of the calcium carbonate-accreting organisms and are the major structural contributor to modern reef formation. Hard coral colony morphology is variable and dictated primarily by species and environmental factors. For example, low-profile colony morphologies often referred to as plate and encrusting forms, are more indicative of high-energy environments. Hard corals provide structural complexity and increase surface area and abundance of sessile macroinvertebrates which influence the diversity and abundance of fishes (Ferreira et. al., 2001). Hard corals provide habitat three dimensionality in the form of vertical relief and interstices which influences number of reef fish species and their abundance (Luckhurst and Luckhurst, 1978; Dennis and Bright, 1988). Some of the common species of hard corals found colonizing the shallow hard bottom substrate along the north coast of Puerto Rico are the great star coral (*Montastraea cavernosa),* symmetrical brain coral (*Diploria strigosa*), massive starlet coral (*Siderastrea siderea*), mustard hill coral (*Porites astreoides*), and finger coral (*P. porites*). Of the twenty-four species of hard corals documented along the north coast of Puerto Rico, 12 species were documented to occur in the eolianite reef habitat and were therefore potentially directly injured by the *Morris J. Berman* grounding event (**Appendix B**).

The vast majority of sponges are filter-feeding marine organisms and are an important component of the nearshore hard bottom community. Sponges are highly diverse concerning their ecological functions; in particular shallow-water species have been documented to mediate substrate rubble consolidation (Wulff, 1984), contribute to bioerosion of hard substrates, and modify hard coral morphology (Goreau and Hartman, 1966). At least 24 different species of sponges have been documented along the northern coast of Puerto Rico, nineteen of which were reported to inhabit the eolianite reef (**Appendix B**). Commonly observed sponges on the eolianite reef include the giant barrel sponge (*Xestospongia muta)*, brown variable sponge (*Anthosigmella varians*), and the vase sponge (*Callyspongia vaginalis*). *X. muta*, a visually dominant sponge that can be as wide and as high as one meter, provides increased structural complexity on the reef and habitat for numerous sponge inquilines such as brittle stars and snapping shrimp. *A. varians* has two distinct growth forms that include a massive amorphous lobate form and a sprawling encrusting form. *C. vaginalis* is a relatively large branching sponge that provides habitat for surficial zoanthids (*Parazoanthus* sp.) and other invertebrates.

3.3.3 Herbivores

Herbivores are animals that consume primary producers as an energy source. Both invertebrates, such as sea urchins, and vertebrates, such as fish and sea turtles, can be characterized as herbivores if their diet consists primarily of primary producers. Within reef communities herbivores provide food for predatory organisms and help to maintain a balance between primary producers and structural animals. Fifteen species of herbivorous vertebrates and six species of herbivorous invertebrates occur within the eolianite reef habitat and were potentially injured, by the grounding incident.

3.3.3.1 Invertebrates

Common motile marine invertebrates impacted by the *Morris J. Berman* grounding event included various crustaceans, echinoid echinoderms, and a gastropod mollusk. Echinoid echinoderms (i.e., sea urchins) are an important component of the reef system that helps maintain substrate availability and structural complexity of the habitat. The rock-boring urchin (*Echinometra lucunter*) is a bioeroder which breaks down the substrate and helps maintain highly variable micro-habitats within the reef structure. Habitat creation within the structure facilitates species diversity due to niche partitioning and biotal zonation. Herbivorous urchins, such as the longspine urchin (*Diadema antillarum*), variegated urchin (*Lytechinus variegatus*), and the white sea urchin (*Tripneustes ventricosus*) which graze on algae, facilitate successional progression by providing available substrate for structural reef species. A localized die off of sea urchins was reported just days after the *Morris J. Berman* grounding event; urchins that were found alive showed visible signs of oil influence such as loss of spines, poor adherence to the substrate, and algal tufts growing on the spines (Vicente, 1994). The queen conch, *Strombus gigas*, is an herbivorous mollusk common in seagrass beds and algal flats that was documented in the injury assessment reports as injured by the *Morris J. Berman* grounding incident. The queen conch is an important commercial species in Puerto Rico and is listed as threatened in

Appendix II of the Convention of International Trade in Endangered Species (CITES) as threatened.

3.3.3.2 Vertebrates

The north coast hard bottom habitat is considered a habitat of concern for the threatened green sea turtle (*Chelonia mydas*) and the endangered hawksbill sea turtle (*Eretmochelys imbricata*). During rescue and rehabilitation efforts following the grounding, two oiled green sea turtles were treated by the Caribbean Stranding Network (Mignucci-Giannoni, 1999). Green sea turtles, with a smooth grey, green, brown, and black carapace, can be up to 4 ft long and weigh up to 500 pounds. Adult green sea turtles are herbivorous and eat primarily seagrass and algae. Juvenile green sea turtles are carnivores that consume jellyfish and other invertebrates found in the eolianite reef habitat. The hawksbill is a small to medium turtle approximately 2 – 3 ft long and weighs up to180 lbs. Adult hawksbills forage primarily on sponges found on hard bottom habitats. Juveniles are known to forage and consume algae in coastal hard bottom areas of northern Puerto Rico.

Herbivorous fishes within the eolianite habitat include 8 families of ichthyofauna (**Appendix B**). These herbivores feed exclusively on either the algae that grows directly on the reef or on the plankton in the water column above the reef. Acanthurids (Surgeonfish, 3 species), Pomacentrids (damselfish, 2 species), Scarids (parrotfish, 5 species), a Blenniid (redlip blenny, *Ophioblennius atlanticus*), and a Monacanthid (orange filefish, *Aluterus punctatus*) are herbivorous fish that graze attached algae and are found in the eolianite reef habitat. Planktivorous reef associated herbivores include one Engraulid species (anchoveta, *Cetengraulis edentulus*), Exocoetids (flyingfishes, 2 species), and a Pomacentrid (Blue chromis, *Chromis cyaneus*).

3.3.4 Predators

Predators are animals that feed on other animals. Both invertebrates, such as the spiny lobster (*Panulirus argus*) and vertebrates, such as the red grouper (*Epinephelus morio*), feed on herbivores and other small predatory animals (**Appendix B**). Predatory activities influence the recruitment of juvenile fish and invertebrates to reef communities (Hixon, 1991) and influence reef assemblages by controlling herbivore populations that may overgraze plant assemblages. In total, 57 families encompassing 98 species of predatory ichthyofauna and 2 species of invertebrates have been documented to occur on eolianite reefs on the northern coast of Puerto Rico.

3.3.4.1 Invertebrates

The spiny lobster (*P. argus*) and blue crabs (*Callinectes* spp.) are important commercial species of crustaceans that likely experienced indirect injury due to loss of habitat as a result of the grounding event.

3.3.4.2 Vertebrates

Predatory icthyofauna documented to occur within eolianite reefs along the northern coast of Puerto Rico include top predators, demersally associated species, and pelagic species (**Appendix B**). The bull shark (*Carcharhinus leucas*), blacktip shark (*Carcharhinus limbatus*), barracuda (*Sphyraena barracuda*), tarpon (*Megalops atlanitcus*), and four species of snook (e.g., *Centropomus unidecimali*,) are all top predators found on the eolianite reef habitat. Twenty-two predatory species of the demersally associated grouper-snapper complex [i.e. red grouper (*Epinephelus morio*), margate (*Haemulon album*), jolthead porgy (*Calamus bajonado*), and hogfish (*Lachnolaimus maximus*)] have been documented within the northern Puerto Rican eolianite reef habitat. Three pelagic predatory species such as, the bar jack (Caranx ruber), atlantic bumper (*Chloroscombus crysurus*) and the bigeye scad (*Selar crumenophthalmus*), feed in the open water habitat above and adjacent to the eolianite reef habitat.

3.4 Habitat Suitability Analysis

The HSA compares the ecological services provided by the aforementioned habitats with the eolianite reef habitat in terms of four functional groups: 1) primary producers, 2) structural animals, 3) herbivores (invertebrates and vertebrates), and 4) predators (invertebrates and vertebrates). Because the majority of studies conducted in areas near the grounding site and within the four possible compensatory habitats were primarily qualitative, our analyses were restricted to the comparison of presence/absence data. Non-metric multidimensional scaling (nMDS), a type of ordination which generated plots of the relative similarity of the five habitat types (points closer together have greater similarity), were used as the basis for the HSA analysis. NMDS uses relative ranks in the visualization of plots, the axes have no specified units. Bray-Curtis distances, which were used to determine the relative similarity ranks, are also presented to provide a more numeric index of similarity.

3.4.1 Primary Producers

At the base of the food chain of the eolianite reef habitat, as well as the four possible compensatory restoration habitats, are primary producers (algae, seagrass, and mangroves) which provide two important ecological services: food for herbivores and structural complexity for small invertebrates and juvenile fishes. The presence/absence of 14 species of green, red and brown algae were used as the basis for constructing a similarity matrix. Shallow hard bottom demonstrated the highest degree of similarity to the eolianite reef (**Figure 3**). Mangrove, a habitat which supports a high level of primary production owing to its biogenic nature, ranked 2^{nd}, followed by deep hard bottom and seagrass (**Table 3**).

Figure 3. MDS plot illustrating the resemblance of the five habitats based on the presence/absence of eolianite reef primary producers. Stress indicates the degree to which the plot represents the data, values of less than 0.1 are considered highly representative.

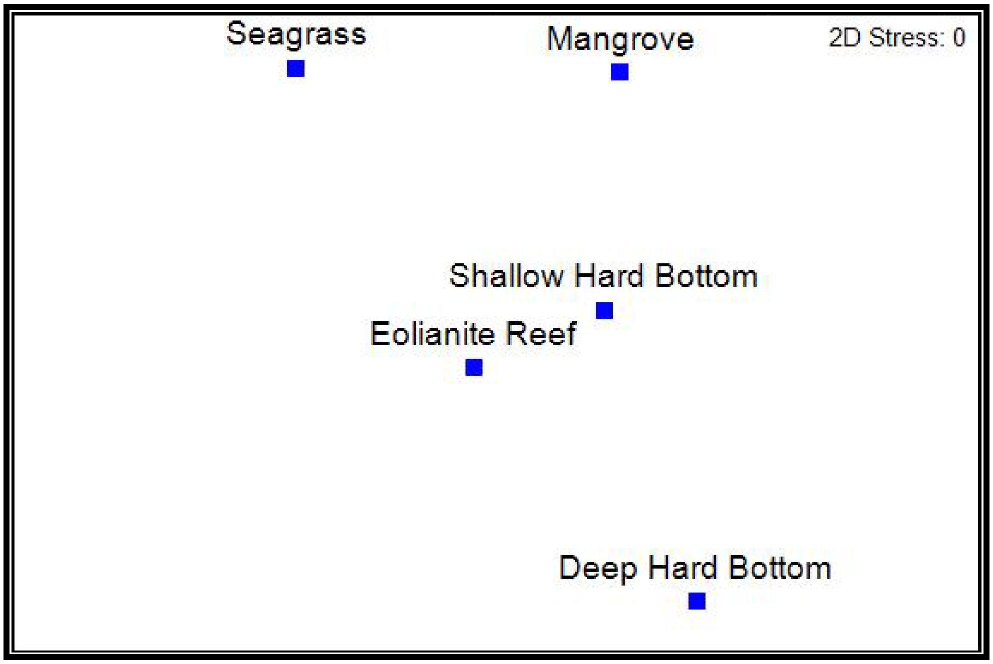

Table 3. Bray-Curtis similarity (0-100 with a value of 100 indicating greatest similarity) coefficients for the five habitats based on the presence/absence of primary producers.

HABITATS	Eolianite Reef	Shallow Hard Bottom	Deep Hard Bottom	Seagrass	Mangrove
Eolianite Reef					
Shallow Hard Bottom	66.7				
Deep Hard Bottom	35.3	40.0			
Seagrass	25.0	22.2	0		
Mangrove	35.4	60.0	0	40.0	

3.4.2 Structural Animals

Corals and sponges are common species found within the eolianite reef habitat and are a key structural element for fish and invertebrates (see Section **3.3.2**). Based on the presence/absence of 53 species (primarily soft corals, hard corals, and sponges), greatest similarity of fauna was found between the eolianite reef and shallow hard bottom habitat (**Figure 4**; **Table 5**). Deep hard bottom, which ranked second, and seagrass, which ranked third in similarity to the eolianite reef in overall similarity, were close in similarity ranking. Mangrove was the most dissimilar habitat to eolianite reef. Differences between the eolianite reef, mangrove, and seagrass habitats in terms of structural animals are partly offset, in terms of provision of structural refuge for fish, by the structure provided by the exposed mangrove root or seagrass leaf area.

Figure 4. MDS plot illustrating the resemblance of the five habitats based on the presence/ absence of structural animals (primarily soft corals, hard corals, and sponges). Stress indicates the degree to which the plot represents the data, values of less than 0.1 are considered highly representative.

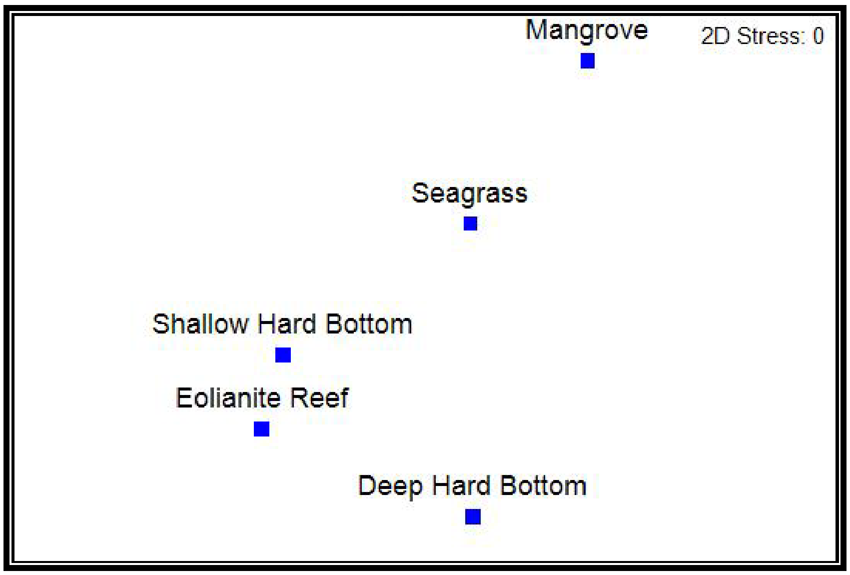

Table 5. Bray-Curtis similarity (0-100 with a value of 100 indicating greatest similarity) coefficients for the five habitats based on the presence/absence of structural animals.

HABITATS	Eolianite Reef	Shallow Hard Bottom	Deep Hard Bottom	Seagrass	Mangrove
Eolianite Reef					
Shallow Hard Bottom	84.8				
Deep Hard Bottom	34.4	32.0			
Seagrass	31.8	36.8	19.1		
Mangrove	10.8	14.3	14.3	46.2	

3.4.3 Herbivores

Inshore and nearshore habitats along the coast of Puerto Rico are known to possess a rich abundance of herbivorous fish and invertebrates. Based on our literature review, 20 species of herbivorous fish (e.g., surgeonfish, parrotfish, mullet) and invertebrates (sea urchins, gastropods) would likely occur within the eolianite reef habitat. With the exception of deep hard bottom, similarity was high among the habitat types (**Figure 5**, **Table 6**). The high degree of similarity among eolianite reef, shallow hard bottom, mangrove, and seagrass habitats was largely driven by the overlap of the herbivorous fish community, and to a lesser degree by the echinoderms. Deep hard bottom had few documented herbivore species: two species of parrotfish and one surgeonfish (see **Appendix B**).

Figure 5. MDS plot illustrating the resemblance of the five habitats based on the presence/absence of herbivorous species (vertebrate and invertebrate). Stress indicates the degree to which the plot represents the data, values of less than 0.1 are considered highly representative.

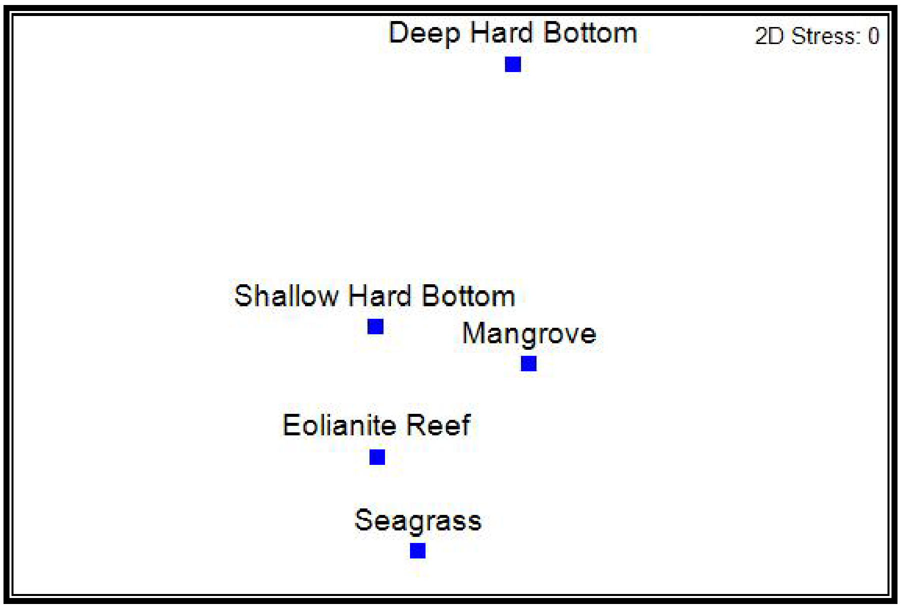

Table 6. Bray-Curtis similarity (0-100 with a value of 100 indicating greatest similarity) coefficients for the five habitats based on the presence/absence of herbivores.

HABITATS	Eolianite Reef	Shallow Hard Bottom	Deep Hard Bottom	Seagrass	Mangrove
Eolianite Reef					
Shallow Hard Bottom	74.3				
Deep Hard Bottom	24.0	37.5			
Seagrass	77.8	59.3	23.6		
Mangrove	66.7	66.7	28.6	64.0	

3.4.4 Predators

Predators represent a highly diverse assemblage of fish and invertebrates that utilize the five habitats as structural refuge and/or foraging grounds. There were 94 predators documented on the eolianite reef habitat. Shallow hard bottom habitat was most similar to the eolianite reef habitat based on the presence of predatory species (**Figure 6**). Overall, all four potential compensatory habitats showed high similarity (Bray Curtis values > 50, **Table 7**) to the eolianite reef. Shallow hard bottom was the most similar followed by seagrass, mangrove and deep hard bottom (**Table 7**). Species of commercial or recreational fisheries significance, in particular, snapper, grouper and grunts, were common in all habitats. Spiny lobsters were present in all habitats except deep hard bottom.

Figure 6. MDS plot illustrating the resemblance of the five habitats based on the presence/absence of predatory species (vertebrate and invertebrate). Stress indicates the degree to which the plot represents the data, values of less than 0.1 are considered highly representative.

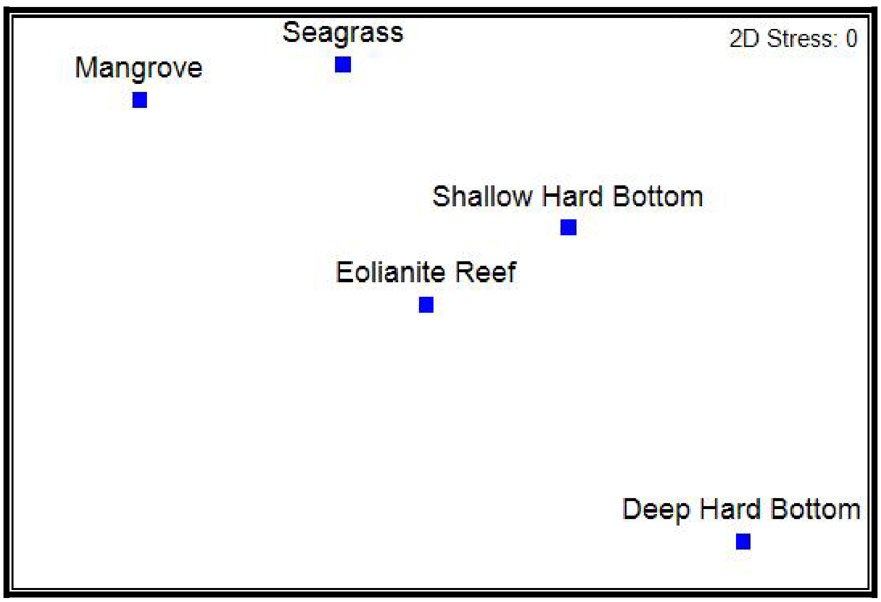

Table 7. Bray-Curtis similarity (0-100 with a value of 100 indicating greatest similarity) coefficients for the five habitats based on the presence/absence of predators.

HABITATS	Eolianite Reef	Shallow Hard Bottom	Deep Hard Bottom	Seagrass	Mangrove
Eolianite Reef					
Shallow Hard Bottom	81.0				
Deep Hard Bottom	54.3	62.6			
Seagrass	73.9	68.9	53.3		
Mangrove	67.6	53.5	50.6	75.7	

Detailed information on habitat utilization was available for some commercially and recreationally important species. Two exploited invertebrate species, spiny lobster (*P. argus*) and queen conch (*Strombus gigas*), were reported to utilize one or more of the five evaluated habitats. Juvenile spiny lobsters were reported in seagrass, mangrove, and shallow water hard bottom. Adult spiny lobsters of harvestable size were reported from shallow hard bottom and seagrass (**Appendix B**). Adult queen conchs were also documented in both shallow hard bottom and seagrass. Juvenile conchs were documented only in seagrass. Although some variability among fisheries species occurred with respect to habitat utilization, in general, mangrove, seagrass, and shallow hard bottom were used as nursery grounds for juvenile fisheries species. In contrast, deep hard bottom was predominantly utilized by adults and to some extent as spawning areas. With the exception of silk snapper (*Lutjanus vivanus*), a deepwater snapper species, most snapper and grouper species utilized mangrove and/or seagrass habitat as nursery grounds (**Table 8** and **Appendix B**). Shallow hard bottom also served as juvenile habitat for some fisheries species; utilization of shallow hard bottom was higher among adults.

Table 8. Documented occurrence of selected fish and invertebrate species of commercial and recreational fisheries significance in the four potential compensatory habitats by life stage (A = adult and J = juvenile) and reported spawning activity (S). A + sign indicates that the references denoted presence but did not give information on life stage.

Species	**Common name**	**Shallow Hard Bottom**	**Deep Hard Bottom**	**Mangrove**	**Seagrass**
Strombus gigas	Queen conch	A			J, A
Panulirus argus	Spiny lobster	J, A		J	J, A
Lutjanus griseus	Gray snapper	J, A, S	S	J, A	J, A
Lutjanus vivanus	Silk snapper	J, A	A		
Lutjanus analis	Mutton snapper	+, S	+, S	J, A	J, A
Ocyurus chrysurus	Yellowtail snapper	A	+, S	J, A	J, A
Epinephelus gutatus	Red hind	A	+	J	J
Epinephelus striatus	Nassau grouper	A	A	J, A	J

4.0 CONCLUSIONS

Our recommendations are based on the analysis of qualitative presence/absence data from the eolianite reef habitat along the north coast of Puerto Rico; a lack of quantitative data limited the level of detail in the HSA. The majority of studies from Puerto Rico, identified in our literature search, were conducted in coral reef habitats along the southwestern coast and were not applicable to the eolianite reef habitat present at the grounding site. Few studies were conducted in areas near the grounding site and these were primarily qualitative (presence/absence) in nature. Similarly, few studies of mangrove and seagrass habitats were found for that pertained to the north coast of Puerto Rico. Quantitative data on densities and demographic parameters by habitat type would have greatly enhanced the HSA capacity to make quantitative predictions on ecological services (Peterson et al., 2003; Powers et al., 2003); however, such an analysis was not consistent with the available information and may not be necessary in a case where damages have been agreed upon. Although it is possible that the current database could be augmented through re-analysis of photographs and video from previous trustee council studies or site-specific biological sampling, additional analyses and sampling could be costly and may not significantly change the conclusions of the HSA.

4.1 Recommendations

A total of 183 species were documented from the literature search to occur on the eolianite reef habitat. Of these species, 18 (9.8%) were unique to the eolianite habitat, therefore the maximum number os eolianite reef species supported by utilizing all four of the compensatory habitats is 165. **Table 9** shows the number and percentage of eolianite reef species shared with each of the four potential compensatory habitats (Shared) and the number of shared eolianite reef species unique to each of the compensatory habitats (Unique). For example, shallow hard bottom shares 128 species with the eolianite reef habitat and of those 128 shared eolianite reef species 42 are found only at the shallow hard bottom habitat (**Table 9**). **Figure 7** is an nMDS plot illustrating the similarity between the habitats based on all of the eolianite species.

Table 9. Number and percentage of eolianite reef species shared with each of the four potential compensatory habitats and the number of shared eolianite reef species unique to each of the compensatory habitats.

	Compensatory Habitat Type			
Eolianite Reef Species	**Shallow Hard Bottom**	**Deep Hard Bottom**	**Mangrove**	**Seagrass**
Shared	128 (70%)	56 (31%)	68 (37%)	84 (46%)
Unique	42 (23%)	7 (3.8%)	8 (4.4%)	9 (4.9%)

Habitats were ranked according to degree of similarity to the eolianite reef as shown by the nMDS plots as well as the number of shared eolianite reef species (**Table 10**). Shallow hard bottom appears to have the highest degree of similarity, sharing 128 species with the eolianite reef habitat; and deep hard bottom was the least similar, with only 56 shared species. Seagrass habitat, an important recruitment and nursery habitat, ranked second in similarity to the eolianite reef sharing 46% (84 species) of the eolianite reef species. Mangrove habitat ranked third overall. Difference in ranking between seagrass and mangrove is relatively minor and both should be considered similar to one another in terms of compensation potential. Seagrass was the only area utilized by juvenile queen conch, a species of significant management concern; seagrass also provides habitat for the two species of sea turtles common to the northern coast of Puerto Rico.

Figure 7. MDS plot illustrating the overall resemblance of the five habitats based on all of the habitat services. Stress indicates the degree to which the plot represents the data, values of less than 0.1 are considered highly representative.

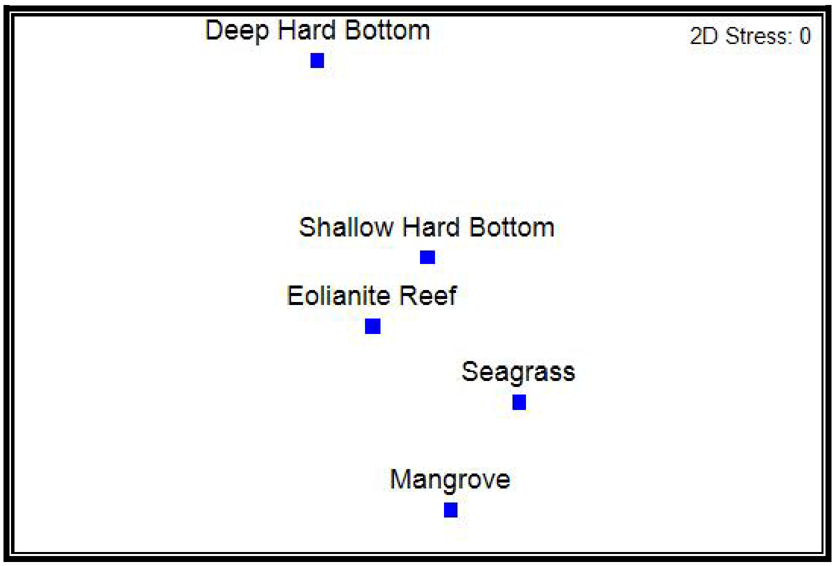

Table 10. Relative rankings of compensatory habitats based on Bray-Curtis similarity of four services to eolianite reef habitat and fisheries significance of habitats.

Services and Fisheries Significance	Shallow Hard Bottom	Deep Hard Bottom	Seagrass	Mangrove
Primary production	66.7	35.3	25.0	35.4
Structural animals	84.8	34.4	31.8	10.8
Herbivores	74.3	24.0	77.8	66.7
Predators	81.0	54.3	73.9	67.6
Recruitment Habitat (Fisheries)	High	Low	High	Moderate
Ranking	**1**	**4**	**2**	**3**

4.1.1 Shallow Hard Bottom (5-10 m)

In examination of the four ecological service categories, the number of species in common with the eolianite reef, and consideration of species of fisheries significance, the shallow hard bottom showed the greatest similarity to the eolianite reef habitat (**Table 10**) and would be considered to be the most appropriate compensatory habitat. Artificial reefs created in the shallow water areas would be expected to function similarly to the injured habitat, provided the design of such reefs could reasonably mimic the eolianite reef. However, the logistical difficulties associated with construction along the exposed north coast of Puerto Rico will preclude on-site restoration. Placing artificial reefs within more protected areas may be a reasonable alternative to on-site restoration if the habitat is created in close proximity to the shallow hard bottom so there is a shared pool of larvae and propagules. The artificial reef created in protected areas would be expected to yield many of the same ecological benefits as the eolianite reef habitat.

4.1.2 Habitat Mosaic

No single habitat was identical to the injured habitat for all four services: therefore a mosaic approach of compensatory restoration of more than one habitat may be the best alternative. In many areas the restoration of adjacent or nearby habitats has proven economically and ecologically effective in restoring habitat function and providing greater fisheries enhancement (Micheli and Peterson, 1999; Grabowski, 2002; Peterson and Lipcius, 2003). The number of eolianite reef species that are in common with each habitat are given in **Table 11.** The number of eolianite reef species that would be expected to benefit from the compensatory restoration of two nearby habitat types is shown in **Table 12.** Of the two compensatory habitat mosaics, shallow hard bottom coupled with either a seagrass or mangrove habitat nearby would provide compensatory restoration for 150 and 149 eolianite reef species, respecitively. **Table 13** shows the number of eolianite reef species that would benefit from the compensatory restoration of three habitat types. **Appendix C** provides a breakdown of the number of additional species that would benefit from the sequential addition of each habitat type; beginning with the shared species provided by a single compensatory habitat and sequentially adding compensatory habitats and their shared eolianite reef species. **Appendix C** could be a useful tool for management purposes to determine the order in which the habitats are chosen for compensatory restoration. Utilization of all four compensatory habitats yields 165 eolianite reef species, regardless of the order in which they are created (**Appendix C**). **Figure 8** provides a schematic representation of a compensatory restoration area prior to and following coupled compensatory restoration (i.e., seagrass and artificial reef placement).

Table 11. Number of eolianite reef species in common between compensatory habitats.

Compensatory Habitat	**Shallow Hard Bottom**	**Deep Hard Bottom**	**Mangrove**	**Seagrass**
Shallow Hard Bottom		48	47	62
Deep Hard Bottom	48		27	30
Mangrove	47	27		53
Seagrass	62	30	53	

Table 12. Number of eolianite reef species that would potentially benefit from the given mosaic of two compensatory habitats.

Compensatory Habitats	Shallow Hard Bottom	Deep Hard Bottom	Mangrove	Seagrass
Shallow Hard Bottom	------	136	149	150
Deep Hard Bottom	136	------	97	110
Mangrove	149	97	------	99
Seagrass	150	110	99	------

Table 13. Number of eolianite reef species that would potentially benefit from a mosaic of three compensatory habitats.

Compensatory Habitats	Shallow Hard Bottom & Deep Hard Bottom	Mangrove & Seagrass
Shallow Hard Bottom	------	158
Deep Hard Bottom	------	123
Mangrove	156	------
Seagrass	157	------

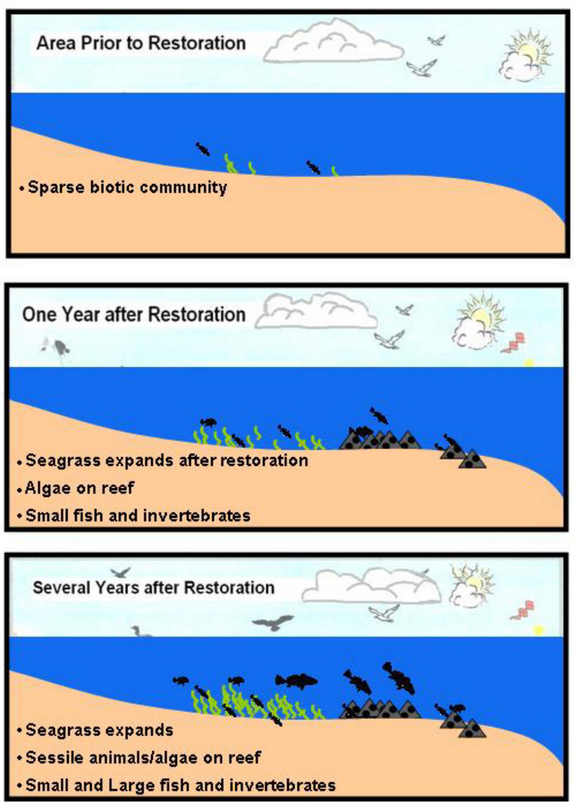

Figure 8. Schematic representation of a mosaic compensatory restoration area prior to and following coupling of seagrass and artificial reef habitat creation/restoration.

4.1.2.1 Two Habitat Mosaic: Shallow Hard Bottom and Seagrass or Shallow Hard Bottom and Mangrove

A desirable coupling may be the restoration of seagrass beds or mangroves near a shallow artificial reef, providing compensatory services to 150 or 149 eolianite reef species, respectively. Greater species richness and higher densities of fish are found in areas where seagrass habitats are adjacent to coral reef habitats (Dorenbosch et al., 2004; Nagelkerken and Van der Velde, 2004; Weinstein and Heck, 1979). The juxtaposition of seagrass or mangrove with hard bottom mimics the landscape of many productive coral reefs as well as habitats within San Juan Bay. Recruitment of juvenile fishes is facilitated by the expanse of seagrass beds or shallow water mangrove habitats which provide shelter from predators and abundant food sources. In addition, seagrass beds may provide nursery area for planktonic fish larvae more effectively than reefs, which are normally utilized by later stage juveniles and adults (Powers et al., 2003). Seagrass and mangrove habitats are nursery areas for many reef fish. Juvenile *Haemulon flavolineatum, H. sciurus, Lutjanus analis, L. apodus, L. mahogoni, Ocyurus chrysurus, Acanthurus chigurus, Scarus coerulus,* and *Sphyraena barracuda* are found predominantly in seagrass beds, where as juvenile *L. apodus, L. griseus, S. barracuda,* and *Chaetodon capistratus* are some of the species more commonly found in mangroves (Nagelkerken et al., 2000). Many juvenile fish within seagrass beds and mangroves exhibit an ontogenenetic habitat shift as they outgrow the protection provided by the juvenile habitat and migrate to nearby reef habitats (Weinstein and Heck, 1979; Nagelkerken et al., 2000; Cocheret de la Moriniere et al., 2002). A nearby artificial reef that mimics the natural hard bottom habitat would provide habitat for adults and could stabilize the seagrass bed or mangrove habitat from wave action and sediment transport. Creating a mosaic habitat of seagrass beds or mangroves and artificial reefs would provide both juvenile and adult habitats for species associated with the eolianite reef habitat injured by the *Morris J. Berman* grounding.

4.1.2.2 Three Habitat Mosaic: Shallow Hard Bottom, Seagrass, and Mangrove

The compensatory restoration of shallow hard bottom, seagrass and mangrove habitats within a lagoonal area would provide compensatory services to 86% of the eolianite reef species that were either directly or indirectly injured by the grounding incident. Combined compensatory restoration of these three habitats would provide habitats for many of the juveniles and adults of the predatory and herbivorous species documented on the eolianite reef. An additional 9 unique seagrass species or 8 unique mangrove species would be compensated for by adding the third habitat type to the above two habitat mosaic (**Section 4.1.3**).

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APPENDICES

APPENDIX A

EVALUATED LITERATURE SOURCES

PRIMARY LITERATURE:
(High Quality)

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APPENDIX B

DOCUMENTED SPECIES LIST

Table B. Species documented along the north coast of Puerto Rico for each of the five evaluated habitats. Service category, a general description and presence absence is designated for each speices . Presence/absence designations are as follows: + indicates present; J indicates that juveniles utilize the habitat; A indicates that adults utilize the habitat; and S indicates that the habitat is utilized for spawning.

Species	Service Category	Organism Description	Evaluated Habitats				
			Grounding Site 0 - 5 m	Shallow Hard Bottom	Deep Hard Bottom	Mangrove	Seagrass
Acetabularia crenulata	Primary Producer	Green algae		+		+	
Anadyomene stellata	Primary Producer	Green algae		+	+	+	
Avrainvillea asarifolia	Primary Producer	Green algae		+	+	+	
Avrainvillea longicaulis	Primary Producer	Green algae		+	+	+	+
Avrainvillea nigricans	Primary Producer	Green algae		+	+		
Avrainvillea rawsonii	Primary Producer	Green algae		+	+		
Avrainvillea silvana	Primary Producer	Green algae		+	+	+	
Bryopsis hypnoides	Primary Producer	Green algae		+		+	
Bryopsis pennata	Primary Producer	Green algae		+		+	
Caulerpa ashmeadii	Primary Producer	Green algae		+		+	+
Caulerpa mexicana	Primary Producer	Green algae	+	+		+	+
Caulerpa microphysa	Primary Producer	Green algae		+	+		
Caulerpa prolifera	Primary Producer	Green algae	+				+
Caulerpa racemosa	Primary Producer	Green algae		+	+	+	+
Caulerpa sertularioides	Primary Producer	Green algae		+		+	+
Caulerpa taxifolia	Primary Producer	Green algae		+		+	
Caulerpa verticillata	Primary Producer	Green algae		+		+	+
Caulerpa webbiana	Primary Producer	Green algae		+	+		
Caulerpa ambigua	Primary Producer	Green algae					
Chaetomorpha aerea	Primary Producer	Green algae		+			
Chaetomorpha antennina	Primary Producer	Green algae		+			
Chaetomorpha brachygona	Primary Producer	Green algae					
Chaetomorpha clavata	Primary Producer	Green algae		+			
Chaetomorpha linum	Primary Producer	Green algae		+			
Chamaedoris peniculum	Primary Producer	Green algae		+			

Species	Service Category	Organism Description	Evaluated Habitats				
			Grounding Site 0 - 5 m	Shallow Hard Bottom	Deep Hard Bottom	Mangrove	Seagrass
Cladocephalus luteofuscus	Primary Producer	Green algae					+
Cladophora catenata	Primary Producer	Green algae		+			
Cladophora conferta	Primary Producer	Green algae					
Cladophora montagnei	Primary Producer	Green algae					
Cladophora prolifera	Primary Producer	Green algae		+			
Cladophora socialis	Primary Producer	Green algae					
Cladophora submarina	Primary Producer	Green algae					
Cladophora vagabunda	Primary Producer	Green algae					
Cladophoropsis membranacea	Primary Producer	Green algae				+	
Codium decorticatum	Primary Producer	Green algae		+			
Codium intertextum	Primary Producer	Green algae		+			
Codium isthmocladum	Primary Producer	Green algae		+	+	+	
Cymopolia barbata	Primary Producer	Green algae		+			
Dictyosphaeria cavernosa	Primary Producer	Green algae		+	+		
Dictyosphaeria ocellata	Primary Producer	Green algae		+		+	
Enteromorpha sp.	Primary Producer	Green algae	+	+		+	+
Enteromorpha lingulata	Primary Producer	Green algae		+		+	+
Enteromorpha flexuosa	Primary Producer	Green algae		+		+	+
Halimeda discoidea	Primary Producer	Green algae		+	+		
Halimeda gracilis	Primary Producer	Green algae		+	+	+	
Halimeda hummii	Primary Producer	Green algae		+			
Halimeda incrassa	Primary Producer	Green algae		+		+	+
Halimeda monile	Primary Producer	Green algae		+			+
Halimeda opuntia	Primary Producer	Green algae		+	+	+	+
Penicillus capitatus	Primary Producer	Green algae		+		+	+
Penicillus dumetosus	Primary Producer	Green algae		+			+
Penicillus pyriformis	Primary Producer	Green algae		+			
Rhizoclonium riparium	Primary Producer	Green algae		+			
Udotea abbottiorum	Primary Producer	Green algae		+		+	

Species	Service Category	Organism Description	Evaluated Habitats				
			Grounding Site 0 - 5 m	Shallow Hard Bottom	Deep Hard Bottom	Mangrove	Seagrass
Udotea conglutinata	Primary Producer	Green algae		+	+		
Udotea cyathiformis	Primary Producer	Green algae		+	+	+	
Udotea flabellum	Primary Producer	Green algae		+			+
Ulva lactuca	Primary Producer	Green algae	+	+			
Ventricaria ventricosa	Primary Producer	Green algae		+	+	+	
Halodule wrightii	Primary Producer	Seagrass					+
Syringodium filiforme	Primary Producer	Seagrass					+
Thalassia testudinum	Primary Producer	Seagrass					+
Acanthophora muscoides	Primary Producer	Red algae		+	+		
Acanthophora spicifera	Primary Producer	Red algae	+	+		+	
Acrochaetium flexuosum	Primary Producer	Red algae					+
Agardhiella ramosissima	Primary Producer	Red algae		+	+		
Agardhiella subulata	Primary Producer	Red algae			+		
Aglaothamnion boergesenii	Primary Producer	Red algae					
Aglaothamnion cordatum	Primary Producer	Red algae			+		
Amansia multifida	Primary Producer	Red algae	+	+			
Amphiroa fradilissima	Primary Producer	Red algae			+		+
Amphiroa rigida	Primary Producer	Red algae		+			+
Amphiroa spp.	Primary Producer	Articulated red algae	+	+			+
Antithamnionella breviramosa	Primary Producer	Red algae			+		
Apoglossum gregarium	Primary Producer	Red algae					
Asparagopsis taxiformis	Primary Producer	Red algae			+	SP	
Asteromenia peltata	Primary Producer	Red algae					
Bostrychia tenella	Primary Producer	Red algae		+		+	
Botryocladia occidentalis	Primary Producer	Red algae			+		
Bryocladia cuspidata	Primary Producer	Red algae					
Bryothamnion seaforthii	Primary Producer	Red algae					
Bryothamnion triquetrum	Primary Producer	Red algae		+	+		
Caloglossa leprieurii	Primary Producer	Red algae		+		+	

Species	Service Category	Organism Description	Evaluated Habitats				
			Grounding Site 0 - 5 m	Shallow Hard Bottom	Deep Hard Bottom	Mangrove	Seagrass
Catenella caespitosa	Primary Producer	Red algae		+		+	
Centroceras clavulatum	Primary Producer	Red algae		+		+	
Ceramium cruciatum	Primary Producer	Red algae					
Ceramium fastigiatum	Primary Producer	Red algae					
Ceramium flaccidum	Primary Producer	Red algae					+
Ceramium nitens	Primary Producer	Red algae				+	
Champia parvula	Primary Producer	Red algae			+		+
Champia salicornioides	Primary Producer	Red algae			+		+
Champia vieillardii	Primary Producer	Red algae		+			+
Chondria littoralis	Primary Producer	Red algae			+		
Chondria polyrhiza	Primary Producer	Red algae			+		
Chrysymenia nodulosa	Primary Producer	Red algae			+		
Coelothrix irregularis	Primary Producer	Red algae	+	+		+	
Corallina panizzoi	Primary Producer	Red algae					
Crouania attenuata	Primary Producer	Red algae			+		
Cryptonemia crenulata	Primary Producer	Red algae		+	+		
Cryptonemia luxurians	Primary Producer	Red algae			+		
Dasya baillouviana	Primary Producer	Red algae			+		+
Dasya mollis	Primary Producer	Red algae			+		
Dasya puertoricensis	Primary Producer	Red algae			+		
Dictyurus occidentalis	Primary Producer	Red algae	+	+	+		
Digenia simplex	Primary Producer	Red algae		+	+		
Diplothamnion jolyi	Primary Producer	Red algae					
Dipterosiphonia dendritica	Primary Producer	Red algae					
Dohrniella antillara	Primary Producer	Red algae					
Enantiocladia duperreyi	Primary Producer	Red algae					
Galaxaura marginata	Primary Producer	Red algae		+		+	
Galaxaura obtusata	Primary Producer	Red algae		+		+	
Galaxaura rugosa	Primary Producer	Red algae		+		+	
Gelidiella acerosa	Primary Producer	Red algae		+			

Species	Service Category	Organism Description	Evaluated Habitats				
			Grounding Site 0 - 5 m	Shallow Hard Bottom	Deep Hard Bottom	Mangrove	Seagrass
Gelidium americanum	Primary Producer	Red algae		+			
Gelidium pusillum	Primary Producer	Red algae		+			
Gelidium spinosum	Primary Producer	Red algae					
Gracilaria sp.	Primary Producer	Red algae	+	+	+		
Gracilaria curtissiae	Primary Producer	Red algae		+			
Gracilaria domingensis	Primary Producer	Red algae			+		
Grateloupia dichotoma	Primary Producer	Red algae					
Griffithsia globulifera	Primary Producer	Red algae		+			
Gymnogongrus tenuis	Primary Producer	Red algae					
Haliptilon cubense	Primary Producer	Red algae			+		
Haliptilon subulatum	Primary Producer	Red algae		+			
Haloplegma duperreyi	Primary Producer	Red algae			+		
Halydictyon mirabile	Primary Producer	Red algae		+			+
Halymenia floresia	Primary Producer	Red algae		+	+		
Helminthocladia calvadosii	Primary Producer	Red algae					
Herposiphonia secunda	Primary Producer	Red algae		+			
Heterosiphonia crispella	Primary Producer	Red algae			+	+	
Heterosiphonia gibbesii	Primary Producer	Red algae			+	+	
Hypnea musciformis	Primary Producer	Red algae	+		+		
Hypnea spinella	Primary Producer	Red algae			+		
Hypnea volubilis	Primary Producer	Red algae					
Hypoglossum anomalum	Primary Producer	Red algae					
Hypoglossum rhizophorum	Primary Producer	Red algae			+		
Hypoglossum simulans	Primary Producer	Red algae					
Jania adhaerens	Primary Producer	Red algae		+	+	+	
Jania capillacea	Primary Producer	Red algae		+			+
Jania rubens	Primary Producer	Red algae		+	+		
Laurencia corallopsis	Primary Producer	Red algae					
Laurencia gemmifera	Primary Producer	Red algae		+	+		
Laurencia intricata	Primary Producer	Red algae		+		+	

Species	Service Category	Organism Description	Evaluated Habitats				
			Grounding Site 0 - 5 m	Shallow Hard Bottom	Deep Hard Bottom	Mangrove	Seagrass
Laurencia microcladia	Primary Producer	Red algae		+			
Laurencia obtusa	Primary Producer	Red algae		+			
Laurencia papillosa	Primary Producer	Red algae		+			
Laurencia poiteaui	Primary Producer	Red algae			+		
Liagora pinnata	Primary Producer	Red algae					
Liagoropsis schrammii	Primary Producer	Red algae		+			
Lithophyllum daedaleum	Primary Producer	Red algae		+			
Lithophyllum intermedium	Primary Producer	Red algae					
Lithophyllum prototypum	Primary Producer	Red algae					
Melobesia membranacea	Primary Producer	Red algae					
Meristiella gelidium	Primary Producer	Red algae					
Micropeuce mucronata	Primary Producer	Red algae					
Mesophyllum aemulans	Primary Producer	Red algae					
Murrayella periclados	Primary Producer	Red algae		+		+	
Neogoniolithon accretum	Primary Producer	Red algae					
Neogoniolithon strictum	Primary Producer	Red algae		+			
Ochtodes secundiramea	Primary Producer	Red algae			+		
Osmundaria obtusiloba	Primary Producer	Red algae		+			
Peyssonnellia sp.	Primary Producer	Red algae	+	+	+		
Peyssonnelia rubra	Primary Producer	Red algae		+	+		
Pleonosporium caribaeum	Primary Producer	Red algae					
Polysiphonia atlantica	Primary Producer	Red algae		+			
Polysiphonia ferulacea	Primary Producer	Red algae		+	+	+	
Polysiphonia howei	Primary Producer	Red algae		+		+	
Predaea feldmanii	Primary Producer	Red algae			+		
Predaea goffiana	Primary Producer	Red algae					
Predaea weldii	Primary Producer	Red algae					
Pterocladiella capillacea	Primary Producer	Red algae		+			
Scinaia complanata	Primary Producer	Red algae			+		
Soliera filiformis	Primary Producer	Red algae		+	+		

Species	Service Category	Organism Description	Evaluated Habitats				
			Grounding Site 0 - 5 m	Shallow Hard Bottom	Deep Hard Bottom	Mangrove	Seagrass
Spermothamnion investiens	Primary Producer	Red algae					
Spyridia clavata	Primary Producer	Red algae					
Spyridia filamentosa	Primary Producer	Red algae		+			
Tiffaniella gorgonea	Primary Producer	Red algae			+		
Trichogloea requienii	Primary Producer	Red algae			+		
Tricleocarpa fragilis	Primary Producer	Red algae			+		
Wrangelia argus	Primary Producer	Red algae		+			
Wrangelia penicillata	Primary Producer	Red algae		+	+	+	
Wurdemannia miniata	Primary Producer	Red algae		+	+	+	
Colpomenia sinuosa	Primary Producer	Brown algae		+			
Dictyopteris sp.	Primary Producer	Brown algae	+	+	+	+	
Dictyopteris delicatula	Primary Producer	Brown algae		+		+	
Dictyopteris jamaicensis	Primary Producer	Brown algae		+	+		
Dictyopteris justii	Primary Producer	Brown algae		+	+		
Dictyota sp.	Primary Producer	Brown algae	+	+	+	+	+
Dictyota alternans	Primary Producer	Brown algae		+	+		
Dictyota bartayresiana	Primary Producer	Brown algae		+		+	
Dictyota cervicornis	Primary Producer	Brown algae		+		+	+
Dictyota ciliolata	Primary Producer	Brown algae		+	+		
Dictyota guineensis	Primary Producer	Brown algae		+			
Dictyota menstrualis	Primary Producer	Brown algae			+		
Dictyota mertensii	Primary Producer	Brown algae		+			
Dictyota pulchella	Primary Producer	Brown algae		+	+	+	+
Hincksia breviarticulata	Primary Producer	Brown algae					
Hincksia mitchelliae	Primary Producer	Brown algae		+		+	
Lobophora variegata	Primary Producer	Brown algae		+	+	+	
Nereia tropica	Primary Producer	Brown algae			+		
Padina boergesenii	Primary Producer	Brown algae		+		+	
Padina gymnospora	Primary Producer	Brown algae		+		+	
Padina sanctae-crucis	Primary Producer	Brown algae		+		+	

Species	Service Category	Organism Description	Evaluated Habitats				
			Grounding Site 0 - 5 m	Shallow Hard Bottom	Deep Hard Bottom	Mangrove	Seagrass
Ralfsia expansa extensa	Primary Producer	Brown algae		+			
Sargassum fluitans	Primary Producer	Brown algae	pelagic				
Sargassum hystrix	Primary Producer	Brown algae		+	+		
Sargassum natans	Primary Producer	Brown algae	pelagic				
Sargassum platycarpum	Primary Producer	Brown algae		+			
Sargassum polyceratium	Primary Producer	Brown algae		+			
Sargassum rigidulum	Primary Producer	Brown algae					
Sargassum vulgare	Primary Producer	Brown algae		+		+	
Spatoglossum schroederi	Primary Producer	Brown algae			+		
Sphacelaria tribuloides	Primary Producer	Brown algae		+		+	
Sporochnus bolleanus	Primary Producer	Brown algae					
Stypopodium zonale	Primary Producer	Brown algae		+	+		
Turbinaria tricostata	Primary Producer	Brown algae		+			
Turbinaria turbinata	Primary Producer	Brown algae		+			
Briareum sp.	Structural Animal	Soft coral		+			
Eunicea sp.	Structural Animal	Soft coral	+	+	+		
Gorgonia flabellum	Structural Animal	Soft coral		+			+
Gorgonia spp.	Structural Animal	Soft coral	+	+			+
Gorgonia ventalina	Structural Animal	Soft coral	+	+			
Millepora alcicornis	Structural Animal	Soft coral		+			+
Millepora complanata	Structural Animal	Soft coral		+			
Millepora squarrosa	Structural Animal	Soft coral		+			
Muricea muricata	Structural Animal	Soft coral	+	+			
Plexaura flexuosa	Structural Animal	Soft coral	+	+			
Plexaura homamalla	Structural Animal	Soft coral		+			
Plexaurella sp.	Structural Animal	Soft coral	+	+			
Pseudoplexaura sp.	Structural Animal	Soft coral	+	+			
Pseudopterogorgia sp.	Structural Animal	Soft coral		+	+		
Pterogorgia citrina	Structural Animal	Soft coral		+			
Acropora cervicornis	Structural Animal	Hard coral		+			

Species	Service Category	Organism Description	Evaluated Habitats				
			Grounding Site 0 - 5 m	Shallow Hard Bottom	Deep Hard Bottom	Mangrove	Seagrass
Acropora palmata	Structural Animal	Hard coral		+			
Agaricia agaricites	Structural Animal	Hard coral		+	+	+	
Agaricia tenuifolia	Structural Animal	Hard coral					
Dendrogyra cylindrus	Structural Animal	Hard coral		+	+		
Dichocoenia stokesi	Structural Animal	Hard coral		+			
Diploria clivosa	Structural Animal	Hard coral	+	+		+	+
Diploria labyrinthiformis	Structural Animal	Hard coral	+	+			
Diploria sp.	Structural Animal	Hard coral	+	+	+	+	+
Diploria strigosa	Structural Animal	Hard coral	+	+	+	+	+
Favia cf. *gravida*	Structural Animal	Hard coral		+			
Favia fragum	Structural Animal	Hard coral		+		+	+
Helioceris cucullata (Leptoseris cucullata)	Structural Animal	Hard coral		+	+		
Isophyllia multiflora	Structural Animal	Hard coral		+			
Isophyllia sinuosa	Structural Animal	Hard coral		+	+		
Manicina areolata	Structural Animal	Hard coral		+			+
Meandrina meandrites	Structural Animal	Hard coral	+	+	+		
Montastraea annularis	Structural Animal	Hard coral	+	+			
Montastraea cavernosa	Structural Animal	Hard coral	+	+	+		
Porites astreoides	Structural Animal	Hard coral	+	+			+
Porites porites	Structural Animal	Hard coral	+	+			+
Siderastrea radians	Structural Animal	Hard coral	+	+			
Siderastrea siderea	Structural Animal	Hard coral	+	+			+
Stephanocoenia sp.	Structural Animal	Hard coral	+		+		
Agelas clathrodes	Structural Animal	Sponge	+		+		
Amphimedon compressa	Structural Animal	Sponge	+				
Anthosigmella varians	Structural Animal	Sponge	+	+			
Aplysina fistularis	Structural Animal	Sponge	+				
Callyspongia fallax	Structural Animal	Sponge	+				
Callyspongia vaginalis	Structural Animal	Sponge	+	+			

Species	Service Category	Organism Description	Evaluated Habitats				
			Grounding Site 0 – 5 m	Shallow Hard Bottom	Deep Hard Bottom	Mangrove	Seagrass
Chodrilla nucula	Structural Animal	Sponge	+	+			
Cliona delitrix	Structural Animal	Sponge	+				
Cliona langae	Structural Animal	Sponge	+				
Desmapsamma anchorata	Structural Animal	Sponge	+	+			
Ectyoplasia ferox	Structural Animal	Sponge	+				
Holopsamma helwigi	Structural Animal	Sponge	+				
Ircinia campana	Structural Animal	Sponge	+	+	+		
Ircinia strobilina	Structural Animal	Sponge	+	+			
Iricinia felix	Structural Animal	Sponge	+		+		+
Leucetta floridana	Structural Animal	Sponge	+				
Monanachora barbadensis	Structural Animal	Sponge	+				
Niphates erecta	Structural Animal	Sponge	+	+			
Pseudaxinella lunaecharta	Structural Animal	Sponge	+	+			+
Pseudoceratina crassa	Structural Animal	Sponge	+				
Spinosella vaginalis	Structural Animal	Sponge	+	+	+		
Spirastrella sp.	Structural Animal	Sponge	+				
Verongula gigantea	Structural Animal	Sponge	+	+			
Xestospongia muta	Structural Animal	Sponge	+	+	+		
Ricordea florida	Structural Animal	Corallimorph	+	+			
Halocordyle disticha	Structural Animal	Hydroid	+	+			
Palythoa caribboea	Structural Animal	Zoanthid	+	+			
Palythoa sp.	Structural Animal	Zoanthid		+			
Zoanthus sociatus	Structural Animal	Zoanthid	+				
Zoanthus sp.	Structural Animal	Zoanthid	+	+			
Diadema antillarum	Herbivorous Invert.	Urchin	+	+			J, A
Diadema reticulatus	Herbivorous Invert.	Urchin	+				+
Echinometra lucunter	Herbivorous Invert.	Urchin	+				+
Lytechinus variegatus	Herbivorous Invert.	Urchin	+				+
Tripneustes ventricosus	Herbivorous Invert.	Urchin	+				
Tripneustes esculentus	Herbivorous Invert.	Urchin	+	+			+

Species	Service Category	Organism Description	Evaluated Habitats				
			Grounding Site 0 - 5 m	Shallow Hard Bottom	Deep Hard Bottom	Mangrove	Seagrass
Panulirus argus	Predatory Invertebrate	Spiny Lobster	+	J, A		J	J, A
Strombus gigas	Herbivorous Invert.	Queen Conch		A			J, A, S
Chelonia mydas	Herbivorous Vertebrate	Turtle	+				+
Eretmochelys imbricata	Herbivorous Vertebrate	Turtle		+	+	+	
Dermochelys coriacea	Herbivorous Vertebrate	Turtle			+		
Caretta caretta	Herbivorous Vertebrate	Turtle		+			
Ginglymostoma cirratum	Predatory vertebrate	Predatory reef shark				+	+
Negaprion brevirostris	Predatory vertebrate	Predatory reef shark	+			J, A	
Carcharhinus leucas	Predatory vertebrate	Predatory reef shark	+			J	
Carcharhinus limbatus	Predatory vertebrate	Predatory reef shark	+			J, A	
Dasyatis sp.	Predatory vertebrate	Predatory reef fish		+	+	+	+
Aetobatus narinari	Predatory vertebrate	Predatory reef fish				A	
Megalops atlanticus	Predatory vertebrate	Predatory pelagic fish				J, A	J
Elops saurus	Predatory vertebrate	Predatory seagrass fish	+			J, A	+
Albula vulpes	Predatory vertebrate	Predatory seagrass fish	+				A
Anguilla rostrata	Predatory vertebrate	Predatory benthic eel				A	
Enchelycore nigricans	Predatory vertebrate	Predatory reef fish	+	+			
Gymnothorax moringa	Predatory vertebrate	Predatory reef fish		+			+
Moringua edwardsi	Predatory vertebrate	Predatory zoobenthic reef fish				A	
Myrophis punctatus	Predatory vertebrate	Predatory zoobenthic reef fish				+	
Conger triporiceps	Predatory vertebrate	Predatory mangrove fish				A	
Sardinella sp.	Planktivore vertebrate	Planktivorous pelagic fish/filter feeder		A		A	+
Harengula humeralis	Predatory vertebrate	Planktivorous pelagic fish/filter feeder				A	
Opisthonema oglinum	Predatory vertebrate	Predatory mangrove fish				J, A	
Anchoa parva or *filifera*	Planktivore vertebrate	Planktivorous pelagic fish/filter feeder				A	

Species	Service Category	Organism Description	Evaluated Habitats				
			Grounding Site 0 - 5 m	Shallow Hard Bottom	Deep Hard Bottom	Mangrove	Seagrass
Anchoa hepsetus	Planktivore vertebrate	Planktivorous pelagic fish/filter feeder				+	+
Cetengraulis edentulus	Planktivore vertebrate	Planktivorous pelagic fish/filter feeder	+			A	
Synodus foetens	Predatory vertebrate	Predatory reef fish	+			+	+
Lepophidium spp.	Predatory vertebrate	Predatory reef fish	+				
Arcos macrophthalmus	Predatory vertebrate	Predatory reef fish	+	+			
Hemiramphus brasiliensis	Predatory vertebrate	Planktivorous pelagic fish/filter feeder	+	+			+
Hyporhamphus unifasciatus	Predatory vertebrate	Planktivorous reef fish/ filter feeder	+			A	+
Strongylura notata	Predatory vertebrate	Predatory fish	+			J	
Strongylura timucu	Predatory vertebrate	Predatory fish				J, A	
Tylosurus sp.	Predatory vertebrate	Predatory reef fish	+	+			+
Platybelone argalus	Predatory vertebrate	Predatory seagrass fish	+				
Atherinomorus stipes	Predatory Fish	Zooplanktivorous reef fish				J, A	
Holocentrus ascensionis	Predatory vertebrate	Predatory zoobenthic reef fish	+	A	A	+(night)	A
Holocentrus coruscus	Predatory vertebrate	Predatory zoobenthic reef fish	+				
Holocentrus rufus	Predatory vertebrate	Predatory zoobenthic reef fish	+	+	A	A	+
Holocentrus vexillarius	Predatory vertebrate	Predatory zoobenthic reef fish	+	+			
Plectrypops retrospinis	Predatory vertebrate	Predatory zoobenthic reef fish	+		+		
Myripristis jacobus	Predatory vertebrate	Predatory zoobenthic reef fish	+	+			
Neoniphon marianus	Predatory vertebrate	Predatory zoobenthic reef fish	+		+		
Aulostomus maculatus	Predatory vertebrate	Predatory reef fish	+	+			+

Species	Service Category	Organism Description	Evaluated Habitats				
			Grounding Site 0 - 5 m	Shallow Hard Bottom	Deep Hard Bottom	Mangrove	Seagrass
Fistularia tabacaria	Predatory vertebrate	Predatory reef fish	+				+
Syngnathus dunckeri	Predatory vertebrate	Predatory reef fish				A	J, A
Syngnathus pelagicus	Predatory vertebrate	Predatory reef fish					J, A
Dactylopterus volitans	Predatory vertebrate	Predatory zoobenthic reef fish					J
Scorpaena plumieri	Predatory vertebrate	Predatory reef fish	+				J
Scorpaenodes caribbaeus	Predatory vertebrate	Predatory reef fish	+	+			
Scorpaenopsis grandicornis	Predatory vertebrate	Predatory reef fish				J	A
Sebastes melanops	Predatory vertebrate	Predatory reef fish	+				
Centropomus enciferus	Predatory vertebrate	Predatory reef fish				J, A	
Centropomus parallelus	Predatory vertebrate	Predatory reef fish				+	
Centropomus undecimalis	Predatory vertebrate	Predatory reef fish				J, A	+
Centropomus pectinatus	Predatory vertebrate	Predatory reef fish				J	
Epinephelus spp.	Predatory vertebrate	Predatory reef fish	+				
Epinephelus adscensionis	Predatory vertebrate	Predatory reef fish	+	+	+		
Epinephelus fulvus	Predatory vertebrate	Predatory reef fish	+	A	A		A
Epinephelus gutatus	Predatory vertebrate	Predatory reef fish	+	A	+	J	J
Epinephelus morio	Predatory vertebrate	Predatory reef fish	+	+	+		J
Epinephelus striatus	Predatory vertebrate	Predatory reef fish		A	A	J, A	J
Priacanthus arenatus	Predatory vertebrate	Predatory reef fish	+		+		
Apogon maculatus	Predatory vertebrate	Predatory reef fish	+	+			
Malacanthus plumieri	Predatory vertebrate	Predatory reef fish	+	A	+		
Oligoplites saurus	Predatory vertebrate	Planktivorous pelagic fish/filter feeder				J	
Caranx sp.	Predatory vertebrate	Predatory pelagic fish	+				
Caranx bartholomaei	Predatory vertebrate	Predatory pelagic fish		J, A	A		+
Caranx hippos	Predatory vertebrate	Predatory pelagic fish				J	
Caranx ruber	Predatory vertebrate	Predatory pelagic fish	+	J, A		A	A
Caranx latus	Predatory vertebrate	Predatory pelagic fish				J, A	A
Selar crumenophthalmus	Predatory vertebrate	Predatory pelagic fish	+	+			+

Species	Service Category	Organism Description	Evaluated Habitats				
			Grounding Site 0 - 5 m	Shallow Hard Bottom	Deep Hard Bottom	Mangrove	Seagrass
Selene vomer	Predatory vertebrate	Predatory pelagic fish		+			+
Trachinotus falcatus	Predatory vertebrate	Predatory pelagic fish				J	A
Trachinotus goodei	Predatory vertebrate	Predatory pelagic fish				J	
Lutjanus analis	Predatory vertebrate	Predatory reef fish		+, S	+, S	J, A	J, A
Lutjanus apodus	Predatory vertebrate	Predatory reef fish	+	J, A	+, S	J, A	J, A
Lutjanus cyanopterus	Predatory vertebrate	Predatory reef fish	+		S	J	J
Lutjanus griseus	Predatory vertebrate	Predatory reef fish	+	J, A, S	S	J, A	J, A
Lutjanus jocu	Predatory vertebrate	Predatory reef fish	+	+	S	J, A	J, A
Lutjanus mahogoni	Predatory vertebrate	Predatory reef fish	+	+	+	J	J, A
Lutjanus synagris	Predatory vertebrate	Predatory reef fish	+	+	+, S	J, A	J, A, S
Lutjanus vivanus	Predatory vertebrate	Predatory reef fish		J, A	A		
Ocyurus chrysurus	Predatory vertebrate	Predatory reef fish	+	A	+, S	J, A	J, A
Gerres cinereus	Predatory vertebrate	Predatory reef fish	+	J	+	J, A	+
Eugerres plumieri	Predatory vertebrate	Predatory reef fish/ Micorcrustacean feeder				J, A	
Eucinostomus argenteus	Predatory vertebrate	Predatory zoobenthic fish	+			J	+
Eucinostomus gula	Predatory vertebrate	Predatory zoobenthic fish				J	+
Eucinostomus lefroyi	Predatory vertebrate	Predatory zoobenthic fish				J	+
Eucinostomus melanopterus	Predatory vertebrate	Predatory zoobenthic fish				J	
Diapterus olistostomus	Predatory vertebrate	Predatory zoobenthic fish				J	
Diapterus rhombeus	Predatory vertebrate	Predatory zoobenthic fish				J	+
Anisotremus surinamensis	Predatory vertebrate	Predatory reef fish	+	A	+		
Anisotremus virginicus	Predatory vertebrate	Predatory reef fish	+	+	+	J	J
Haemulon album	Predatory vertebrate	Predatory reef fish	+	+		J, A	+

Species	Service Category	Organism Description	Evaluated Habitats				
			Grounding Site 0 - 5 m	Shallow Hard Bottom	Deep Hard Bottom	Mangrove	Seagrass
Haemulon aurolineatum	Predatory vertebrate	Predatory reef fish	+	J	+	J, A	J, A
Haemulon bonariensis	Predatory vertebrate	Predatory reef fish	+			A	J
Haemulon chrysargyreum	Predatory vertebrate	Predatory reef fish	+	+	+		J
Haemulon flavolineatum	Predatory vertebrate	Predatory reef fish	+	A	+	J, A	J, A
Haemulon plumieri	Predatory vertebrate	Predatory reef fish	+	J, A	+	J, A	J, A
Haemulon sciurus	Predatory vertebrate	Predatory reef fish	+	A	+	J, A	J, A
Pomadasys crocro	Predatory vertebrate	Predatory reef fish				A	
Archosargus probatocephalus	Predatory vertebrate	Predatory reef fish		+		J, A	J
Archosargus rhomboidalis	Predatory vertebrate	Predatory reef fish		+		J, A	J, A
Calamus bajonado	Predatory vertebrate	Predatory reef fish	+	+	+	+	J, A
Lagodon rhomboides	Predatory vertebrate	Predatory seagrass fish	+			A	J, A
Odontoscion dentex	Predatory vertebrate	Predatory reef fish	+	+			+
Micropogonias furnieri	Predatory vertebrate	Predatory seagrass fish	+			J	
Ophioscion punctatissimus	Predatory vertebrate	Predatory seagrass fish					J, A
Bairdiella sanctaeluciae	Predatory vertebrate	Predatory mangrove fish					+
Equetus lanceolatus	Predatory vertebrate	Predatory reef fish					J
Mulloides martinicus	Predatory vertebrate	Predatory zoobenthic reef fish	+	J, A	A	A	J
Pseudupeneus maculatus	Predatory vertebrate	Predatory zoobenthic reef fish		J	A		J, A
Pempheris schomburgki	Predatory vertebrate	Planktivorous reef fish	+	+			
Chaetodipterus faber	Predatory vertebrate	Predatory reef fish				J	+
Chloroscombus crysurus	Predatory vertebrate	Predatory pelagic fish	+			J	+
Chaetodon capistratus	Predatory vertebrate	Predatory reef fish	+	+	+	J	J
Chaetodon sedentarius	Predatory vertebrate	Predatory reef fish	+	+	+		
Chaetodon striatus	Predatory vertebrate	Predatory reef fish	+	J, A	+	J	J
Pomacanthus arcuatus	Predatory vertebrate	Predatory reef fish	+	+		A	S
Pomacanthus paru	Predatory vertebrate	Predatory reef fish	+	+			+
Holacanthus tricolor	Predatory vertebrate	Predatory reef fish	+	J, A			
Abudefduf saxatilis	Predatory vertebrate	Omnivorous reef fish	+	J		J, A	A

Species	Service Category	Organism Description	Evaluated Habitats				
			Grounding Site 0 - 5 m	Shallow Hard Bottom	Deep Hard Bottom	Mangrove	Seagrass
Stegastes adustus (Pomacentrus fucus) (Stegastees dorsopunicans)	Herbivorous vertebrate	Herbivorous reef fish	+	A		A	
Stegastes diencaeus	Herbivorous vertebrate	Herbivorous reef fish	+	+			
Microspathodon chrysurus	Herbivorous vertebrate	Omnivorous reef fish	+	J, A		J	
Abudefduf taurus	Predatory vertebrate	Omnivorous reef fish	+	J, A			
Stegastes leucostictus	Predatory vertebrate	Predatory reef fish	+			J, A	
Stegastes partitus	Predatory vertebrate	Predatory reef fish		+	A	A	
Stegastes planifrons	Predatory vertebrate	Predatory reef fish	+	A	A		
Stegastes variabilis (Pomacentrus variabilis)	Predatory vertebrate	Predatory reef fish	+	A	A		
Chromis cyaneus	Predatory vertebrate	Zooplanktivorous reef fish	+	+			
Mugil curema	Herbivorous vertebrate	Herbivorous pelagic fish	+			J, A	+
Mugil liza	Herbivorous vertebrate	Herbivorous pelagic fish				J, A	
Sphyraena barracuda (Sphyraena guachancho)	Predatory vertebrate	Predatory reef fish	+			J, A	J, A
Sphyraena guachancho	Predatory vertebrate	Predatory reef fish				J	+
Sphyraena picudilla	Predatory vertebrate	Predatory reef fish					+
Polydactylus virginicus	Predatory vertebrate	Predatory zoobenthic seagrass fish				J	+
Bodianus rufus	Predatory vertebrate	Predatory reef fish	+	+		J, A	
Halichoeres bivittatus	Predatory vertebrate	Predatory reef fish	+	J, A, S		+	+
Halichoeres garnoti	Predatory vertebrate	Predatory reef fish	+	J		A	
Halichoeres maculipinna	Predatory vertebrate	Predatory reef fish	+	J			
Halichoeres poeyi	Predatory vertebrate	Predatory reef fish		J			A
Halichoeres radiatus	Predatory vertebrate	Predatory reef fish	+	J, A	+		
Lachnolaimus maximus	Predatory vertebrate	Predatory reef fish	+	+			J
Thalassoma bifasciatum	Predatory vertebrate	Predatory zoobenthic reef fish	+	J, A		A	+
Sparisoma aurofrenatum	Herbivorous vertebrate	Herbivorous reef fish	+	J	+		

Species	Service Category	Organism Description	Evaluated Habitats				
			Grounding Site 0 - 5 m	Shallow Hard Bottom	Deep Hard Bottom	Mangrove	Seagrass
Sparisoma chrysopterum	Herbivorous vertebrate	Herbivorous reef fish	+	+		J, A	A
Sparisoma radians	Herbivorous vertebrate	Herbivorous reef fish	+			J	J, A
Sparisoma rubripinne	Herbivorous vertebrate	Herbivorous reef fish	+	+		J	+
Nicholsina usta usta	Herbivorous vertebrate	Herbivorous seagrass fish					+
Sparisoma viride	Herbivorous vertebrate	Herbivorous reef fish	+	J	+	J, A	J
Scarus coeruleus	Predatory vertebrate	Predatory reef fish					J, A
Scarus guacamaia	Predatory vertebrate	Predatory reef fish	+			J, A	A
Scarus vetula	Predatory vertebrate	Predatory reef fish	+	+	+		
Labrisomus nuchipinnis	Predatory vertebrate	Predatory reef fish		A			+
Malacoctenus triangulatus	Predatory vertebrate	Predatory reef fish		+	A		+
Ophioblennius atlanticus	Herbivorous vertebrate	Herbivorous reef fish	+	A			
Parablennius marmoreus	Predatory vertebrate	Omnivorous reef fish	+	+			
Dormitator maculatus	Predatory vertebrate	Predatory mangrove fish				A	
Eleotris pisonis	Predatory vertebrate	Predatory mangrove fish				A	
Lophogobius cyprinoides	Predatory vertebrate	Omnivorous reef fish				J, A	+
Bathygobius soporator	Predatory vertebrate	Predatory reef fish				A	+
Gobionellus oceanicus	Predatory vertebrate	Predatory reef fish				A	
Acanthurus bahianus	Herbivorous vertebrate	Herbivorous reef fish	+	A		A	J, A
Acanthurus chirugus	Herbivorous vertebrate	Herbivorous reef fish	+	J		J, A	J, A
Acanthurus coeruleus	Herbivorous vertebrate	Herbivorous reef fish	+	A	+	J, A	J, A
Bothus sp.	Predatory vertebrate	Predatory reef fish	+				+
Bothus lunatus	Predatory vertebrate	Predatory reef fish					J, A
Citharichthys spilopterus	Predatory vertebrate	Predatory seagrass fish				J	+
Symphurus plagusia	Predatory vertebrate	Predatory seagrass fish				J	+
Aluterus punctatus	Herbivorous vertebrate	Herbivorous reef fish	+				
Aluterus scriptus	Predatory vertebrate	Predatory reef fish				J	
Balistes vetula	Predatory vertebrate	Predatory reef fish		A, S	+		A
Cantherhines pullus	Predatory vertebrate	Predatory reef fish	+	+			
Lactophrys bicaudalis	Predatory vertebrate	Predatory reef fish					A

Species	Service Category	Organism Description	Evaluated Habitats				
			Grounding Site 0 - 5 m	Shallow Hard Bottom	Deep Hard Bottom	Mangrove	Seagrass
Lactophrys triqueter	Predatory vertebrate	Predatory reef fish	+	+			+
Diodon holocanthus	Predatory vertebrate	Predatory mangrove fish	+	+		A	A
Diodon hystrix	Predatory vertebrate	Predatory mangrove fish	+	+	+	+	J, A
Canthigaster rostrata	Predatory vertebrate	Predatory reef fish	+	+			J, A
Sphoeroides spp.	Predatory vertebrate	Predatory reef fish	+			+	
Spheroides spengleri	Predatory vertebrate	Predatory reef fish	+	+			+
Sphoeroides testudineus	Predatory vertebrate	Predatory reef fish		+		J	J

APPENDIX C:

NUMBER OF SPECIES BENEFITING FROM HABITAT ADDITIONS

The following tables give the number of additional eolianite species that would benefit by the addition of subsequent compensatory habitats beginning with one habitat and ending with four habitats. The maximum number of shared eolianite reef species is 165.

Habitat	Additional # of Species
Shallow Hard Bottom (5-10 m)	128
Deep Hard Bottom (>10 m)	8
Seagrass	21
Mangrove	8

Habitat	Additional # of Species
Deep Hard Bottom (>10 m)	56
Seagrass	54
Mangrove	13
Shallow Hard Bottom (5-10 m)	42

Habitat	Additional # of Species
Shallow Hard Bottom (5-10 m)	128
Deep Hard Bottom (>10 m)	8
Mangrove	20
Seagrass	9

Habitat	Additional # of Species
Deep Hard Bottom (>10 m)	56
Seagrass	54
Shallow Hard Bottom (5-10 m)	47
Mangrove	8

Habitat	Additional # of Species
Shallow Hard Bottom (5-10 m)	128
Seagrass	22
Mangrove	8
Deep Hard Bottom (>10 m)	7

Habitat	Additional # of Species
Deep Hard Bottom (>10 m)	56
Shallow Hard Bottom (5-10 m)	80
Seagrass	21
Mangrove	8

Habitat	Additional # of Species
Shallow Hard Bottom (5-10 m)	128
Seagrass	22
Deep Hard Bottom (>10 m)	7
Mangrove	8

Habitat	Additional # of Species
Deep Hard Bottom (>10 m)	56
Shallow Hard Bottom (5-10 m)	80
Mangrove	20
Seagrass	9

Habitat	Additional # of Species
Shallow Hard Bottom (5-10 m)	128
Mangrove	21
Seagrass	9
Deep Hard Bottom (>10 m)	7

Habitat	Additional # of Species
Deep Hard Bottom (>10 m)	56
Mangrove	41
Seagrass	26
Shallow Hard Bottom (5-10 m)	42

Habitat	Additional # of Species
Shallow Hard Bottom (5-10 m)	128
Mangrove	21
Deep Hard Bottom (>10 m)	7
Seagrass	9

Habitat	Additional # of Species
Deep Hard Bottom (>10 m)	56
Mangrove	41
Shallow Hard Bottom (5-10 m)	59
Seagrass	9

Habitat	Additional # of Species
Seagrass	84
Mangrove	15
Shallow Hard Bottom (5-10 m)	59
Deep Hard Bottom (>10 m)	7

Habitat	Additional # of Species
Mangrove	68
Shallow Hard Bottom (5-10 m)	81
Deep Hard Bottom (>10 m)	7
Seagrass	9

Habitat	Additional # of Species
Seagrass	84
Mangrove	15
Deep Hard Bottom (>10 m)	24
Shallow Hard Bottom (5-10 m)	42

Habitat	Additional # of Species
Mangrove	68
Shallow Hard Bottom (5-10 m)	81
Seagrass	9
Deep Hard Bottom (>10 m)	7

Habitat	Additional # of Species
Seagrass	84
Shallow Hard Bottom (5-10 m)	66
Deep Hard Bottom (>10 m)	7
Mangrove	8

Habitat	Additional # of Species
Mangrove	68
Deep Hard Bottom (>10 m)	29
Seagrass	26
Shallow Hard Bottom (5-10 m)	42

Habitat	Additional # of Species
Seagrass	84
Shallow Hard Bottom (5-10 m)	66
Mangrove	8
Deep Hard Bottom (>10 m)	7

Habitat	Additional # of Species
Mangrove	68
Deep Hard Bottom (>10 m)	29
Shallow Hard Bottom (5-10 m)	59
Seagrass	9

Habitat	Additional # of Species
Seagrass	84
Deep Hard Bottom (>10 m)	26
Shallow Hard Bottom (5-10 m)	47
Mangrove	8

Habitat	Additional # of Species
Mangrove	68
Seagrass	31
Deep Hard Bottom (>10 m)	24
Shallow Hard Bottom (5-10 m)	42

Habitat	Additional # of Species
Seagrass	84
Deep Hard Bottom (>10 m)	26
Mangrove	13
Shallow Hard Bottom (5-10 m)	42

Habitat	Additional # of Species
Mangrove	68
Seagrass	31
Shallow Hard Bottom (5-10 m)	59
Deep Hard Bottom (>10 m)	7

APPENDIX D

RESPONSES TO PEER REVIEWER COMMENTS

DOCUMENT REVIEW BY
R. GRANT GILMORE, JR., PH.D.,
SENIOR SCIENTIST
ESTUARINE, COASTAL AND OCEAN SCIENCE, INC.
5920 FIRST ST. SW
VERO BEACH, FL 32968

HABITAT SUITABILITY ANALYSIS: COMPENSATION FOR INJURED REEF IN SUPPORT OF RESTORATION PLANNING FOR THE BERMAN OIL SPILL, SAN JUAN, PUERTO RICO, JUNE 2005.

DOCUMENT SUBMITTED BY
MARINE RESOURCES INC.,
7897 SW JACK JAMES DRIVE, SUITE A,
STUART, FLORIDA 34997.

Dr. Gilmore's comments and our responses to them follow the pagination order for the document.

Comment 1:

This habitat suitability analysis (HSA) was based on historical data and some recent extant data for marine habitats along the northern coast of Puerto Rico in the vicinity of the "Berman Oil Spill" site. The HSA was unfortunately limited due to the lack of good quantitative data on the relative abundance of marine organisms along this coast of Puerto Rico. The literature utilized for the analyses appeared to be comprehensive and some additional references have been suggested, but are not totally necessary due to the comprehensive bibliography already constructed. The statistical analyses were appropriate for the data at hand. More detail in techniques of data retrieval and techniques used by the studies examined would have been helpful in determining the nature of the specific faunal data base the authors were able to use. This would have influenced my interpretation of Table B.

Response 1:

We appreciate Dr. Grant Gilmore's comments on the *Habitat Suitability Analysis: Compensation for Injured Reef in Support of Restoration Planning for the Berman Oil Spill, San Juan Puerto Rico.* The overall premise for the Habitat Suitability Analysis (HSA) was to compare species that were documented in injury assessment reports to occur at the injury location with species that were documented in our literature search to occur in the potential Compensatory restoration habitats along the northern coast of Puerto Rico. A list of species likely to have been injured by the grounding incident was compiled from injury assessment documents provided by the Trustees as well as from recent studies conducted along the north coast of Puerto Rico within similar hard bottom habitats. Most of the studies from the north coast provided only species lists and lacked relative abundances of the species encountered. We understand that our species list is not exhaustive and that other species may utilize the injured and compensatory restoration habitats; the HSA included only species that were documented in our literature search.

<u>Comment 2:</u>

Page 4 - Elimination of zooplanktivores from the HSA may not be justified for an oil spill event as they are likely to have been directly influenced by surface oil films due to their typical association with surface waters. These species are not always considered highly migratory, particularly atherinids (seagrass, reef, and mangrove) and poeciliids (mangrove). Although engraulids and clupeids have a greater daily range, they also may associate with particular regions of high productivity for prolonged periods of time (bay and river mouths, upwelling zones). It would be interesting to know their distribution, relative to the high energy zones of the north coast of Puerto Rico and San Juan harbor, as there are several potential nutrient and planktonic enrichment zones in this area which have permanent zooplanktivore populations that could have been directly impacted by the oil spill.

Response 2:

We agree with Dr. Gilmore's comment that zooplanktivores are particularly susceptible to oil spills. Studies of Pacific herring populations in Prince William Sound following the *Exxon Valdez* Oil Spill provide clear proof of impacts to zooplanktivores. However, the purpose of our HSA was to evaluate compensatory habitats for the injury that occurred due to the physical damage to the reef structure from the grounding, not the impacts of the release of oil. Because the injured habitat and the habitats considered appropriate for compensation are benthic (bottom), species expected to be impacted by loss of reef habitat and addition of new benthic habitat are demersal (bottom oriented) fish and herbivores. This was our original basis for excluding these fish from the analysis. In reality, the number of fish species excluded from the analysis (2 zooplanktivores) was small and their inclusion would not alter our conclusions.

<u>Comment 3:</u>

Page 9 - It is not clear how the "likely injured" categories for impacted organisms were determined.

Response 3:

Organisms were designated as "likely injured" if the damage assessment reports provided by the trustees documented their occurrence in the impacted area or that the organisms were injured by the incident.

<u>Comment 4:</u>

Page 11 - One important group of surface predators were not mentioned, and were likely to be the species most impacted by the oil spill. These are the needlefishes, belonids, halfbeaks, hemiramphids, and flying fish, exocoetids that have an intimate association with the water's surface and represent a significant biomass in tropical coastal waters. Halfbeaks are omnivores and herbivores during diurnal periods, predators (zooplanktivores) at night. Various species associated with seagrass (Hyporhamphus unifasciatus, Strongylura timucu & S. notata), mangroves (Strongylura notata) and reef formations (Hemiramphus spp., Tylosurus corcodilus and T. acus, Exocoetus spp, Parexocoetus spp.). Halfbeaks and needlefishes are more likely to be residential.

Tarpon are obligate air breathers as juveniles, first ten years (1 m in SL) , and therefore, are highly likely to have come in contact with oil during this event . Even though they may be considered transients, they do duel in areas of particular prey abundance and stay in certain areas for months at a time. They could have been significantly impacted by the oil spill. Young tarpon are likely resident in inshore coves, mangrove and seagrass ecosystems for months at a time.

Response 4:
Again, we recognize that surface feeding species are susceptible to the effects of oil spills, but not so much to the physical damage to the reef structure from the grounding. Several of the above mentioned fish were documented to occur in the area and are therefore included in our analysis. The surface predators were not discussed in the text because we focused on the species expected to be impacted due to the loss of reef habitat caused by the physical damage to the reef structure, not the impacts of the release of the oil. We recognize that there are many species that may occur in the area, but lack published validation of their occurrence. To maintain the rigor of our analysis, we restricted our analysis to those species that were documented to occur in the study area.

<u>Comment 5:</u>
Page 17 - Since high energy, shallow hard bottom habitat, <5-10 m deep is the primary habitat of concern the literature by Ken Lindeman for similar high energy nearshore rock reef formations in east Florida is particularly valuable in addressing the impacted fauna.

Response 5:
Lindeman and Snyder (1999), listed in Appendix A, was reviewed and used for background information and cross referencing of species that were documented from the north coast of Puerto Rico. Due to the location of the study, the document was not cited in the text.

<u>Comment 6:</u>
Table 9 - Since many species are actually omnivores, was this ever considered as a category?

Response 6:
Dr. Gilmore's comment is well-supported; many of the species we classified as predatory or herbivorous show some degree of omnivory (i.e. feeding at different trophic levels). However, the designation of species as omnivores is highly subjective. Further, the majority of omnivorous species are primarily predatory; the addition of an omnivore classification would simply subdivide this group. While we did not perform this separate analysis, it is unlikely that this subdivision would greatly effect our conclusions.

<u>Comment 7:</u>
Page 19 - I agree that the seagrass (possibly algae), hard substrate (artificial reef) mosaic may be the optimum compensation scenario. I suggest that a structure that mimics the original reef configuration be the best to utilize. I did not see illustrations of the potential hard reef habitat form that would be used. This is very important. It would also be advantageous to place this compensatory restoration site as close to the original site as possible. The reason for this is that an increasing literature point to patchy distribution of fish and invertebrates is relatively

homogenous habitats such as seagrass or mangrove communities. This is often due to preferred local hydrological, oceanographic or geological/topographical conditions.

Response 7:
We agree that the artificial structure should mimic the natural reefs occurring within the area and be placed as close as possible to the injury site. The configuration of the artificial structure itself is beyond the scope of the current document and was therefore not included. Due to the conditions at the injured reef site, placement of an artificial reef is not considered feasible. Therefore, the compensatory restoration habitat should be located as close as possible to the injured habitat to best mitigate for the lost resources of the injured reef habitat.

<u>Comment 8:</u>
PRIMARY LITERATURE - Section A-2 - Suggest adding more Stoner et al Puerto Rican literature, J. Kemmel (PR & Fla.), J. Serafy et al recent paper on mangrove communities in SE Fla., possibly these RGG pubs would be helpful
- Gilmore, R.G. and S.C. Snedaker. 1993. Chapter 5: Mangrove Forests pp 165-198 <u>In</u> W. H. Martin, S.G. Boyce and A.C. Echternacht (eds.) Biodiversity of the Southeastern United States: Lowland Terrestrial Communities. John Wiley & Sons, Inc., Publishers, N.Y. 502 pp.
- Gilmore, R.G. 1977. Fishes of the Indian River lagoon and adjacent waters, Florida. Bulletin of the Florida State Museum 22: 101-147. (lists species by relative habitat association)

Response 8:
We appreciate your suggestions for additional literature. We searched for additional Stoner et al. documents, as well as literature from Kimmel, and have looked over the Gilmore (1977) paper. As part of the initial literature search, MRI contacted Dr. J. Kimmel requesting any relevant literature that focused on the north coast of Puerto Rico. Dr. Kimmel reviewed our literature cited and could not provide any additional references. We conducted a specific key word literature search in which this additional literature did not appear and due to constraints in time, have decided not to incorporate these papers into the final document.

<u>Comment 9:</u>
B-12 Suggest using “shark” for Negaprion as it is a shark. However, since elasmobranchs are fishes, fish can be used correctly for the rays listed, Dasyatis sp, Aetobatus, etc. as well as for the sharks.

Response 9:
The organism description for Negaprion has been changed to predatory shark rather than predatory fish. This correction does not change the functional group in which the organism was characterized; therefore the outcome of the analysis is not be influenced.

<u>Comment 10:</u>
B-12 Megalops atlanticus is a mangrove and seagrass species as well as pelagic reef species.

Response 10:
To maintain the rigor of our analysis, we restricted our habitat characterizations to those that were documented in the literature search. *M. atlanticus* is listed in Table B as a mangrove and seagrass species, but we did not come across any documentation for the reef habitat.

Comment 11:
B-12 Albula vulpes is a "seagrass" fish.

Response 11:
The organism description for *A. vulpes* was changed from predatory reef fish to predatory seagrass fish. This correction does not change the functional group in which the organism was characterized; therefore the outcome of the analysis is not influenced.

Comment 12:
B-12 Anguilla rostrata is NOT a "pelagic" fish and is questionable as a mangrove associate.

Response 12:
The designation was changed to benthic fish, but it was kept as a mangrove associate as cited by Austin (1971). This correction does not change the functional group in which the organism was characterized; therefore the outcome of the analysis is not influenced.

Comment 13:
B-12 Mycrophis spp....What is a "zoobenthic" reef fish and why are the ophichthyids not on this list in this category? Several eel species are missing from the list.

Response 13:
Zoobenthic feeders are predatory fishes which feed specifically on vertebrates and invertebrates that live within or rely directly on the substrate regardless of hard or soft bottom habitat type. To maintain the rigor of our analysis, we did not add any additional species to the list because they were not documented in our literature search to occur in the injured habitat.

Comment 14:
B-12 Harengula jaguana and H. clupeola should be on this list.

Response 14:
To maintain the rigor of our analysis, we did not add any additional species to the list because they were not documented in our literature search to occur in the injured habitat.

Comment 15:
B-13 Anchoa lyolepis is missing.

Response 15:
To maintain the rigor of our analysis, we did not add any additional species to the list because they were not documented in our literature search to occur in the injured habitat.

Comment 16:
B-13 It is highly unlikely that Strongylura marina (warm temperate-temperate Atlantic continental species) occurs in Puerto Rico and highly likely that it is an old record for a misidentified Strongylura timucu. Adult S. timucu and S. notata are common in mangrove and seagrass habitats.

Response 16:
S. marina **was removed from the species list.** ***S. timucu*** **and** ***S. notata*** **were not documented in our literature search as occurring in seagrass beds and therefore the habitat characterizations were not adjusted. Removing one fish from the analysis would not influence the outcome of the analysis.**

Comment 17:
B-13 Hemiramphus balao should be considered for the list.

Response 17:
To maintain the rigor of our analysis, we did not add any additional species to the list because they were not documented in our literature search to occur in the injured habitat.

Comment 18:
B-13 How come Holocentrus spp and Plectrypops are reef fish and Myripristis is "zoobenthic"?

Response 18:
The recommended changes to the organism descriptions have been made in Table B. This correction does not change the functional group in which the organism was characterized; therefore the outcome of the analysis is not influenced.

Comment 19:
B-14 Centropomus mexicanus has also been recorded from Puerto Rico ..published.

Response 19:
To maintain the rigor of our analysis, we did not add any additional species to the list because they were not documented in our literature search to occur in the injured habitat.

Comment 20:
B-14 What about Epinephelus itajara, which is a reef and mangrove associate?

Response 20:
To maintain the rigor of our analysis, we did not add any additional species to the list because they were not documented in our literature search to occur in the injured habitat or in any of the compensatory restoration habitats. Only three additional species were suggested that occurred in two of the four compensatory habitats. These additions would not change the outcome of the analysis and were therefore not incorporated.

Comment 21:
B-14 No *Hypoplectrus* spp. were listed and they undoubtedly occur on these reefs as well as in certain mangroves (recorded from mangroves in Cuba).

Response 21:
To maintain the rigor of our analysis, we did not add any additional species to the list because they were not documented in our literature search to occur in the injured habitat. Only three additional species were suggested that occurred in two of the four compensatory habitats. These additions would not change the outcome of the analysis and were therefore not incorporated.

Comment 22:
B-14 What about Apogon pseudomaculatus...reef associate?

Response 22:
To maintain the rigor of our analysis, we did not add any additional species to the list because they were not documented in our literature search to occur in the injured habitat.

Comment 23:
B-14 Caranx barthelomaei should be spelled C. bartholomaei.

Response 23:
The spelling was corrected for this species.

Comment 24:
B-14 What happened to C. chrysos?

Response 24:
Although *C. chrysos* is a reef associated fish, they were only documented as occurring along the north coast of Puerto Rico in one of the studies found during our literature search. The stations at which *C. chrysos* was documented were offshore and not associated with hard bottom habitats. Since this species was not documented in our literature search to occur in the injured habitat, it was not included in the species list.

Comment 25:
B-15 The mojarras, geriidae, are listed as reef microcrustacean consumers when they are actually benthic sediment predators feeding on polychaetes and a wide variety of other benthic invertebrates ("zoobenthic"). I would only consiter Gerres cinereus as a reef species, possibly E. lefroyi. E. gula is primarily a seagrass species, Diapterus spp. estuarine and freshwater soft sediment associates also occurring in mangroves commonly. E. argenteus and E. melanopterus occur in high energy beach situations. E. harengulus is not listed, but is the most common estuarine and freshwater tributary mojarra in the sub-tropical and tropical western Atlantic (previously misidentified as E. argenteus).

Response 25:
The above species were incorrectly labeled as microcrustacean consumers. The table has been corrected to properly characterize them as predatory zoobenthic fish. This correction does not change the functional group in which the organism was characterized; therefore the outcome of the analysis is not influenced.

Comment 26:
B-16 Diplodus argenteus is not on the list, but should be as a omnivorous reef fish. Most of the sparids are decidedly omnivorous. Other species of Calamus have been omitted for some reason.

Response 26:
To maintain the rigor of our analysis, we did not add any additional species to the list because they were not documented in our literature search to occur in the injured habitat. These recommendations would not change the functional group in which the organisms were characterized; therefore the changes were not incorporated.

Comment 27:
B-16 Bairdiella sanctaeluciae is definitely a reef fish, but most often associated with tropical algal reef formations rather than coral reef formations. Continental juveniles are most common in seagrass not mangroves.

Response 27:
The recommended changes to the organism description have been incorporated. This recommendation does not change the functional group in which the organisms were characterized and therefore does not influence the outcome of the analysis.

Comment 28:
B-16 What happened to the other Equetus species, Parequetus as well?

Response 28:
To maintain the rigor of our analysis, we did not add any additional species to the list because they were not documented in our literature search to occur in the injured habitat.

Comment 29:
B-16 What happened to Holacanthus ciliaris and H. bermudensis?

Response 29:
To maintain the rigor of our analysis, we did not add any additional species to the list because they were not documented in our literature search to occur in the injured habitat.

<u>Comment 30:</u>
B-17 Sphyraena guachancho and S. picudilla should also be listed for “reef” formations.

Response 30:
To maintain the rigor of our analysis, we restricted our habitat characterizations to those that were documented in the literature search; therefore this recommendation was not incorporated.

<u>Comment 31:</u>
B-17 Halichoeres bivittatus occurs in seagrass as juveniles & so do H. maculipinna.

Response 31:
To maintain the rigor of our analysis, we restricted our habitat characterizations to those that were documented in the literature search; therefore this recommendation was not incorporated.

<u>Comment 32:</u>
B-17 What happened to Doratonotus megalepis a common reef and seagrass associate?

Response 32:
To maintain the rigor of our analysis, we did not add any additional species to the list because they were not documented in our literature search to occur in the injured habitat or in any of the compensatory habitats. Only three additional species were suggested that occurred in two of the four compensatory habitats. These additions would not change the outcome of the analysis and were therefore not incorporated.

<u>Comment 33:</u>
B-17 No Cryptotomus roseus?

Response 33:
To maintain the rigor of our analysis, we did not add any additional species to the list because they were not documented in our literature search to occur in the injured habitat.

<u>Comment 34:</u>
B-18 Both Labrisomus nuchipinnus and Malacoctenus triangulatus occur commonly in high energy rock reefs at depths 0-5 m in Florida as assume that they would have been at the Grounding Site in PR. They also can occur in mangroves and seagrass in decidedly marine conditions, not well within estuaries.

Response 34:
To maintain the rigor of our analysis, we restricted our analysis to those species that were documented to occur in the study area and our habitat characterizations were restricted to those that were documented in the literature search; therefore this recommendation was not incorporated. These species are listed in the table as likely to occur within the injured area as documented in our literature search, but were not documented as injured in our documents.

<u>Comment 35:</u>
B-18 What happened to Bathygobius curcao, Ctenogobius spp, particularly C. smaragdus and C. stigmaturus, Gnatholepis thompsoni, Elacatinus spp, and all Coryphopterus spp.? It appears that the reef, seagrass and mangrove gobiids have been underestimated.

Response 35:
To maintain the rigor of our analysis, we did not add any additional species to the list because they were not documented in our literature search to occur in the injured habitat.

<u>Comment 36:</u>
B-18 What happened to Monocanthus spp. and Stephanolepis spp.? These latter species are quite common in various tropical habitats.

Response 36:
To maintain the rigor of our analysis, we did not add any additional species to the list because they were not documented in our literature search to occur in the injured habitat.

NOTE: Relative to these comments on Table B, I realize the authors have apparently had little literature for this region of Puerto Rico on which to depend. However, my comments are based on what we do know of these species elsewhere in Puerto Rico, Cuba, the Windward Islands, South, Central and tropical/subtropical North America.

A major constraint of this Habitat Suitability Analysis was the lack of quantitative data for the hard bottom habitat of the northern coast of Puerto Rico. Several species lists from various studies conducted along the north coast and from injury assessment reports for the *Morris J. Berman* grounding incident were utilized to compile the likely injured species list in Table B. Our literature search encompassed information from the Caribbean and south Florida in addition to literature from Puerto Rico. The north coast of Puerto Rico is a high energy, low-relief, hard bottom habitat dominated by soft corals and mixed algal assemblages which varies greatly from the coral reef dominated habitats throughout the Caribbean, southern Florida and the southern coast of Puerto Rico. Due to the differences in habitats, we did not include fish from the southern coast of Puerto Rico or surrounding areas if they were not also documented from the northern coast of Puerto Rico.

APPENDIX E

RESPONSES TO TRUSTEE COMMENTS

Comment 1:

Table B. Please define how the species assemblage included in the "Grounding Site 0-5m" was obtained. Is this solely a list of species provided from Trustee Documents or did this habitat receive as thorough a literature review as the other habitat types.

- If this column represents a thorough literature review then we would recommend re-labeling the column name as "eolianite reef" – since "Grounding site" may give the impression that we are only looking impact site –potentially after grounding and not in its prior condition. This distinction should also be made under Section 2.0 Methods and elsewhere though the document
- If this column only represents species from Trustee documents, then it doesn't seem appropriate that any other species would be included for the other habitat types. This is because the Trustees are interested in how other potential habitat types may provide habitat for the exact same set of species as those that were found on the reef.

Response 1:

In Table B the species documented as occurring in the column labeled "grounding site" were compiled from a thorough literature review including damage assessment studies provided by the Trustees. The damage assessment documents contained species lists for unimpacted areas similar to the habitat injured by the *Morris J. Berman* grounding incident. Therefore, we have changed the column heading to "Eolianite Reef" since the species documented within this column are found in an eolianite reef habitat. This distinction is made in SECTION 2.0 and is consistent throughout the document.

Comment 2:

Use of a similarity index is not really the appropriate approach. By including species from other habitat types that are not found on the "injured habitat type", you are automatically driving the similarity indices further apart. In other words, what the Trustees are interested in is "Given the species that exist on the injured habitat type, what other habitats will provide them benefit." The Trustees are not interested in how similar the habitats are – but in how other habitat types may provide service to species found on the injured (eolianite) reefs.

- The use of a similarity index could still be applied looking only at the similarity of species between the different habitats – only for species that exist on the injured habitat type.
- Alternatively, a simple matrix which includes "Total number of species on injured habitat type", and a break down of the habitat type with the highest number of overlapping species, then the habitat type with the most number of species matching the injured habitat but not captured by the first habitat. See example Table. Using this approach, up to 16 different tables could be generated, each one representing a different order of the compensatory habitat types as represented in the last column of the example table below. In this manner, the Trustees can choose a mosaic of habitats with some logic behind the combination that benefits the most species.

Table. # species utilizing Eolianite reef that also utilize other habitat types.

Habitats	Total # species matching Eolianite Reef	# species of interest unique to one alterative	# of unique species to benefit by adding on the next alternative
Eolianite Reef	100	(10 not found in any other habitat types)	
Hard Bottom 5-10	60	20	60
Hard Bottom > 10	40	2	2
Mangroves	25	10	15
Seagrass	20	3	5

Response 2:
The Habitat Suitability Analysis was modified to include only the 183 documented eolianite reef species as suggested by the Trustees.

We have included a group of matrices to help the reader better understand the similarities and differences between the species composition of eolianite reef and compensatory habitats. The tables show the number of eolianite species also documented in the compensatory habitats and in the two-habitat and three-habitat compensatory mosaics. The number of species to benefit by the addition of another compensatory habitat type is provided in APPENDIX C.

<u>Comment 3:</u>
The conclusions are not necessarily supported by the analysis that was completed. "No single habitat was identical to the injured habitat for all four services; therefore a mosaic approach of restoration/creation of more than one habitat may be the best alternative."

- The analysis that was completed was a similarity comparison that looked at presence/absence of species in the individual habitats – <u>not their mosaic ability to compensate</u>. In order to draw this conclusion, it would be necessary to say something about the ability of the "preferred" habitat to compensate and given that level of compensation, something about the 2nd habitat, and given that level of compensation, something about the 3rd habitat.
- Artificial reefs are specifically identified as a reasonable compensatory restoration alternative yet artificial reefs are not included in the similarity analysis along with hard bottom 5-10m, hard bottom >10m, seagrass or mangrove habitats. In order to justify including artificial reef under the conclusion, artificial reef should be treated as a separate habitat type (i.e., a fifth habitat type) in order to provide a reasonable basis for this conclusion. Otherwise, a separate analysis demonstrating that hard bottom habitats, specifically those used in the analysis, are sufficiently similar to artificial reef is required to demonstrate that hard bottom habitat and artificial reefs are interchangeable. Looking through the literature citations, several artificial reef references are included. Indeed the SOW provides the latitude to look at other habitats (i.e., SOW III, B, 2, fourth bullet: "analysis of other habitats that provide the same or comparable type and quality of habitat services to faunal communities associated with the injured habitat <u>including, but not</u>

limited to, mangroves, seagrass beds and hard bottom habitats (at various depths up to 90 feet)"

Response 3:
Based on the comments and issues provided in Comment 3, MRI has assembled TABLES 11-13 in SECTION 4.0. The purpose of the tables is to present the number of species that are shared between each compensatory restoration habitat and the eolianite reef habitat. The compiled tables illustrate the ability of the preferred mosaic compensatory restoration to compensate for the highest number of species found within the eolianite habitat.

In the second comment, the NOAA reviewers requested that we demonstrate or document the high relational similarity or interchangeability of artificial reef habitats to the shallow water eolianite reef habitat. No quantitative or qualitative data regarding artificial reefs on the northern coast of Puerto Rico was discovered during the literature search effort. Based on the absence of data we could not include artificial reefs as a compensatory habitat in our similarity analysis. In SECTIONS 2.0 and 4.1.1 MRI and Dr. Sean Powers have expanded on the functional application of artificial reefs to recruit and support ichthyofaunal and invertebrate assemblages that are highly similar if not more diverse than local natural reefs systems. The literature presented in these sections demonstrates how effective artificial reefs can be as a compensatory habitat if constructed in an appropriate manner.

Comment 4:
Throughout the document, the term mitigation and/or mitigation habitat is used. The appropriate term, in the context of natural resource damage assessment, is compensatory restoration. The term mitigation should not be used in this document.

Response 4:
The term mitigation and/or mitigation habitat was changed to compensatory restoration and/or compensatory habitat throughout the document.

Comment 5:
Figure 2. under Step II, uses the term "listed species". Because the term "listed species" has meaning under the Endangered Species Act, an alternative term should be used.

Response 5:
The term "listed species" in FIGURE 2 was changed to documented species.

Comment 6:
What is the purpose of Figure 3.? Primary Impact Area and Secondary Impact Area designated but the injured eolianite reef was a discrete area impacted by the barge grounding. If the large polygons identified as Primary and Secondary Impact areas and depicted by Figure 3. characterize the area of oiling, then what is the purpose? Similar to HSA Response #4 to the Reviewer comments, the analysis should focus on the eolianite reef, a physical loss not a loss due to oil exposure. Figure #3, which is also used on the front cover, gives an impression of an oil exposure area. Either eliminate the figure or explain its relationship to the analysis.

Response 6:
We agree and have removed the Primary and Secondary Impact Area designations from the figure. We have kept the figure without the impact areas to provide the reader with a map to orient themselves with the area in which the grounding occurred.

Comment 7:
Section 2.0 Methods, second paragraph, #3 "... greater than > 10 m;" This is redundant. It should read either "greater than 10 m" or "> 10 m".

Response 7:
The greater than symbol (>) has been removed.

Comment 8:
Section 2.0 first numbered item, Strike "injured" per comments above.

Response 8:
All references to the "injured" habitat throughout the document have been changed to "eolianite reef habitat".

Comment 9:
Section 2.0 Second Paragraph ; Is the assumption that an artificial reef , after a brief period of succession (~5 years) would mimic the natural reef system supported by the data collected during the literature search? Do the artificial habitats described in the literature search mimic the natural hard bottom areas to such a degree that the fish associated with the artificial reefs can be assumed to be associated with the various hard bottom habitats (i.e., 0-5m, 5-10 m & > 10 m)? If not, then artificial reef ought to be listed as a separate habitat and compared to the other four compensatory restoration alternatives.

Response 9:
A discussion concerning artificial reef providing ecological services similar to natural hard bottom has bee included in the revised text SECTION 2.0.

Comment 10:
Section 2.2 Habitat Suitability Analysis, first paragraph, 2nd sentence: recommend adding "either directly or indirectly" after "…species likely injured…"

Response 10:
The sentence has been changed to: The species that were documented to utilize the eolianite reef habitat were considered to be species either directly or indirectly injured by the grounding incident.

Comment 11:
Section 2.2 Habitat Suitability Analysis, first paragraph, 4th line: "Trustees" is misspelled.

Response 11:
The spelling has been corrected in the text.

Comment 12:
Section 3.2: A general description of the services provided by eolianite reef at the beginning of the document would be helpful to frame the analysis and conclusion. Currently, the functional groups serve as a metric of services, but a concise description of the services provided by the eolianite reef is lacking. Recognizing there is little quantitative data, is it possible to provide a breakdown of the expected community structure of the reef in regards to the functional groups (i.e., % producers, % structural animals etc.,) as part of the service description?

Response 12:
SECTION 1.2 has been expanded to provide an introductory description of the eolianite reef habitat. A general description of the services provided by an eolianite habitat is found in the 4th paragraph of SECTION 2.0 and a thorough discussion of the eolianite reef habitat and the organisms within each service category is provided in SECTION 3.3.

Comment 13:
Section 3.2 3rd paragraph first sentence: Need to explain Figure 3 better. Specifically, what is meant by the Primary and secondary impact areas?

Response 13:
As per Comment 6, the impact areas have been removed from the figure.

Comment 14:
Section 3.2 3rd paragraphs, Sentence beginning with "The most commonly affected biota…" This statement is confusing when compared with the last sentence in the 1st paragraph of Section 3.3 that begins with "Faunal groups with the most species likely injured…"

Response 14:
The statement made in the 3rd paragraph of SECTION 3.2 referred to the organism injured by the grounding incident and the subsequent oil spill whereas the sentence in SECTION 3.3 referred to organisms documented within the eolianite reef habitat only. This was clarified in the document.

Comment 15:
Section 3.3 Appendix B includes more than indicated in the first paragraph of 3.3 for instance a description of the faunal communities is also included.

Response 15:
APPENDIX B is initially described in SECTION 2.2. SECTION 3.3 was expanded to provide a more thorough description of the APPENDIX B table.

Comment 16:
Section 3.3.1 Primary Producers, 4th line from the bottom should read, "Halimeda spp., calcareous green algae,..." since spp. indicates more than one species.

Response 16:
The correction was made in the text.

<u>Comment 17:</u>
Section 3.3.1 No mention that primary producers provide food as a service.

Response 17:
SECTION 3.3.1 was expanded to give a general description of the services provided by primary producers and provides specific descriptions of primary producers in the eolianite reef habitat.

<u>Comment 18:</u>
Section 3.3.2 Second Paragraph, last sentence – Were the 10 species documented likely injured determined by Trustee documents or were they associated with the eolianite habitat as determined by the literature search? (As a general comment similar to this specific comment, it may be clearer to the reader to identify which species were documented as injured during the assessment and which are included because of the literature search.)

Response 18:
The sentence was changed to more clearly explain that the 12 species (the number was incorrect after a recount) were documented in the eolianite habitat from the literature search and were therefore either indirectly or directly injured by the grounding.

<u>Comment 19:</u>
Section 3.3 & 3.4 According to Section 2.2, species are assigned one of four service categories (primary producers, structural animals, herbivores and predators) so the headings for Section 3.3.3 (Motile Invertebrates) and 3.3.4 (Vertebrates) doesn't relate to a functional group as described in 2.2

Response 19:
SECTION 3.3 has been reorganized to reflect the service categories as described in SECTION 2.2. The revised portions of SECTION 3.3 are now labeled as follows:

SECTION 3.3.3 Herbivores;
SECTION 3.3.3.1 Invertebrates;
SECTION 3.3.3.2 Vertebrates;
SECTION 3.3.4 Predators;
SECTION 3.3.4.1 Invertebrates
SECTION 3.3.4.2 Vertebrates

SECTION 3.3.3 and 3.3.4 provide a general description of the services provided within the eolianite reef habitat by the identified service category. The invertebrate and vertebrate subsections provide specific examples of the services provided by the identified faunal groups within the eolianite reef habitat.

<u>Comment 20:</u>
Section 3.3.3 Motile invertebrates, final line recommended addition, "...important commercial species in Puerto Rico, and is listed in Appendix II of CITES as Threatened."

Response 20:
Recommended addition was included in the document.

<u>Comment 21:</u>
3.4.2 Structural Animals Isn't it logical to include all species that provide structure (algae, seagrass…) instead of just animals that provide structure?

Response 21:
In SECTION 3.4.2 we have included that many primary producers also contribute to the structural complexity of the habitat but explain that they are not included in the analysis as structural animals because their primary role is primary production. We do discuss in SECTION 3.3.1 that some primary producers also provide structure as a habitat service.

<u>Comment 22:</u>
3.4.2. Question regarding plot. Does having more structural animals make a habitat more structurally complex? Seagrass is very structurally complex yet probably has far less structural animals…

Response 22:
Structural complexity of a habitat is not directly correlated to the number of structural animals. For example, seagrass and mangroves create structurally complex habitats with a relative few species of structural animals.

<u>Comment 23:</u>
3.4.3 Is a habitat service of the Herbivores to be prey?

Response 23:
This service of herbivores is explained in SECTION 3.3.3.

<u>Comment 24:</u>
Figure 3. legend repeats redundancy: "less < 0.1". Should be less than 0.1 or < 0.1.
Figure 4. legend same problem as Figure 3.
Figure 6. legend same problem as Figure 3.

Response 24:
The legend has been changed to remove the redundancy in all of the aforementioned figures.

<u>Comment 25:</u>
Table 8. correct scientific name is: Epinephelus gutatus for Red hind.

Response 25:
The spelling was corrected in TABLE 8.

<u>Comment 26:</u>
In the paragraph following Figure 7, I wonder whether we could modify the first sentence to read, "A desirable coupling may be the restoration * or protection * of seagrass beds..."

Response 26:
Sentence has been changed to use the term compensatory restoration, which encompasses all possible options for the Trustees.

<u>Comment 27:</u>
Further down in that same paragraph, there are unnecessary italics following "Chaetodon capistratus".

Response 27:
Unnecessary italics were removed from the text.

<u>Comment 28:</u>
In Appendix B, Page B-4, three species of seagrass are included as primary producers within seagrass habitat. Is it appropriate to include the species that makes up the habitat in the similarity index?

Response 28:
All of the species documented in the habitats can be considered to make up the habitat. We have included seagrasses because they are important primary producers in the seagrass habitat.