Mona Channel Marine Debris Removal (Puerto Rico)

Amigos de Amoná, Inc.

PMB 143, P O Box 5103
Cabo Rojo, Puerto Rico 00623

Amigos_Amoná@hotmail.com

Final Report

June 2004

This report should be cited as:

Schärer, Michelle T. (2004) Mona Channel Marine Debris Removal, Puerto Rico. Final Report to Amigos de Amoná, Inc. 37 pp.

ABSTRACT

The non-profit community based organization Amigos de Amoná, Inc. implemented this project to help mitigate damage caused by marine debris on coral reefs and associated habitats of the Mona Channel Islands (Mona, Monito and Desecheo), Puerto Rico. One of the projects goals was to remove marine debris objects that affected marine life and coastal habitats including coral reefs of the Mona Channel Islands. Additionally a conservation guide was developed for the visitors and boaters of the islands. The main objectives of the field expeditions were: (1) Remove marine debris form the reefs and shoreline, (2) Determine the types of debris and their distribution, (3) Quantify the species and habitats impacted by marine debris and (4) Determine the damage caused by marine debris to the coral reef and coastal habitats. Workshops were carried out to train volunteers prior to the 5 field expeditions (4 to Mona, 1 to Desecheo) held between May 2003 and March 2004. During the expeditions 30 volunteers donated 1,363 hours of labor to survey 26.5 km of coast and reef areas. During the surveys 3,235 kg (7,117 lbs) of marine debris were removed and classified as fishing gear (48%), plastics (13%), glass (14%), metal (8%) and others (17%). Most debris classified as others included rubber shoes, refrigerator doors, packing and insulating materials, and washing machines. Objects classified as fishing gear surpassed all other types of debris by weight including trawl nets, ropes, buoys and fishing lines. The greatest amount of debris was found on the southern coast of Mona Island followed by the east and then west coasts of this island. Debris accumulations were observed affecting sea turtle nesting areas beaches mostly by driftwood interrupting access to the ocean. Underwater 25 coral colonies (mostly *Acropora palmata*) were damaged by debris including nets, ropes, plastic bags, fishing line, anchors, clothes and plastic bags. Damage to these colonies varied from superficial scraping of live tissue to bleaching and breakage of coral. In order to create awareness of the marine debris problem among visitors of the Mona Channel Islands a marine life conservation guide was developed. Posters with general recommendations to the general public were printed to help reduce the amount of debris entering the Mona Channel and eventually floating to the islands. The educational materials were developed for the general public that visits the Mona Channel Islands.

RESUMEN

La organización sin fines de lucro Amigos de Amoná, Inc. llevó a cabo este proyecto para mitigar los daños causados por la basura marina en los arrecifes de coral de las Islas del Canal de la Mona (Mona, Monito y Desecheo), Puerto Rico. Uno de los propósitos del mismo fue remover artículos de basura que afectan negativamente la vida marina y los habitáculos que se encuentran en las costas y arrecifes de las islas. Además se diseñó una guía educativa para los nautas y visitantes de las islas. Los objetivos del trabajo de campo fueron los siguientes: (1) Remover basura marina de arrecifes de coral y playas, (2) Determinar el tipo de basura y su distribución, (3) Cuantificar las especies y habitáculos impactados por basura marina y (4) Determinar el daño causado al ambiente marino por la basura marina. Luego de talleres de entrenamiento de voluntarios se completaron 5 viajes de campo (4 a Mona y 1 a Desecheo) entre mayo de 2003 y marzo de 2004. Durante estos viajes de campo 30 voluntarios trabajaron durante 1,363 horas para evaluar 26.5 km de costa. Durante los censos se removieron 3,235 kg (7,117 lbs) de basura inorganica que se clasificó en artes de pesca (48%), plástico (13%), vidrio (14%), metal (8%) y otros (17%). La mayoría de la basura clasificada como otors incluyó zapatos de goma, neveras, lavadoras, material de empaque y material insulante. Las artes de pesca parecen ser la mayor fuente de basura en las islas, principalmente redes de arrastre, sogas, boyas y líneas de pescar. La mayor cantidad de basura se encontró en el sur de las Isla de la Mona seguido por las costas este y oeste. En las playas se observó daño a los habitáculos de anidaje de tortugas marinas por acumulaciones de basura (mayormente la madera y bambú). En los arrecifes 25 colonias de coral (mayormente *Acropora palmata*) se encontraron afectadas por redes, sogas, linea de pescar, anclas, bolsas plasticas y ropa. Los daños a las colonias de coral varió de abrasiones leves hasta blanqueamiento y rompimiento de fragmentos. Para crear conciencia entre los visitantes de las Islas del Canal de la Mona se desarolló una guía para la conservación de la vida marina. Además se imprimieron afiches con las recomendaciones al público en general de minimizar la basura que alcanza las aguas del Canal de la Mona y eventualmente sus islas. Los materiales educativos son para el público en general que visita las Islas del Canal de la Mona.

Acknowledgements

The completion of this project was possible thanks to the cooperation of a great number of individuals and organizations that came forward with great enthusiasm and courage to work. We are indebted to the staff of the NGO Amigos de Amoná, for their efforts to gather donations, volunteers, permits and organize expeditions to Mona Island. The volunteers are an essential part of this project without them there would not have been a Marine Debris Removal Project. A number of local commercial enterprises donated time, supplies or financial help for this project and we are thankful. Logistic maritime support during transport and debris removal was provided by the vessels "*Orca Too*" and "*Tourmarine*" whose crew worked hard along our staff and volunteers to meet project goals. The Department of Natural and Environmental Resources provided special permits to conduct this work and provided support in the field by the collaboration of on site staff. The municipalities of Cabo Rojo and Mayagüez provided tremendous help by transporting debris to recycling or dumping facilities on the island of Puerto Rico. A number of partners collaborated on the educational component of this project including the Department of Marine Sciences of the University of Puerto Rico at Mayagüez as well as the expertise of the Sea Grant College Program staff at the University of Puerto Rico, Mayagüez. Special thanks to Ruperto Chaparro and Dr. Manuel Valdés-Pizzini from the Sea Grant Program who provided encouragement and support at the beginning of the project. This work would have not been possible without the financial support of the National Fish and Wildlife Foundation and the AWARE Foundation and we acknowledge their assistance and thank these foundations for the opportunity to carry out this project. Finally Michael Nemeth and Kimberly Ferrán of the Department of Marine Sciences of the University of Puerto Rico were instrumental in the field component of this project and helped in the completion of this report.

Michelle T. Scharer
April 22, 2004

FUNDING

Financial support for the completion of this project was provided by the following agencies:

The National Fish and Wildlife Foundation financed a portion of this project through the Coral Reef Grants of the National Oceanic and Atmospheric Administration. This was the principal investor in the project and administrator of grant funds. The project was initiated in October 2002 and lasted 18 months.

The AWARE Foundation was a contributor to this project in cash donations for materials related to this project. The foundation has been funding similar projects of Amigos de Amoná, Inc. since the year 2000.

Amigos de Amoná, Inc. is a non-profit community based organization in Puerto Rico and was the recipient of the grant that made this project possible. The organization was founded in 1998 and was the administrator and main in-kind donor for the project.

The Puerto Rico Department of Natural and Environmental Resources was the host partner in the field work portion of this project and donated in-kind services to the organization. The Department provided special permits and camping fee waivers during the field expeditions.

The Sea Grant College Program of the University of Puerto Rico at Mayagüez provided in-kind services to match project funds. The program collaborated towards the development of workshops and educational materials as well as printing of posters and the conservation guide.

INDEX

INTRODUCTION

There is overwhelming evidence that marine debris, especially plastic debris, is a threat to marine biodiversity. This amplifies the threat to biodiversity of marine ecosystems that are already under pressure from other anthropogenic impacts (Derraik, 2002). Entanglement, ingestion and abrasion of benthic organism are a source of species mortality and habitat destruction that lacks proper quantification. Anecdotal information is common and increasingly popular volunteer beach clean-ups have provided a gauge with which to measure marine debris accumulation and changes at specific areas. However the threat of marine pollution provides a challenge in estimation of the spatial and temporal scales as well comparisons to other forms of anthropogenic impacts. The issue has been identified as a concern by a variety of marine resource professionals (see Derraik, 2002). In Puerto Rico the combined threats of anthropogenic origin are affecting the environment and especially the marine resources of which coral reefs are an important component.

Beach usage has been identified as a potential source of debris (Nagelkerken *et al.*, 2001). Floating debris has a high probability of remaining in oceanic currents and may impact remote habitats as well (Otley and Ingham, 2003). Fishing activities have been identified as a significant source of debris in coastal submarine habitats (Donohue *et al.*, 2001; Chiappone *et al.*, 2002). The impact of these different sources of debris remains to be evaluated for most marine regions and species. This should be determined in order to be able to gauge the importance of this threat in comparison to other problems affecting marine resources. A greater understanding of the factors controlling the distribution and dispersion of debris and its deposition on coastal habitats will provide better ways to manage the sources and minimize the impacts on marine ecosystems.

Amigos de Amoná, Inc. initiated the Mona Channel Marine Debris Removal Project to assess the marine debris situation in remote islands off the western coast of Puerto Rico. This not for profit, community based organization unites persons from various stakeholder groups including boaters, campers, divers, hikers, hunters, naturalists, students, and scientists with interests in the natural resources of Mona Island. The group has been collaborating with the Department of Natural and Environmental Resources (DNER) that is in charge of managing the Mona Island Natural Reserve. Amigos de Amoná, Inc. is involved in a variety of conservation activities, which include habitat restoration of terrestrial and aquatic habitats, management tasks at Mona, symposia, and other educational activities. One of the collaborators in the marine clean-ups performed at Mona Island was the AWARE Foundation. Amigos de Amoná, Inc. had previously performed marine debris clean-ups in beach areas visited by campers on Mona Island. Most of this debris was identified as land or vessel based and transported by oceanic currents from other Caribbean islands. Accumulation rates were not calculated but more debris was deposited on the same beaches soon thereafter and this prompted consideration of a more rigorous project. Thus, based on the findings from the marine clean-up projects, a more comprehensive proposal was elaborated in order to reach other marine and coastal areas of the Mona Island Natural Reserve and Desecheo Island Marine Reserve located in the Mona Passage. Both these areas are important for a variety of endangered species and habitats such as coral reefs and seagrass lagoons. The National Fish and Wildlife Foundation provided an opportunity to carry out this project under the Coral Reef Conservation Grant program.

The Mona Channel Marine Debris Removal Project's main goal is to reduce impacts of marine debris on coastal and marine habitats of the Mona Channel. One component involved field work to remove marine debris from beaches and coral reefs in order to assess the threat of this form of pollution. Additionally an educational component was included in this effort in order to educate the public about the marine ecosystems in the Mona Passage and how marine debris affects the organisms that compose this system. Since these islands are relatively remote (13 and 42 nm) access is limited, thus few Puerto Ricans can experience this pristine natural environment. The focus of the educational component was the campers, boaters, hunters and fishers that utilize the islands regularly. They are the first line of defense in support of the conservation measures for these areas. Additional targets of the educational campaign were the coastal communities of western Puerto Rico where much of the debris is suspected of entering the marine system. The goal is to create awareness for better waste management on the main island of Puerto Rico in order to minimize the land based source pollution in the Mona Channel.

The objectives of the Mona Channel Marine Debris Removal Project include the following:

- Identification of the type, density and distribution of debris in the Mona Channel
- Removal of marine debris from coral reef and beach habitats of the Mona Channel Islands
- Quantification of the species and habitats impacted by marine debris
- Damage assessment of coral reef organisms impacted
- Create educational materials for a marine life awareness campaign

With this information the spatial distribution of debris can be displayed in relation to habitat and oceanographic data, which will allow managers to focus efforts on habitats important for endangered and threatened species or coral reefs. With this map, management strategies can be better implemented for specific sites or regions where impacts can be pinpointed and negative impacts can be minimized. This baseline study will provide a reference point for future studies and the spatial and temporal distribution of debris can be investigated. Additionally the recovery of coral colonies after debris removal will be an important potential benefit of this project that will determine if the efforts to carry out this kind of work are worthwhile. The Mona Channel Marine Debris Removal Project provides an assessment of the impact of debris on Puerto Rican coral reefs, which are currently the focus of various local (Commonwealth of Puerto Rico) and regional (U.S. Coral Reef Task Force) strategies to prioritize conservation measures in face of different threats. Additionally the Mona Channel Islands are the focus of a series of marine conservation measures that include no take areas and gear restrictions and the reduction of marine debris will contribute to their preservation.

STUDY SITE

The Mona Passage divides the island of Hispaniola from Puerto Rico and connects the Atlantic Ocean with the Caribbean Sea on the western coast of Puerto Rico. Within this passage there are three relatively small islands that are part of the Puerto Rican archipelago, Mona, Monito and Desecheo Islands (Figure 1). The islands are uninhabited, but Mona is occupied by DNER personnel, and visited regularly by campers, hunters, fishers, divers and boaters. Monito and Desecheo Island are off limits to humans due to past military practices and unexploded ordinance on land and underwater.

Figure 1. Islands of the Puerto Rican Archipelago.

Mona Island is located 73.6 km from the west coast of Puerto Rico, geographically located between 18º 10' N and 18º 02.5' N latitude, and 67º 57.5' W and 67º 50' W longitude. The main island, Mona measures 6.8 km by 10.9 km and its satellite Monito is located 6km to the northwest separated by a channel approximately 220m in depth. Both islands are surrounded by deep waters of the Mona Passage ranging from 370 to 1160 m. The waters surrounding Mona and Monito are extremely clear and free of terrestrial inputs (Cintrón *et al.*, 1975), although fresh water percolates through the limestone rock faces of both islands.

The marine habitats of Mona Island include cliff walls that may extend 40 m above and below the ocean surface, shallow fringing reefs along the eastern and southern coasts, deeper patch and spur and groove formations are found along the eastern, southern and western shores, and small fringes of seagrass lagoons on the eastern and southern shores (Appendix 1). Surface currents are predominantly from the east (Perl & Cintrón, 1974). The outer limits of the Natural Reserve designation expand to 9 nm around the perimeter of both islands (Figure 2). The reserve is managed by the DNER with on-site staff that include enforcement rangers, and a no fishing area up to 0.5 nautical miles from shore was recently approved in a fisheries regulation, although implementation has not begun.

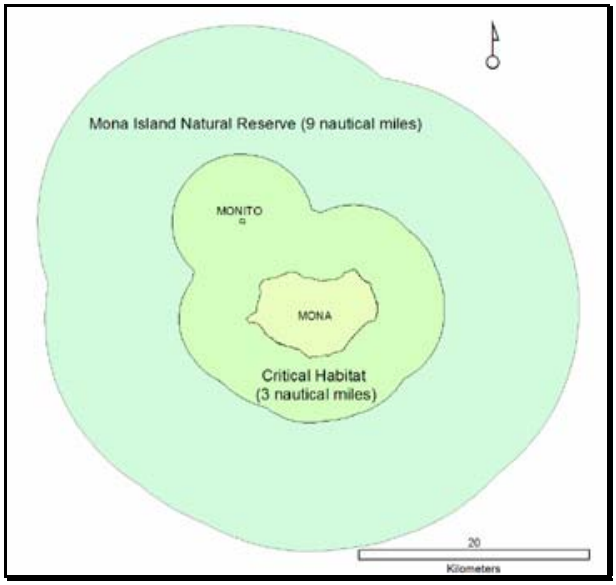

Figure 2. Mona and Monito Island with Natural Reserve and Critical Habitat designations.

Isla Desecheo is much smaller (360 ha) and is located in the northeastern Mona Passage (18º 22' 08 N, 67º 29' 02 W) approximately 21 km west of Rincón, Puerto Rico. The waters surrounding Desecheo support diverse benthic habitats including coral, rock reefs, and sponge encrusted walls on a narrow shelf that skirts out into depths of 500 m to 3000 m (Puerto Rico Trench to the north). The island is designated as a US Fish and Wildlife Service (USFWS) National Wildlife Refuge although it lacks on-site staff. Besides bombing practices (USAF) and unexploded ordinance, introduced species (goats and monkeys) have impacted the terrestrial vegetation and sea bird nesting areas. Waters surrounding 0.5 nautical miles were designated as a Marine Reserve to be managed by the DNER (Law 57; March 10, 2000), although enforcement is lacking (Figure 3).

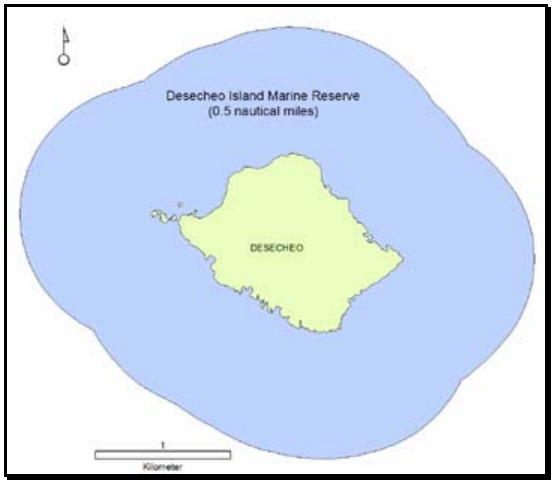

Figure 3. Desecheo Island and Marine Reserve extending 0.5 nm from the shoreline.

Only Mona Island has sandy beaches (7.2 km) that support one of the largest hawksbill sea turtle (*Eretmochelys imbricata*) nesting rookeries (see Appendix 2) in the Caribbean and has been identified as Critical Habitat for the species. Monito and Desecheo have rocky shores (see Appendix 1) that sometimes extend vertically as cliff walls that surround the islands, but no sandy beaches are present that support sea turtle nesting. Nonetheless all three islands support a variety of submerged habitats that support populations of important coral, fish, and sea turtle habitats as well as terrestrial habitats important for sea bird nesting colonies. Three nautical miles surrounding Mona and Monito are also considered Critical Habitat (Figure 2) for hawksbills (*E. imbricata)* due to the large numbers that have been tagged in the area. Juvenile and adult hawksbill (*E. imbricata)* and green (*Chelonia mydas)* turtles are commonly observed underwater and at the surface. The DNER and Chelonia, Inc. have a long term study of foraging and nesting sea turtles at Mona and Monito Island with which Amigos de Amoná has collaborated in nesting habitat protection from wild pigs.

Desecheo Island is visited for diving, whale watching and fishing purposes during most of the year by operators located in Rincón and Cabo Rojo on the west coast of Puerto Rico. The coral reefs located off the southern shores of the island are considered some of the best formations in the Puerto Rican Archipelago. But the coral reefs cover a relatively small proportion of the insular shelf of the island. In the year 2000 the DNER in collaboration with local dive operators installed mooring buoys in these high coral cover areas in order to reduce anchoring impacts on the reef.

Mona and Monito are also frequently visited by fishers, divers and boaters due to the refuge they offer in the vast Mona Channel. Dive operators may visit the island for day trips or may camp on the island and dive during multiple days. Depending on sea conditions, all areas of Mona and Monito are targeted for diving and spearfishing with the aid of SCUBA. Mooring buoys have been installed by DNER at 3 dive locations outside the lagoons and within the camping area lagoons.

Fishers that visit the island are mostly recreational, although some commercial fishers of deep water snappers visit the nearshore waters during fishing operations to rest or for repairs. Fishing gears utilized by fishers in the local area include hook and line, traps. Spearguns and nets are less commonly observed. Deep sea fishers include Marlin, Sailfish and Mahi-Mahi fishers that set out in tournaments throughout the Mona Channel and come in to Mona Island safe harbors for the night. The number of vessels observed during these tournaments can exceed 55 of which at least 35 have been observed entering the small Sardinera harbor (Figure 4).

Figure 4. Recreational deep sea fishing vessels during tournament anchored in Sardinera Lagoon, Mona.

METHODOLOGY

Groups of volunteers were trained to be able to assess debris impacts and carry out removal and quantification on beaches and in coral reef environments. Field cruises were conducted to these offshore islands in order to quantify, classify and remove marine debris from coastal and submerged habitats. Volunteers carried out beach and benthic snorkeling surveys to identify debris, determine abundance, and impact if any, on marine habitats and endangered species. Snorkeling surveys were limited to areas where the seafloor could be observed from the surface and floating debris would be likely to accumulate.

Surveys were conducted in 3 coastal zones; beach, littoral and reef. Surveys were composed of linear transects with as many volunteers as were available who would find, assess, collect and remove inorganic debris items (no wood debris was removed). During these transects GPS points were collected and the area covered by the survey was subsequently estimated. All debris was removed, classified, lumped by class and weighed to the nearest 0.1 Kg. Classes of debris were based on the material of the items such as plastic, glass, metal, ropes and nets or other for miscellaneous items. For underwater surveys, snorkelers searched in lines parallel to the coast or the reef. Each item affecting a live coral colony was assessed individually as to the species affected and the type of impact or mortality that could be attributed to the debris. All debris encountered was collected and removed with the aid of a small vessel and SCUBA when necessary. Great care was taken in order to avoid breaking or further damaging the coral when removing debris, shears and scissors were used to aid removal of entangled debris. These items were classified and quantified after at least 6 hours of drying. Upon completion of the field cruise all debris was transported to the main Island of Puerto Rico where it was disposed of with help from the coastal municipal governments of Cabo Rojo and Mayagüez.

All data was compiled in a database that included the location, zone, habitat, volunteer effort, geographical coordinates and weights of debris types. With this information and GIS software the linear distance surveyed was estimated and density measures were calculated (grams/meter). The occurrence of debris on coral reef organisms was also determined in GIS in relation to benthic habitat maps.

The educational and outreach component of the Mona Channel Marine Debris Removal Project commenced with a series of workshops that were required for volunteers interested in participating in field cruises. During these workshops a series of presentations by outreach professionals were given on the impacts of marine debris and the importance of conserving the marine resources of the Mona Channel Islands. Volunteers were presented with the methodology that would be employed in the field and in the educational component of the project. The goals and objectives of the educational campaign was determined by the workshop participants and this was shared and modified as necessary with members of Amigos de Amoná, Inc. in subsequent meetings. The group decided to produce educational materials in the form of a small poster and a full color brochure that could be easily handed out to visitors of the Mona Channel Islands. The content and format of these products was reviewed with the working group on various occasions and during Amigos de Amoná, Inc. meetings.

RESULTS

Five field cruises were carried out, 4 to Mona Island and one to Desecheo (Table 1). All cruises were organized by Amigos de Amoná, Inc. and volunteers who donated time towards attaining DNER permits, equipment and materials preparation, loading, transport, camp setup, meal preparation and debris management tasks. Each one of the cruises to Mona Island targeted a different area of coast in order to cover all the southern shores of the island where sea turtle nesting beaches and coral reef habitats are located (cliff wall shores are deeper and floating debris would probably not accumulate there). The DNER provided the research and camping permits for these cruises. The reserve manager and various employees cooperated in the logistics of conducting the surveys and disposing of debris. During three of the surveys of Mona Island and the Desecheo survey the dive vessel 'Orca Too' provided support for offshore surveys and debris management.

Table 1. Field cruises of the Mona Channel Marine Debris Removal Project

Trip #	Departure Date	Location	Duration (d)
1	May 29, 2003	Sardinera, Mona	3
2	September 9, 2003	Desecheo	1
3	October 2, 2003	Sardinera, Mona	3
4	October 30, 2003	Pájaros, Mona	3
5	March 20, 2004	Pájaros, Mona	2

Overall 40 transects were performed covering a linear distance of approximately 26.5 km with a combined area of 0.70 km^2. Of these transects 22 (55%) were on beaches and the rest surveyed submerged habitats. The linear distances covered per trip and estimated areas surveyed are summarized in Table 2.

Table 2. Linear distance and estimated area covered by surveys per trip.

Location	Linear Dist. (km)	Area (km^2)
Mona 1	13.89	0.33
Mona 2	4.71	0.14
Mona 3	3.14	0.14
Mona 4	1.95	0.03
Desecheo 1	2.84	0.06
Total	26.54	0.70

Transects at Mona Island covered a total linear distance of approximately 23.7 km of which 40% was beach area and 60% submerged habitats (Figure 5). Beach transects were conducted from the water line to the vegetation line and their width varied greatly by beach. Underwater surveys covered littoral, rocky shores, coral lagoon, backreef and forereef habitats. Due to sea conditions the reef crest was not surveyed completely due to the risk to volunteers. During calm seas some of these areas were surveyed, but in order to prevent unintentional damage to corals these surveys were limited. Depths of submarine areas surveyed ranged from 0.25 m to 15 m where visibility allowed debris recognition, free diving or SCUBA diving to collect and assess damage to habitat.

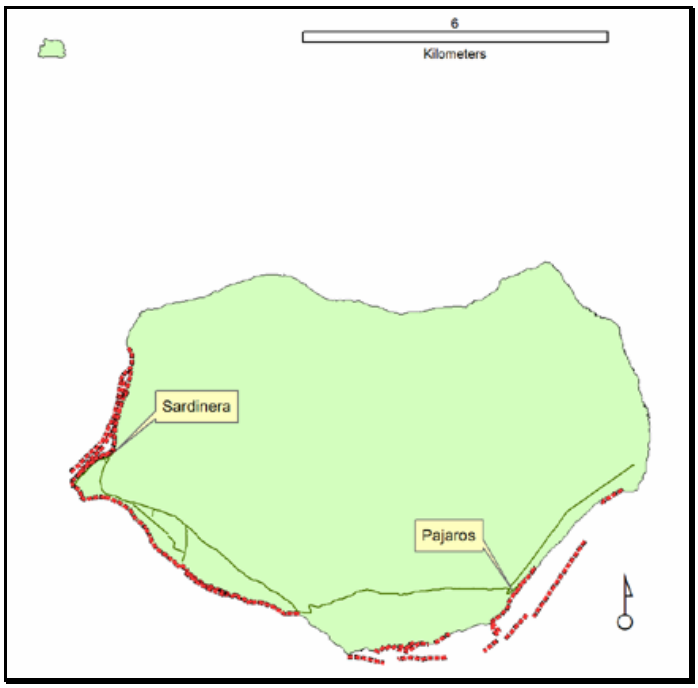

Figure 5. Transect lines surveyed at Mona Island.

At Desecheo Island only submarine habitats were surveyed as access on land is restricted by the USFWS. Approximately 3 km were surveyed along the southern and western coasts of Desecheo, where coral reefs are more prevalent (Figure 6). The northeastern shores of this island are exposed to strong swells and these areas were not surveyed for safety reasons. We are confident that at Desecheo Island the areas with greatest coral cover were surveyed adequately, although most of the near shore habitats are rocky shore and only sparse coral colonies were observed. Most coral reefs at Desecheo are at depths greater than 15 m, therefore it is unlikely that floating marine debris is affecting these habitats.

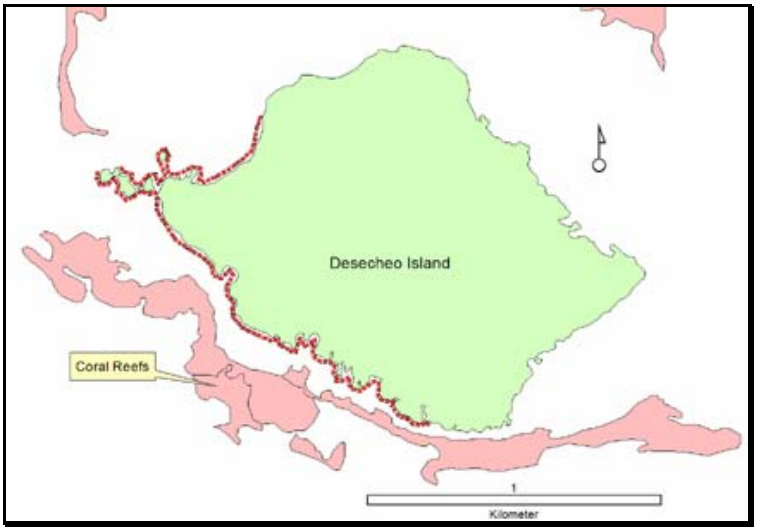

Figure 6. Transect lines (red) surveyed at Desecheo Island. Coral reef habitats are depicted in pink.

Volunteer survey efforts totaled 193.3 hours during the Mona Channel Marine Debris Removal Project. Effort was distributed unequally throughout the islands as depicted in Figure 7 and identification codes for all regions surveyed are identified in Table 3. Images of volunteers are presented in Appendix 3.

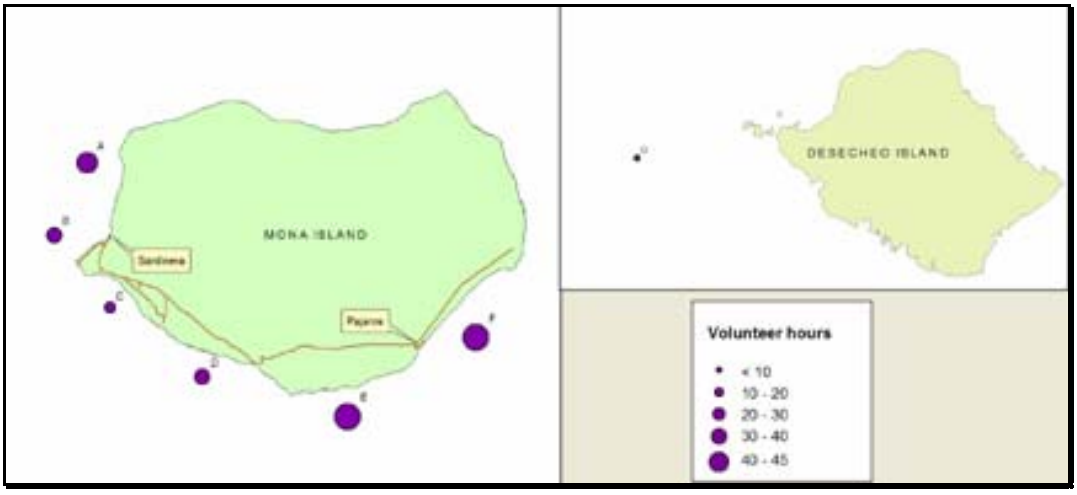

Figure 7. Distribution of effort during surveys by region.

Table 3. Areas surveyed and time invested in each by location.

ID	Location	Area (m^2)	volunteer hrs
A	Sardinera North	173930.0	35
B	Sardinera South	125748.2	23.6
C	Mujeres	19228.0	12.3
D	Carabinero-Uvero	40228.9	26.4
E	Caigo, Coco, Brava	105950.0	43
F	Pajaro	182194.0	43
G	Desecheo	56714.0	10

The amount of debris collected per volunteer hour provides a catch per unit effort (CPUE) estimate for the surveys. Kilograms of debris per unit hour of surveys ranged from 2.5 Kg/hour at Desecheo Island to 28.5 Kg/hour at surveys covering area E (Caigo, Cocos, Brava) on the southern shore of Mona Island. A summary of the CPUE is presented in Table 4.

Table 4. Catch per unit effort for all locations surveyed.

ID	Location	Kg/hour
A	Sardinera North	6.60
B	Sardinera South	25.42
C	Mujeres	6.08
D	Carabinero-Uvero	18.20
E	Caigo, Coco, Brava	28.49
F	Pajaro	13.92
G	Desecheo	2.53

The total amount of debris collected was 3,235 Kg during the Mona Channel Marine Debris Removal Project. Most debris by weight (38 %) was collected from region E which is the southern shore of Mona Island, while at Desecheo Island only 0.8 % of all debris was collected. Total weights of debris removed from the different regions are summarized in Table 5 and Figure 8.

Table 5. Total amounts of debris recovered from each location

ID	Location	Kg
A	Sardinera North	231.15
B	Sardinera South	599.9
C	Mujeres	74.79
D	Carabinero-Uvero	480.35
E	Caigo, Coco, Brava	1225.05
F	Pajaro	598.65
G	Desecheo	25.25
	Total	3235.14

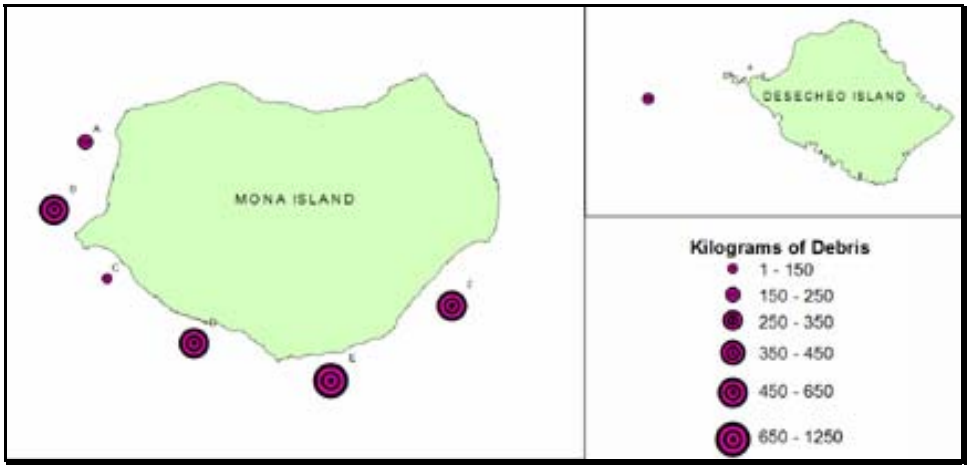

Figure 8. Amount and distribution of marine debris.

The density of debris measured as kilogram per meter squared ranged from 0.000445 kg/m^2 to 0.01194 kg/m^2 and was unequally distributed throughout the study area. For all surveys within the Mona Channel the mean density of debris was 0.0053 kg/m^2.

Table 6. Densities of debris recovered per area sampled.

ID	Location	Kg/m^2
A	Sardinera North	0.001329
B	Sardinera South	0.004771
C	Mujeres	0.00389
D	Carabinero-Uvero	0.01194
E	Caigo, Coco, Brava	0.011563
F	Pajaro	0.003286
G	Desecheo	0.000445

The classification of debris collected during the Mona Channel Marine Debris Removal Project was ranked for the whole island and the greater percentage is dominated by fishing gear by weight. The relative abundances of debris by type is presented in Figure 9. Fishing gear dominated in relative abundance during 4 of the 5 survey trips (Figure 10), except for the last trip to Pájaros where plastics dominated in relative weight.

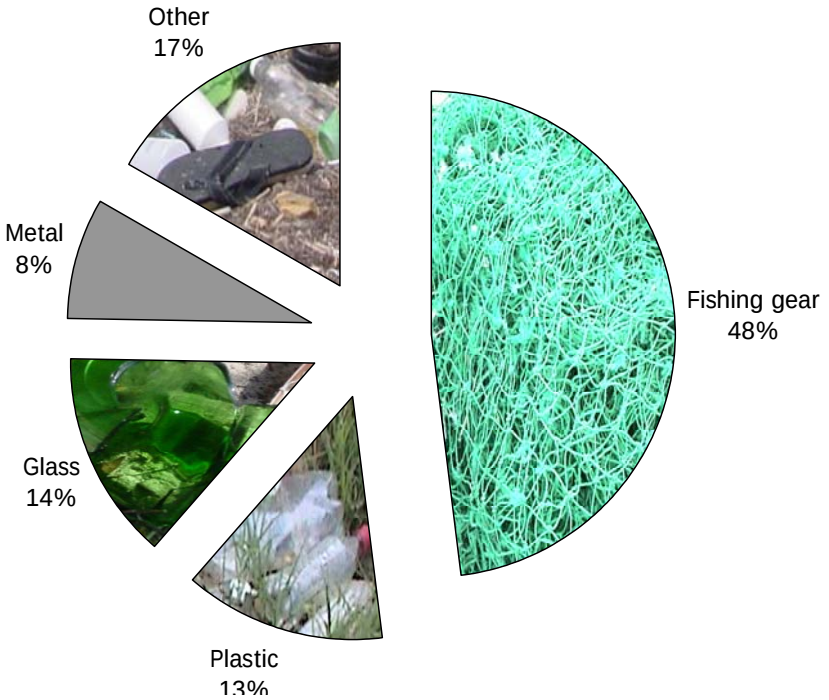

Figure 9. Proportion of debris types removed during Project.

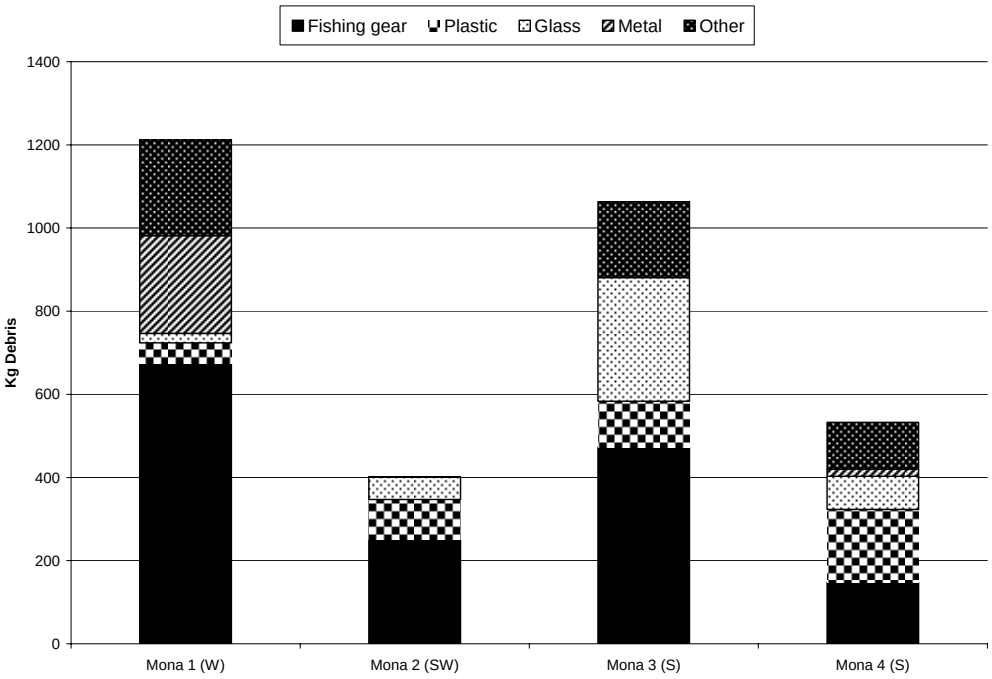

Figure 10. Types of debris removed per trip.

Debris items that were classified as fishing gear included ropes, nets and fishing line. Plastic debris was made up of bottles (water, soft drink, oil, detergents and household chemicals), toys, buckets, crates and others. Glass bottles and light bulbs made up most of the glass collected while metal objecs such as anchors, airplane parts, vessel debris and chains composed the metal classification. A varied group of smaller items made up the classification of other, such as clothes, shoes, fishing light sticks, buoys, refrigerators, washing machine casings, car tires, vessel pieces, rubber vessel, balloons, garbage and other plastic bags and many other items. Total weights of each debris type are summarized by trip in Table 7. Images of some of these items are presented in Appendix 4.

Table 7. Total weights per debris type removed during the Mona Channel Marine Debris Removal Project

Location	Fishing gear	Plastic	Glass	Metal	Other
Mona 1	673.55	50.49	22.3	235.35	230.5
Mona 2	250	96.9	53.75	0	1.1
Mona 3	472.3	111	297.6	0	182.4
Mona 4	148.45	174.85	79.4	16.9	113.05
Desecheo 1	6.5	0	0	7	11.75

IMPACTS

Most debris found on beaches was not observed damaging the habitat although endangered species of sea turtle (*E. imbricata)* were found trapped behind bamboo and wooden logs which interrupted their access to the sea. 26 hatchlings were rescued from the hollow insides of bamboos and released to the ocean during late afternoon hours. Other wildlife impacted on beaches was small hermit crabs that entered glass or clear plastic bottles where they were trapped and killed.

Underwater the impacts were more commonly observed on live coral colonies *Acropora palmata* (92%), *Diploria strigosa* and *Montastrea annularis*. On 25 occasions, debris (mainly nets and ropes) was removed from live coral, which was partially or completely dead from rubbing of debris on coral tissue (see Appendix 5). Upon debris removal branches of *A. palmata* seemed pale or bleached if not dead and overgrown by pink calcareous sheet algae. A summary of each coral affected by debris and the type of debris is presented in Appendix 6. The distribution of corals affected by marine debris seems to be patchy and was concentrated in areas on the southern coast of Mona Island (Figure 11). Three of these colonies were tagged with plastic cable ties to be able to monitor the growth of coral tissue over areas that were killed by debris.

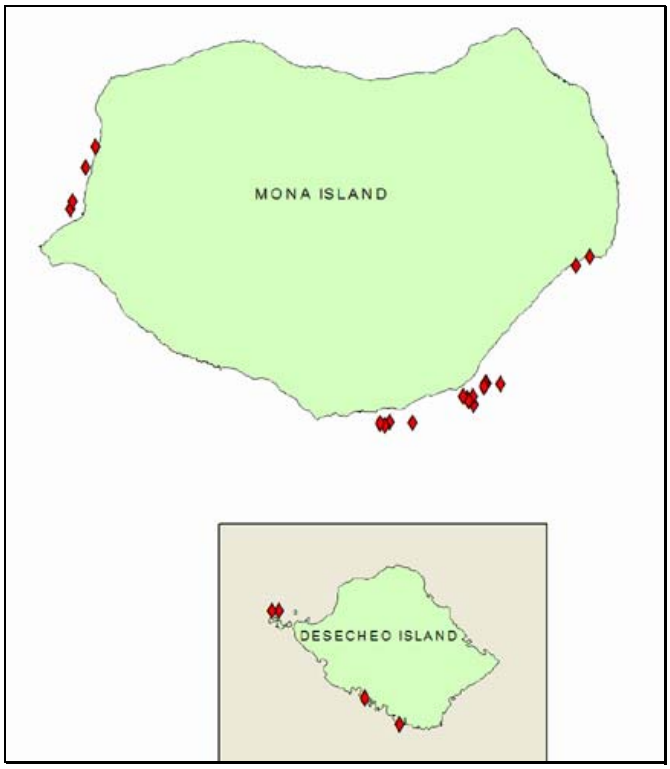

Figure 11. Distribution of debris impacting live coral colonies.

EDUCATION

As part of this proposal an educational campaign has been initiated to help create awareness of the importance of the marine life of this area and the threats that they encounter at sea. A conservation guide for the marine life of the Mona Channel has been produced. This 11X17 four-fold full color brochure was elaborated with the help of Amigos de Amoná, Sea Grant and DNER personnel. The guide includes a brief introduction as to the nature of the brochure on the cover page. Inside the brochure gives information on marine life in the Mona Channel, coral reefs and their importance, fish and their role in the ecosystem, marine debris and pollution, hints for snorkelers and divers and a brief description of the marine reserve principle. The inner portion of the brochure includes tips for boaters on the ways they can help prevent impacts on coral reefs and other benthic ecosystems as well as how to properly tie up to mooring buoys. There are also three maps indicating marine protected areas in the Mona Channel, approximate buoy locations and coral reef distributions within these areas. This brochure will be reproduced in Spanish for local users and will be distributed on site to users and will be laminated and mounted at the nautical facilities that serve vessels that use the Mona Channel. It is expected to produce 1500 brochures for distribution and approximately 1000 posters with the marine debris artwork produced by a local artisan.

DISCUSSION

The main goal of this project was to reduce the impacts of marine debris on coral reefs and other critical habitats essential to marine biodiversity. In assessing the amount and type of debris recovered there are clear indications of the seriousness of the threats this debris presents. The sources and types of debris are presented in Figures 9 and 10, where we see that 48% of the total weight is from fishing gear. The magnitude of the threat is proportional to the amount of this type of debris removed. Thus 48% of the debris is of a type that poses a serious threat to entanglement and abrasion within the coral reef and beach habitats. The abundance of plastics is also cause for concern. It is the second most abundant type of debris with 13% of the total, but this number is misleading in that the amount of volume required for 430 kg of plastic is significant. With fishing gear far outweighing other types of debris and plastics running a distant second in weight (but not in volume), the threat to marine life is significant.

The most damage quantified was observed underwater on the coral reef. This can be anticipated from the amount and type of debris collected. Primarily the type of debris exacerbates the problem. Fishing nets and lines pose a serious threat to benthic organisms such as the branching corals that constitute a part of the reef crest in Caribbean coral reef ecosystems. It is here that most floating debris becomes entangled and accumulates. Additionally larger sections of nets that have sufficient weight can sink and become entangled in corals and other benthic organisms that inhabit both the shallow back reef and the deeper fore reef. Plastics contribute to this threat of entanglement and abrasion as well as creating an additional threat of ingestion by larger pelagic organisms such as sea turtles and seabirds. Debris that does not become entangled in the reef system poses a threat to those organisms that exist in the rocky shores or utilize the beach for completion of their life cycle such as epilithic molluscan and sponge species as well as fish, sea birds and sea turtles.

In quantifying the impacts of debris on the beach it remained relatively undamaged but the accumulation of debris hindered the movements of sea turtle hatchlings (Figure 11 in Appendix 2). Mona Island has sandy beaches (7.2 km) that support one of the largest hawksbill sea turtle (*Eretmochelys imbricata*) nesting rookeries (see Appendix 2) in the Caribbean and has been identified as Critical Habitat for the species. Three nautical miles surrounding Mona and Monito are also considered Critical Habitat (Figure 2) for hawksbills (*E. imbricata)* due to the large numbers that have been tagged in the area. Juvenile and adult hawksbill (*E. imbricata)* and green (*Chelonia mydas)* turtles are commonly observed underwater and at the surface. The accumulation of bamboo, which does not occur on the Mona Channel Islands, and wood, most often from anthropogenic rather than natural sources, creates a significant hazard to sea turtle hatchlings. The hatchlings become trapped behind the debris and die before reaching the water. Thus the accumulation of organic debris in their critical habitat is also a cause for concern in the management of these species.

The anthropogenic origin of the debris complicates the problem further in that it is seemingly endless. The progression of ideas that prompted this investigation began with the recurrent accumulation of debris in areas that were previously cleared by volunteer groups. This and anecdotal information regarding debris entangled in the reef suggested that despite the remote nature of the Mona Channel Islands, they were subject to continuous stresses from

anthropogenic sources. Thus an educational brochure, focused on informing the primary users of the Mona Channel Islands, was an integral part of this project. They are the first line of defense in support of the conservation measures for these areas. The amounts and types of debris removed are unlikely to come exclusively from the recreational users of the Mona Channel Islands, therefore additional targets of the educational campaign were the coastal communities of western Puerto Rico where much of the debris is suspected of entering the marine system. The debris encountered at Desecheo Island did not amount to much (< 0.01%) of all debris recovered, therefore it was decided that it was not cost efficient to perform a second trip to this area, instead more effort was employed in the educational campaign.

The objectives of the Mona Channel Marine Debris Removal Project included the following:

- Identification of the type, density and distribution of debris in the Mona Channel
- Removal of marine debris from coral reef and beach habitats of the Mona Channel Islands
- Quantification of the species and habitats impacted by marine debris
- Damage assessment of coral reef organisms impacted
- Create educational materials for a marine life awareness campaign

These objectives were met and information was gathered that could be utilized by marine resource managers to manage for the sources and impacts of marine debris. The educational campaign is expected to have a significant impact on the Mona Channel users and on the general public on the west coast of Puerto Rico where the materials are to be distributed. We hope that this heightened environmental awareness will lead to a better informed public that will support the conservation of the marine resources in the Mona Channel Islands.

RECOMMENDATIONS

Investigators can elucidate the sources of debris by examining the temporal and spatial scales initiated with this project. We propose that continuing investigations of the sources and impacts of the different types of debris should be determined in order to be able to gauge the importance of this threat in comparison to other problems affecting marine resources. A greater understanding of the factors controlling the distribution and dispersion of debris and the impacts of its deposition on coastal habitats will provide better ways to manage the sources and minimize the impacts on marine ecosystems.

Fishing gear presents origins of commercial (trawl, long line and purse seine gears) as well as small-scale artisanal and recreational fisheries. Creating awareness within the fishing communities to the impacts of discarded fishing gear should be a continuing priority in the management of these impacts. Plastics and most of the floating debris classified as 'others' are suspected as originating in areas distant from the clean-up site such as the west coast of Puerto Rico. By managing for these sources, the amount of the debris from these origins can be reduced.

The management of debris originating from the west coast of Puerto Rico should focus on creating awareness with regards to the end result of waste disposal within the hydrologic regime of this area. By focusing awareness on 'where the water (and debris) goes', resource users can become aware of the impacts of waste disposal into rivers, roads and storm drains which have drainage basins that empty into the easterly currents that carry debris to the Mona Channel Islands. Additionally storm water runoff from urban areas can be addressed within the context of a 'where the water goes' educational campaign. By focusing on the source of the marine debris, management can minimize impacts and thus mitigations efforts such as beach and reef clean ups which can be time consuming and costly without the benefit of conservation groups and volunteers.

We propose that management continue to take advantage of the impetus of volunteer groups like Amigos de Amoná, Inc. in order to continue monitoring the distribution and abundance of marine debris in the Mona Channel Islands. By promoting beach clean-ups resource users can gain first hand experience in the threats to the marine environment posed by marine debris. Additionally both beach and coral reef should be monitored for success of mitigation efforts, including the recovery of coral colonies from entanglement and abrasion. Monitoring of recovery from these mitigation measures is essential in determining the efficacy of the mitigation effort involved.

An additional threat that requires attention from management efforts is the accumulation of organic debris on the beach areas on Mona Island that is critical habitat for nesting sea turtles. This accumulation of debris can be fatal to hatchlings that are unable to reach the water. This was in evidence during this project in which 26 hatchlings were found lodged behind such an accumulation (Figure 11, Appendix 2). Thus management is compelled to mitigate for this problem by dealing with the accumulation as well as the source if possible. Due to the threat posed by organic debris (bamboo and wood) these should be included in future habitat restoration programs at sea turtle nesting beaches.

This baseline study provides a reference point for future studies and the spatial and temporal distribution of debris can be further investigated to elucidate sources and magnitude of impacts. Monitoring the recovery of coral colonies after debris removal will be an important potential benefit that will determine if mitigation efforts are worthwhile. Additionally education and outreach can further the goals of management by making resource users and abusers aware of the impacts of their actions. The Mona Channel Marine Debris Removal Project provides an assessment of the impact of debris on Puerto Rican coral reefs, which are currently the focus of various local (Commonwealth of Puerto Rico) and regional (U.S. Coral Reef Task Force) strategies to prioritize conservation measures in face of different threats. Additionally the Mona Channel Islands are the focus of a series of marine conservation measures that include marine reserves and gear restrictions. Thus reduction of marine debris can further the conservation efforts and will contribute to their preservation.

LITERATURE CITED

Chiappone, M., A. White, D. Swanson and S. Miller, 2002. Occurrence and biological impacts of fishing gear and other marine debris in the Florida Keys. Marine Pollution Bulletin 44: 597-604.

Derraik, J., 2002. The pollution of the marine environment by plastic debris: a review. Marine Pollution Bulletin 44: 842-852.

Donohue, M., R. C. Boland, C. M. Sramek, and G. A. Antonelis, 2001. Derelict Fishing Gear in the Northwestern Hawaiian Islands: Diving Surveys and Debris Removal in 1999 Confirm Threat to Coral Reef. Marine Pollution Bulletin 42:1301-1312.

Nagelkerken, I., G. Wiltjer, A. Debrot and L. Pors, 2001. Baseline study of submerged marine debris at Beaches Curacao, West Indies. Marine Pollution Bulletin 42:786-789.

Perl, H. & G. Cintrón. 1974. Preliminary findings: Nearshore surface currents in the vicinity of Sardinera and Uvero, Mona Island: 73-80. Primer Simposio de Recursos Naturales. Departamento de Recursos Naturales y Ambientales, San Juan, Puerto Rico.

Cintrón, G., J. Thurston, J. Williams & F. Mackenzie. 1975. Características de la plataforma insular de Isla de Mona. 69-91. Segundo Simposio de Recursos Naturales. Departamento de Recursos Naturales y Ambientales, San Juan, Puerto Rico.

Appendix 1. Images of Mona Channel Islands

Figure 12. Monito Island, important sea bird nesting area.

Figure 15. Sardinera Beach camping area on the western shore of Mona Island.

Figure 13. Sandy Beaches and Cliff Walls of southern shore of Mona Island.

Figure 16. Aerial view of Desecheo Island's southern coastline.

Figure 14. Pajaro Beach camping area and distant Lirio Limestone cliff wall on the eastern shore of Mona Island.

Figure 17. Exposed rocks on western side of Desecheo Island with sea bird loafing areas.

Appendix 2. Images of Mona Channel Island Species

Figure 18. Rock Iguana, endemic species only found at Mona Island.

Figure 19. Brown booby (*Sula* sp.) died by entanglement on roost by rope on feet, Monito Island, Photo E. Figueroa

Figure 20. Hawksbill sea turtle hatchling (*Eretmochelys imbricata*).

Figure 21. Hawksbill sea turtle juvenile (*Eretmochelys imbricata*).

Figure 22. Hawksbill sea turtle hatchlings (*Eretmochelys imbricata*) entrapped by bamboo on Cocos Beach, Mona.

Figure 23. Reef building elkhorn coral (*Acropora palmata*).

Appendix 3. Images of Mona Channel Island Marine Debris Project Volunteers

Figure 24. Volunteers pick up debris, Pájaros Beach, Mona.

Figure 25. Volunteers sorting debris as it is collected, Cocos Beach, Mona.

Figure 26. Volunteers carrying debris to transport it to main camp.

Figure 27. Chain of volunteers loading smaller vessel to transport debris in larger vessel "Orca Too" in the distance.

Figure 28. Volunteer removing net from elkhorn coral (*Acropora palmata*) at Mona.

Appendix 3 (continued). Images of Mona Channel Island Marine Debris Project Volunteers.

Figure 29. Volunteers with Hauser rope found in Sardinera Beach backreef area.

Figure 30. Volunteers weighing debris at Sardinera Beach, Mona Island.

Figure 31. Loading transport vessel “Orca Too” at Pájaros Beach pier for return trip to Puerto Rico.

Figure 32. Transport vessel at Pajaro Pier, Mona.

Figure 33. Arrival at Boquerón where Cabo Rojo Recycling Office Personnel loaded truck.

Appendix 4. Images of Mona Channel Island Marine Debris Items

Figure 34. Aluminum parts from an airplane wreck removed from Mujeres Beach, Mona.

Figure 37. Plastic debris removed from reef areas of Mona Island include a clear balloon and plastic bags.

Figure 35. Fiberglass from refugee vessel removed from Carmelitas lagoon, Mona.

Figure 38. Fish trap lines and attached buoys classified as fishing gear.

Figure 36. Ropes and nets on Pajaros Beach, Mona.

Figure 39. Green polypropylene fiber nets that were most commonly removed, foam insulated water heater box on top, Sardinera, Mona.

Appendix 5. Images of Mona Channel Island Marine Debris Project Impacts on habitat

Figure 40. *Acropora palmata* colony affected by net at Sardinera forereef, Mona.

Figure 41. Vessel fiberglass pieces on *Montastrea annularis* Sardinera Beach backreef, Mona.

Figure 42. Vessel fiberglass pieces on *Montastrea annularis* Sardinera Beach backreef, Mona.

Figure 43. *Acropora palmata* colony affected by net Pajaro Lagoon, Mona (Mar, 2004).

Figure 44. *Acropora palmata* colony affected by net Pajaro Lagoon, Mona (Mar, 2004).

Figure 45. *Acropora palmata* colony affected by net Fortuna Reefer, Mona (May, 2003) Foto by A. Bruckner.

Appendix 5 (continued). Images of Mona Channel Island Marine Debris Project Impacts on habitat

Figure 46. Close up of *Acropora palmata* colony affected by net Fortuna Reefer, Mona (May, 2003). Foto by A. Bruckner.

Figure 47. Net removal from *Acropora palmata* colony affected at Fortuna Reefer, Mona (May, 2003).

Figure 48. *Acropora palmata* colony affected by net Fortuna Reefer, Mona (May, 2003).

Figure 49. *Acropora palmata* colony affected by net, Desecheo Island (September, 2003).

Figure 50. *Acropora palmata* colony affected by net, Desecheo Island (September, 2003).

Appendix 5 (continued). Images of Mona Channel Island Marine Debris Project Impacts on habitat

Figure 51. *Acropora palmata* colony affected by fishing line at Desecheo Island (September, 2003).

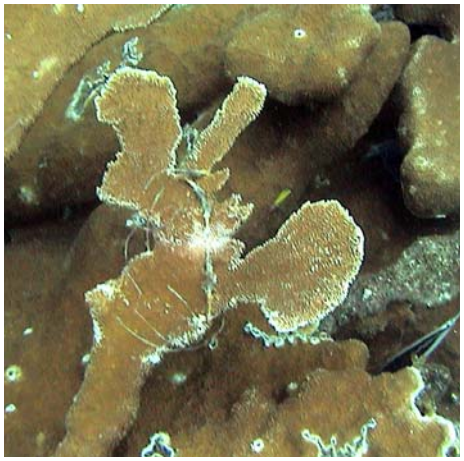

Figure 52. *Acropora palmata* colony affected by fishing line at Desecheo Island (September, 2003).

Appendix 6. Mona Channel Island Marine Debris on Corals

#	Date	Site	Spp.	Lat. (N)	Lon. (W)	Debris
1	29-May-03	Sardinera Pasa	*A. palmata*	18.09016	-67.94034	Net
2	5/329/2003	N. Sardinera Pasa	*A. palmata*	18.09150	-67.93999	Net
3	29-May-03	N.Sardinera	*A. palmata*	18.09750	-67.93764	Rope
4	29-May-03	Carmelitas Lagoon	*A. palmata*	18.10107	-67.93597	Net
5	20-May-03	Fortuna Reefer	*A. palmata*	18.05560	-67.86912	Net
6	1-Aug-03	Fortuna Reefer (S)	*A. palmata*	18.05000	-67.86900	Net
7	9-Sep-03	Desecheo SW	*A. palmata*	18.37802	-67.47979	Rope
8	9-Sep-03	Desecheo SW	*A. palmata*	18.37964	-67.48230	Net
9	9-Sep-03	Desecheo NW	*A. palmata*	18.38564	-67.48855	Anchor & Line
10	9-Sep-03	Desecheo NW	*A. palmata*	18.38565	-67.48904	Fishing Line
11	3-Oct-03	Mona	*A. palmata*	18.05227	-67.87984	Plastic
12	3-Oct-03	Mona	*A. palmata*	18.05244	-67.88386	Net
13	3-Oct-03	Mona	*A. palmata*	18.05183	-67.88476	Net
14	3-Oct-03	Mona	*A. palmata*	18.05214	-67.88560	Net
15	4-Oct-03	Mona (S)	*D. strigosa*	18.05921	-67.86676	Rope
16	4-Oct-03	Mona (S)	*D. strigosa*	18.05926	-67.86694	Rope
17	4-Oct-03	Mona (S)	*A. palmata*	18.05929	-67.86703	Rope
18	4-Oct-03	Mona (S)	*A. palmata*	18.05863	-67.86721	Net
19	4-Oct-03	Mona (S)	*A. palmata*	18.05698	-67.86916	Plastic
20	4-Oct-03	Mona (S)	*A. palmata*	18.05654	-67.87022	Rope
21	4-Oct-03	Mona (S)	*A. palmata*	18.05622	-67.87000	Net
22	31-Oct-03	Mona (S)	*A. palmata*	18.05919	-67.86436	Plastic
23	31-Oct-03	Mona (S)	*A. palmata*	18.08012	-67.85094	Net
24	31-Oct-03	Mona (S)	*A. palmata*	18.08165	-67.84856	Fishing Line
25	21-Mar-04	Mona (S)	*A. palmata*	18.056919	-67.87097	Net