Managing Marine Corridors

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MANAGING MARINE CORRIDORS

This project report is submitted in partial fulfillment of the degree requirements of Worcester Polytechnic Institute. The views and opinions expressed herein are those of the authors and do not necessarily reflect the positions or opinions of the University of Puerto Rico or Worcester Polytechnic Institute.

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Abstract

Human activities have many harmful effects on marine ecosystems. The Fajardo area alone is home to seven marinas, over 40,000 boats, and many construction projects that damage marine environments around them. The goal of this project was to provide recommendations to minimize negative impacts on near shore marine corridors, defined as the interrelated, mangrove, seagrass, and coral reef habitats. To achieve this goal, we determined the major factors in marine corridor deterioration through interviews with fishermen, SCUBA divers, and members of the academic and scientific communities and analysis of fish catch data and remote sensing images. Using these data, we developed recommendations to alleviate impacts from land-based development, overfishing, and recreational overuse.

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Executive Summary

Puerto Rican marine corridors represent a diverse ecosystem composed of native seagrasses, mangroves, and coral reefs that are vital to marine life, providing shelter for juvenile fish populations and permanent homes to various other species of plants, fish, and aquatic life. Currently, the state of these areas is being continuously degraded by urban development, tourism, fishing, and pollution. While previously conducted studies have led to laws intended to protect the species in these vicinities, continued degradation threatens to disrupt these fragile ecosystems. This study aims to fill gaps in research by examining the social and scientific causes of this degradation and provides recommendations that will benefit not only marine life, but also the fishing and tourism industries that rely heavily on the health of this marine life.

Historically, marine corridor areas have been thought of and studied as three individual, unrelated, ecosystems consisting of coral reefs, mangroves, and seagrasses. While these habitats are all quite different, they all play similar and connected roles in the development of fish and other marine organisms from eggs to adults. Mangroves are defined as any of several tropical evergreen trees or shrubs of the genus *Rhizophora,* having stilt-like roots and stems, and forming dense thickets along tidal shores. They are vital in preventing erosion and runoff from the mainland. This runoff can directly affect coral reefs and seagrasses. Many of the fish living in mangroves and coral reefs are spawned by adult fish in seagrasses, which are dense reed clusters that provide shelter from larger predators. Coral reefs consist mainly of compacted coral with algal material and calcium. The species of fish that live on the reefs come from seagrasses and mangroves. These interconnections make it difficult to study the negative effects on

coral reefs, seagrasses, and mangroves individually, as they are all intricately tied together, and the degradation of one will have a negative impact on another.

The goal of our project was to determine the causes of marine corridor deterioration around Puerto Rico, and supply suggestions on how to decrease the severity of the problem. These recommendations focus on preservation of marine corridor areas, and the effects that this preservation will have on the local fishing and tourism industries. In order to obtain data relating to marine corridor health and degradation, we first examined fishermen's, diving companies', and locals' current practices and knowledge of the deterioration of the marine corridors. Through communication with local fishermen and divers, we determined the human factors directly affecting marine ecosystems.

To establish the current state of marine corridors and the changes that have been made in their physical areas, we used remote sensing images obtained by our liaison from the government in Puerto Rico to qualitatively track factors such as development, sedimentation levels, numbers of marinas, and the physical areas of marine corridors from 1962 to 2004. This remote sensing analysis showed that while development and sedimentation levels were at high levels and steadily rising, the areas of reefs, seagrasses, and mangroves have decreased significantly. To examine the effects of these changes on the fish inhabiting these ecosystems, we compared these data with fish catch data provided to us by Graciela Garcia of the Caribbean Fisheries Management Council. These data showed a steadily downward trend in the average pounds of fish caught per year from the year 1983 to 2005 in four indicator species, the yellowtail snapper, queen conch, spiny lobster, and red hind. These data both showed, consistently, that not only are marine corridors decreasing, but the fish native to them are also on a steady decline.

With the intention of determining the causes behind the decrease in marine corridor areas, we interviewed professors, government officials, fishermen, and dive shop owners. The fishermen and divers provided specific information concerning changes in reefs and fish, as well as many causes of corridor deterioration. Among these data, the most significant factor was recreational boating, as anchor damage and lack of knowledge concerning the locations of marine corridors accounted for a considerable amount of mechanical destruction. Fishermen and dive shop owners were aware of the frailty of these ecosystems and the benefit to the fishing and diving industries that exists in the preservation of marine corridors. With the completion of interviews with members of the scientific and academic communities, as well as the Department of Natural and Environmental Resources, we were able to ascertain further information concerning land based sources of corridor deterioration.

Through our research in Puerto Rico, we obtained ample data regarding the state of marine corridors, and the factors that are negatively impacting marine corridors. This information was supported by data obtained from interviews, and we were able to understand the social reasons behind many of these damaging actions, ranging from ignorance to gaps in legislation and enforcement. To stem a majority of these problems, we developed a set of recommendations concentrating on education, enforcement, and recreational regulations and licensing. If followed, these recommendations will be a step in the right direction for the immediate and future protection of these vital and fragile ecosystems.

1 Introduction

Human beings regularly impact the environment and encroach on ecosystems all around the world through urban sprawl, industrialization, and their need for natural resources. Marine corridors are ecosystems encompassing coral reefs, seagrasses, and mangroves, and according to the Nature Conservancy, if improvements are not made, 70% of the coral reefs in the world will die by the year 2050 (*The Nature Conservancy*, 2006, New Hope for Coral Reefs). Although the careful balance of nature on land and in the sea is being disturbed, marine corridors are especially vulnerable because people do not realize the fragility of near shore ecosystems.

Specifically, near shore marine corridors around Puerto Rico are becoming unhealthy. Coral reefs, seagrasses, and mangroves are an important part of the Puerto Rican appeal as a tourist destination but also provide countless benefits to the natural environment (*U.S. Coral Reef Task Force,* 2006, Why care about Coral Reefs?). In many areas around Puerto Rico, developers are building large hotels, apartment complexes, and marinas. Unfortunately, all of these construction projects are causing a large amount of sedimentation runoff into the ocean, which kills corals and forces bottom-dwelling creatures such as the queen conch to move into deeper waters. Recreational boating and overfishing have also had detrimental affects on these ecosystems. With all of these factors combined, the marine corridors of Puerto Rico will continue to degrade if no efforts are made to prevent these damages.

Basic research had determined how a balanced marine ecosystem functions and how its disturbance would affect the area around it. Studies conducted in other areas of the world, such as the marine corridors in Belize and the Great Barrier Reef, concerning

the health of and damage to coral reefs and mangroves did not encompass all three habitats and their interconnections. While many studies have been done concerning problems in coral reefs, few exist that concentrate on seagrasses or mangroves. In addition, we found only one article about research done in the Caribbean that brings into consideration the connection between the three habitats and names the entire ecosystem a marine corridor.

The use of the term marine corridor is not widespread, and because of a lack of understanding of the interdependence between coral reefs, seagrasses, and mangroves, people were and still are often careless about the areas that are not as visually appealing, like mangroves or seagrasses. The unstudied relationship between the marine corridor ecosystems and the actions of fishermen indicated to our project sponsor at the University of Puerto Rico – Rio Piedras a possibility of increasing near shore protection by proving the existence of a connection among the health of the three habitats and the levels of fishing in the area. We assumed that the area coverage of marine corridors was directly related to the fish populations, and by doing a simple comparison of the two over time, we would be able to inform people of the harm they were causing through their actions. The University of Puerto Rico wanted to determine how people's attitudes and actions may change with their knowledge of a problem and to discover if people in Puerto Rico, especially fishermen, divers, and SCUBA guides, realize that they may be impacting marine corridors and how they are doing so and whether this information would lead to changes in their behavior.

As a result, our project goal was to provide recommendations for the continued preservation of marine corridor ecosystems. In order to achieve this goal, we had to

complete certain objectives. First, we needed to establish the association between fish catch trends and marine corridor health over the past twenty years to determine the specifics of the problem and to show fishermen hard data on how they have affected marine corridors. Next, it was important that we evaluate fishermen's and SCUBA dive masters' adherence to current preservation regulations and their knowledge of both the health of and connection between the different marine corridor habitats. Armed with the results of those objectives, we would be able to achieve our goal of providing worthwhile and acceptable recommendations for marine corridor preservation. The University of Puerto Rico and other government agencies will be able to use these recommendations in protecting marine corridors and educating communities on the importance and interconnection of habitats within this ecosystem.

2 Background and Literature Review

This chapter introduces the biology of marine corridors, the impact of human activities on these ecosystems, and the social factors that may be causing these impacts. This literature review will provide the background necessary to determine the connection and balance among coral reefs, sea grasses, and mangroves, and their association with outside factors, and it also discusses the research that has already been done and establishes gaps in that information in order to create a well planned methodology for achieving our goal.

2.1 Tragedy of the Commons

In contrast to many resources like petroleum or coal, which can be harvested and used by single persons or companies, natural environments can easily be used by anyone encountering them; this leads to overexploitation (Hardin, 1968, pp. 1243-1247). A good example of this is a small farming village from the 18th century, where there was one field set aside for anyone to let their cattle graze. The farmers figured out that the more cattle they put in this field, the more cattle they could raise and sell. However, once everyone started doing this, the quality of the field was quickly degraded and became unable to sustain any cattle, hence the term, "Tragedy of the Commons." This concept can easily be applied to marine ecosystems with the overexploitation of both their valuable resources and inhabitants, which we will be exploring throughout this chapter.

2.2 Marine Corridors

Ecological corridors are defined as "…avenues along which wide-ranging animals can travel, plants can propagate, genetic interchange can occur, populations can move in response to environmental changes and natural disasters, and threatened species can be replenished from other areas" (Good, 1998, p. 10). Specifically, marine corridors consist of mangroves, coral reefs, and seagrass beds. The health of these areas is vital for the well-being of thousands of marine plant and animal species. Below is a description of the role of each zone in maintaining a healthy ecosystem.

2.2.1 Mangroves

Puerto Rico has approximately 73 square kilometers of mangroves, which are defined as any of several tropical evergreen trees or shrubs of the genus *Rhizophora,* having stilt-like roots and stems, and forming dense thickets along tidal shores (The American Heritage Dictionary of the English Language, 2000). Mangroves, shown in Figure 2-1, are essential to the marine corridor ecosystem, as these forests help to prevent erosion and runoff from the mainland, which can pollute, cover up, and ultimately kill coral (Burke, 2004, pp. 1-2). The root systems of these mangroves also leave few open spaces, making it difficult for larger fish and predators to occupy these areas and making mangroves an ideal habitat for many

Figure 2-1 - Mangrove Roots (Atlantis Bonaire, 2006)

species of fish in their juvenile stage. A study on the Caribbean rainbow parrotfish in the Caribbean Sea near Aruba helps to prove this phenomenon (Dorenbosch, 2005, pp. 1-4). This species was observed to live only in mangroves and coral reefs, utilizing the protection they provide. Fish residing in the mangroves were all less than thirty centimeters long, whereas individuals in the coral reefs were exclusively twenty-five centimeters or longer, hence the rainbow parrotfish spends its life as a juvenile in mangroves and adulthood in coral reefs.

2.2.2 Seagrasses

Considering Puerto Rico's expansive 721 square kilometers of seagrass beds (See Figure 2-2), it is clear that they are also an important aspect of the marine corridor ecosystem. Many fish choose these areas as their spawning grounds. A visual fish census of the humphead wrasse was done in the Indian Ocean off the coast of Tanzania to provide evidence of this fact (Dorenbosch, 2005, pp. 1-4). The only environments this species is found in are seagrass beds and coral reefs. All individuals found in the seagrasses were less than 27.5 centimeters in length, and 75% occupying the coral reefs were longer than 27.5 centimeters. These data illustrate that the juvenile humphead

Figure 2-2 - Seagrasses (Harmelin, 2006)

wrasse remains in seagrass beds until it is large enough to move into the coral reefs for adulthood.

Seagrasses are also important feeding grounds for many species including the queen conch, sea turtle, parrotfish, pinfish, and sea urchin. Although not all of these are directly harvested by the fishing communities, all are important to the marine corridor ecosystem as a whole and any decreases in these populations would affect the industry through primary or secondary effects. A significant population decrease in any species would have direct effects on the fragile ecosystem. For instance, overfishing of one species could result in deaths of that species' predators in addition to an increase in their prey. This increase could then affect other species, resulting in a chain effect throughout the ecosystem.

2.2.3 Coral Reefs

A coral reef is an erosion-resistant marine ridge or mound consisting chiefly of compacted coral together with algal material and biochemically deposited magnesium and calcium carbonates (The American Heritage Dictionary of the English Language, 2000) (See Figure 2-3). Reefs are formed as a result of a symbiotic relationship between a coral polyp and photosynthetic algae (CoRIS, 2004b). A coral polyp is a sea animal with stinging tentacles and a

Figure 2-3 - Coral Reef (Ove Hoegh-Guldberg, 2006)

stomach to digest plankton and provide nutrients to the algae, which in turn lives within the polyp and provides the sugar products of photosynthesis. Over time, the polyp skeletons build up to create a reef. The natural evolution of Puerto Rico's environment has carried out this process and manages to sustain over 1600 square kilometers of coral reefs.

"Coral reefs are invaluable for their riches in biodiversity and essential resources for the sustainable livelihoods of many coastal communities" (Wilkinson, 2004, p. 4). The reefs produce a variety of commercial chemicals, reduce shore erosion, provide a home for many plant and animal species, and allow communities to benefit from the tourism that they attract. Activities such as scuba diving, snorkeling, and fishing are all popular coral reef activities.

Unfortunately, the reefs are the most sensitive of the three marine corridor environments to both natural and anthropogenic events. Currently, it is estimated that 10% of the world's coral reefs are completely destroyed (CoRIS, 2004a). Thirty percent are in critical condition, and there are predictions of up to 60% being killed by the year 2050 if these trends continue.

Puerto Rico is not immune to these trends of coral reef deterioration. Two species in particular are becoming close to endangerment – staghorn and elkhorn coral, both of which have large, branching, antler-like structures (Wilkinson, 2004, p. 4). Hurricanes and white-band disease (a tissue peeling ailment with unknown causes) are the main culprits for this deterioration, but many other factors including fishing, tourism, development, pollution, and other harmful natural factors make the situation even worse.

2.3 Fishing

The gradual deterioration of coastal marine corridors is due in part to the fishing industry of Puerto Rico. There are several attributes of the fishing industry that are continually having a negative impact including fishing tackle and gear, lack of regulations, and poor enforcement of laws.

2.3.1 Puerto Rican Fishermen

Fishing is a common activity for the people of Puerto Rico. Fishermen may do so either recreationally, commercially, or for their own subsistence.

As of 2001, there were over 222,000 recreational fishermen in Puerto Rico (Caribbean Fishery Management Council, [CFMC], 2005). The types of recreational fishing include shoreline based angling, charter boat fishing, and fishing from a private boat. Most of that fishing is performed in nursery grounds where juveniles of species reside.

The number of commercial fishermen has been on the rise; in 1996, there were an estimated 1,758 active commercial fishermen (1,262 full-time and 496 part-time), which increased to 1,973 fisherman in 2000 and 2,023 in 2001 (CFMC, 2005).

The increased number of fishermen has created a concern regarding over-fishing in the area (CFMC, 2005). The Heinz Center Report (2000) on roundtable discussions for improving federal fisheries management called for enhanced social science research. It recommended more proactive use of social and economic information in the fishery management process and placed emphasis on the need for long-term research to collect information on community infrastructure, how fishers learn and produce knowledge,

cultural perceptions and politics, socioeconomic development of fishing communities, gender issues, fishery histories, ethnic composition and background of fishery participants, rules and regulations, and systems of jurisdiction and conflicts. The panel also encouraged the idea of getting fishers to participate more extensively in the data collection and assessment process rather than using surveys. As a result of all this, the panel decided that Puerto Rico needed a commercial and recreational fisheries socioeconomic research program.

2.3.2 Marine Species

There are a plethora of marine species in the waters surrounding Puerto Rico. When studying the correlation of the health of marine corridors to marine species, it is sufficient to concentrate on several indicator species. According to Graciela Garcia of the Caribbean Fishery Management Council, four for common inhabitants of marine corridors that will represent trends in other fish populations in Puerto Rico are the Caribbean spiny lobster, queen conch, yellowtail snapper, and red hind. Throughout their lifetime, these species inhabit and migrate between seagrasses, mangroves, or coral reefs. By studying these indicator specific species and their migration trends, it is possible to make assumptions

Figure 2-4 - Caribbean Spiny Lobster (ReefNews, 2001)

about the overall health of the marine ecosystem.

The Caribbean spiny lobster (*Panulirus argus*) (See Figure 2-4) is "taken in commercial, subsistence, and recreational fisheries" (CFMC, 2005, p. 96) and is found in the "extreme shallows of the littoral fringe to depths of at least 100 meters" (CFMC, 2005, p. 96). Its distribution off Puerto Rico extends to the edge of the shelf (100-fathom contour/183 meters) (See Figure 2-5).

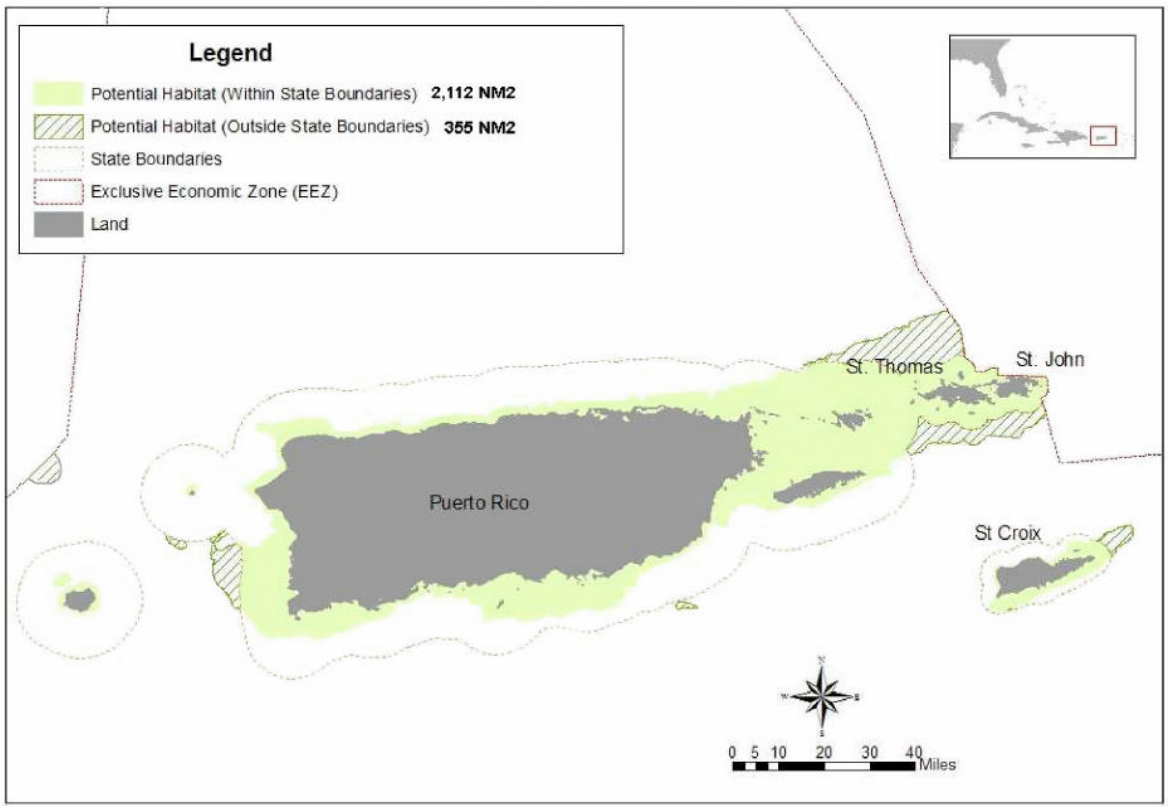

Figure 2-5 - Contour Map (Caribbean Fishery Management Council, 2005)

"Embryos hatch as planktonic larvae, which spend up to eleven months or more at sea before metamorphosing into the puerulus stage and settling on the bottom" (CFMC, 2005, p. 97). Juveniles take refuge in mangroves and seagrasses and move offshore when they reach reproductive size.

Maturity occurs after a single molt, called the "maturity molt." Females reach sexual maturity at a size of 3.1-3.5 inches in carapace length and reach peak egg production between 4.3-5 inches in carapace length. In general, the size of a female and the amount of eggs produced are directly related. Egg production eventually begins to decrease when molting becomes less frequent during females' late teens. Spawning occurs at least once a year, most frequently in the months of February to August and least frequently in the fall. After eggs are externally fertilized, females carry the eggs until they are fully developed. After this period of four weeks of development, females move to deeper waters when the eggs are ready to hatch. Adults then find shelter in shelf areas in holes and crevices of reefs.

Queen conch (See Figure 2-6), *Strombus gigas*, is taken in both commercial and recreational fisheries. Fishermen commonly find this species on the shelf to about 76 meters (250 feet) deep or "on gravel, coral rubble, smooth hard coral or beach rock bottoms, and sandy algal beds" (CFMC, 2005, p. 99).

Figure 2-6 - Queen Conch (Aventuras Vacacionales, 2006)

Queen conch eggs are "usually deposited in clean coral sand with low organic content; but sometimes also in seagrass habitat" (CFMC, 2005, p. 99). After a period of two to three weeks in a planktonic stage, a year of development is spent in shallow waters, grazing on seagrasses and buried in sediment. At shell length of 50 to 100 millimeters, "some studies have documented a habitat shift at the time of emergence, from the area of settlement into

nearby seagrass beds" (CFMC, 2005, p. 100). After reaching maturity at about 2.5-3 years, their first reproductive cycle occurs at age 3-4 years during the month of July. If left uncaught, the queen conch lives between 6-7 years, measuring 6-12 inches in length and around 4.4 pounds.

Yellowtail snapper (*Ocyurus chrysurus*) (See Figure 2-7) generally is targeted by commercial and recreational fishermen in areas well above the bottom in areas around 180 meters deep (CFMC, 2005). Juveniles inhabit seagrass beds and as they age, move into shallow reefs. By adulthood, schooling yellowtail snappers migrate to deeper reefs. Once sexual maturity is reached at four years of age (around 42.5 centimeters), spawning occurs in offshore waters during the full moon in the months of February to October, peaking from April to July. Yellowtail snapper spawn until their maximum age of 14 years.

Figure 2-7 - Yellow Tail Snapper (Rosenstein, 2005)

The red hind, *Epinephelus guttatus* (See Figure 2-8), is caught mainly by commercial and recreational fisheries using hook and line and spearing by divers.

Figure 2-8 - Red Hind (ReefNews, 1998)

Once mature at 5.5 years, corresponding to a size of around 31.4 centimeters, "This species aggregates in large numbers during the spawning season" (CFMC, 2005, p. 165). Aggregation generally occurs from January to March in association with the full moon. Puerto Rico has three documented spawning sites (20-30 meters in depth) off of the western coast, along with a fourth near the shelf edge off the southwest coast. The red hind is a protogynous hermaphrodite and sex reversal occurs at a mean size of 35 centimeters. "Most fish larger than 40 centimeters are males, which is important in terms of numbers caught and total weight of landings in the Caribbean" (CFMC, 2005, p. 164). Until red hind reach their approximate life span of 23.8 years, adults inhabit shallow reefs and rocky bottoms in a range from 2-100 meters deep.

2.3.3 Fishing Techniques

Over the past few years, Puerto Rican fishermen have used a variety of fishing techniques and gear (CFMC, 2004). In shallow-water reef fisheries, most commercial fishing takes place at depths of 18 to 27 meters by hand-line fishermen in outboard-powered vessels with sizes of less than six meters in length. However, mutton snapper has been caught in this area via use of fish traps and gill nets. Deep-water reef fishers generally use heavy-duty traps and bottom long-lines using electronically powered reels.

As of 2003, commercial sales of all fish and shellfish sold in Puerto Rico have been divided amongst cast nets (0.3%), diving (22.6%), nets (9.5%), pots (27.7%), rod and reel (36.9%), seines (1.7%), and vertical lines (1.2%) (Cummings & Matos-Caraballo, 2004, p. 51).

Fishermen use several designated zones. The percentage of fishing that occurs within each zone is distributed according to the following: shoreline (31%), continental

shelf (70%), shelf edge (43%), and beyond the shelf (46%) (CFMC, 2005). The sum of these percentages is greater than 100% because most fishermen fish in more than one area.

Traps and pots are the most likely to damage fish habitat, specifically coral. The trap lines connecting traps and pots cause damage by sweeping across fragile vertical coral and gorgonian structures (CFMC, 2004). Further damage is caused when traps are lost or when buoys are not attached to traps. Additionally, traps that are placed on top of submerged aquatic vegetation cause seagrass to die as a result of crushing and shading from sunlight. The effects of traps and pots have, however, been well studied. Solutions have been suggested to remedy this harmful effect such as storing the gear on land after each fishing trip. This will reduce the damage caused by unattended pots.

Gill and trammel nets have a negative impact on coral reef habitats. If either net becomes entangled with a reef, the coral will break during retrieval (CFMC, 2004). This damage is increased when mechanical net haulers are used. Entanglement is also a concern when scuba divers drive fish into nets with noise and disturbance tactics; occasionally they will pound on the coral to make the correct noise. The main problems that gill and trammel nets cause are due to their effects from ghost fishing; when nets are lost or disposed of in the ocean, they continue to damage marine life by a variety of effects such as entangling fish. Marine organisms quickly cover the nets and eventually the nets become incorporated into the reef.

Bottom longlines cause a great deal of damage to coral and hard bottom habitats, which incorporate fish, gorgonians, and sponges through their interaction (CFMC, 2004). Vertical gear also harms hard-bottom habitats. Fishermen using this type of equipment

sometimes drag or misplace anchors on the hard bottom, coral, and gorgonian biota. This gear is additionally harmful due to its tendency to become entangled. Hooks often also break, foul, or otherwise degrade coral and gorgonian habitat.

When fishermen use spears, additional threats are imposed on the environment. Although the damage is usually minor, spear fishing, particularly when used with scuba, is likely to break coral, re-suspend sediments, and touch reefs (CFMC, 2004). When coral is touched or sediments build up, a protective coating is removed, making the coral susceptible to disease and infection. Additionally, sediment buildup induces the risk of overgrowth of algae.

2.3.4 Laws and Regulations

The Puerto Rican government has taken some action in enforcing proper fishing regulations in order to help stop further deterioration of the marine corridors.

All persons who fish for commercial purposes in jurisdictional waters of the Commonwealth of Puerto Rico must obtain a license to do so. License applications are reviewed, and if issued, expire within a certain period depending on the type of license. Additionally, some species require special permits to be caught (Commonwealth of Puerto Rico [CPR], 2004).

Fishermen must adapt their fishing techniques to comply with regulations. For instance, there are numerous regulations regarding the types of nets that can be used. The construction of seine nets, haul beach seines, or boliches are required to adhere to size specifications. Any net constructed with profiles or rigid structures that impede escape through the mesh or cause damage to the habitat is illegal (CPR, 2004). Additionally, trawl nets and drift nets are now illegal. The use of any net (including gill, fillet, and

trammel nets) or spear guns while scuba diving is illegal. Moreover, use of gill nets, beach seines, and trammel nets (with a perimeter less than 984' feet) from the mouths of rivers is prohibited. Lines must be less than three miles in length. Traps must also follow distinct construction limits. They are required to be a certain size and contain specific escape panels. For all coral reef fishermen, an anchor retrieval system must be implemented, and the use of pots, traps, gill nets, trammel nets, and bottom longlines is prohibited.

In an effort to stop ghost fishing, several policies have been implemented. It is illegal to leave unattended fishing gear (hooks and lines) in interior waters (CPR, 2004). It is also required that at least one buoy float on the surface for every trap used. These efforts were established in order to help prevent the abandoning of gear.

Restrictions regarding size, amount, and type of fish are in effect to limit over-fishing and help promote successful breeding. Designated time periods for certain types of fish have been determined as closed seasons. During closed seasons, fisherman may not fish for or possess the species of fish in consideration. This is a further attempt to support breeding seasons of fish (CPR, 2004). Specific fishery management plans on the spiny lobster, queen conch, and reef fish fisheries of Puerto Rico are located in appendix H.

2.3.5 Enforcement of Laws and Regulations

For compliance to laws and regulations, there must be a governing agent responsible for the enforcement of policies. "The sustainability of coral reef resources is dependent on effective enforcement of existing marine resource regulations and the development of new regulations where appropriate" (NOAA, 2002, p.1).

Fishery management is conducted on both a federal and state level. The federal fishery management is operated under the authority of the Magnuson-Stevens Fishery Conservation and Management Act (MSFCMA) (CFMC, 2005). "The MSFCMA claims sovereign rights and exclusive fishery management authority over most fishery resources within the U.S. EEZ [exclusive economic zone], an area extending 200 nautical miles from the seaward boundary of each of the coastal states, and authority over U.S. anadromous species and continental shelf resources that occur beyond the U.S. EEZ" (CFMC, 2005, p. 18) (See Figure 2-5). Regulations established in fishery management plans are enforced by the U.S. Coast Guard and state authorities.

As a Commonwealth, Puerto Rico has authority of the management of its fishery on a state level (CFMC, 2005). Puerto Rico's Department of Natural and Environmental Resources' Fisheries Research Laboratory manages fisheries in waters extending nine miles from shore (See Figure 2-5). Their fishery management agency has a seat on the federal level agency to represent Puerto Rico and "to ensure state participation in federal fishery management decision-making and to promote the development of compatible regulations in state and federal waters" (CFMC, 2005, 20).

Although there are designated zones of fishery management, there are problems associated with the enforcement and consistency of the regulations. The Heinz Center Report (2000) found that "enforcement in the Caribbean region is severely underfunded. Because personnel and equipment are limited, enforcement depends largely on voluntary compliance" (as cited in CFMC, 2005, p. 19). Moreover, some fishery regulations remain inconsistent between the state and federal level. For example, until recently in 2004, Puerto Rico neither prohibited nor regulated catches of Nassau grouper, which

have been prohibited in federal waters since 1990. "The lack of compatible regulations in state waters makes federal regulations difficult to enforce and hinders the Council's ability to achieve federal management objectives in some instances" (CFMC, 2005). There are, however, efforts being made to help remedy these issues.

The Navigational Commissioner, Coastal Management Program, and the Department of Natural and Environmental Resources (DNER) support maritime enforcement yearly through the combined financial contribution of roughly $1.0 million dollars (NOAA, 2002).

In 1999, the NOAA and DNER agreed to strengthen enforcement of federal laws such as the Endangered Species Act, Marine Mammal Protection Act, and the Magnuson Stevens Fisheries Management Conservation Act through combined effort (NOAA, 2002). Nine DNER Maritime Officers work in conjunction with the U.S. Department of Commerce's National Oceanic and Atmospheric Administration (NOAA) to support law enforcement in Puerto Rico. The nine agents work undercover and are distributed throughout four provinces of the island.

Puerto Rico's Department of Natural and Environmental Resources' Maritime Law Enforcement is the governing agency with the task of ensuring that all regulations are being followed. As of 2002, the department had a total of eighteen boats and five jet skis used for enforcement (NOAA, 2002). The number of fishing law cases has remained fairly steady. In 2000, 115 cases were reported and similarly, 140 cases were reported in 2001, and 110 cases in 2002.

2.4 Tourism

Puerto Rico's ideal climate, lush rainforest, and spectacular beaches make it a popular tourist destination. Unfortunately, people can often be harmful to the surrounding environment. Coral reefs are particularly susceptible to the ills of tourism due to their sensitivity to the surroundings. However, there are some laws and regulations in effect to help combat these issues.

2.4.1 Scuba Diving

Puerto Rico's warm temperature, clear water, coral reefs, and seagrass beds make it a very attractive location for scuba diving and snorkeling (Zakai, 2001, pp. 1-5) (Figure 2-9). Although most people do not deliberately break or touch the coral, inexperienced divers can have trouble maintaining neutral buoyancy. This can lead to unintentional contact with the coral; even the lightest contact can cause breakage due to its brittleness. Another problem divers present to the reefs is raising sediment from the ocean floor. Swimming with fins causes significant water turbulence, which can raise a great deal of sediment; this sediment often settles on top of coral.

Figure 2-9 - Scuba Diving (Puerto Rico Tourism Company, 2006)

Covered by sediment, the algae living in the coral can no longer photosynthesize and it, along with the coral, will die.

Numerous studies have been done on the effect of scuba diving on coral reefs. One study done in the northern Red Sea concentrates on exactly how much and what type of damage is done on an average dive (Zakai, 2001, pp. 1-5). The final estimate was that a diver breaks 1.70 +/- 4.90 corals and raises 9.40 +/- 11.90 sediment clouds during a sixty-minute reef dive. One site in the study was composed of 80.8% +/- 17.0% damaged coral structures. The same site had up to twenty-six broken coral fragments per square meter. Considering that some high traffic dive sites have over ten thousand dives every month, these damage numbers are very significant in regards to a reef's future existence.

Other studies have been done to find out what factors affect the amount of coral damage done in a given dive (Barker, 2004, pp. 1-7). The most obvious conclusion is that more experienced divers are less damaging to the reefs than novice divers. Some of the more interesting findings include men being more hurtful to coral than women, divers with a camera are more prone to damaging than non-camera users, and boat dives are more detrimental than shore dives.

Fortunately, there are certain laws and regulations in place regarding reef preservation. Many governments, including Puerto Rico's, have implemented Marine Protected Areas (MPA) (Burke, 2004, pp. 1-5). Each MPA has its own set of regulations specific to its environmental issues. Some just have more stringent limits on fishing for example, but some go as far as banning fishing and diving altogether. Scuba shops also have certain regulations they choose to follow. All are supposed to inform their divers not to touch anything, but a study done on this preservation method showed that it has no

effect on the amount of damage done. However, if a dive leader from the shop goes along for the dive and intervenes when necessary, the rate of coral contact reduces from .3 contacts per minute to .1 contacts per minute.

2.4.2 Other Forms of Tourism

Scuba diving is not the only tourist attraction that is detrimental to the marine corridor ecosystem. Any activity involving a boat poses a health concern for seagrasses, mangroves, and coral reefs (Saphier, 2005, pp. 1-4). Boaters occasionally dock boats up against mangroves, crushing the root structures. However, the main concern with boats is the anchor. When initially dropped, the anchor can easily crush a large section of coral. The chains also drag across the bottom further breaking coral or pulling up seagrasses. If the waves or wind are significant enough, the anchor will drag across the sea floor destroying everything in its path. Many Marine Protected Areas have anchor bans in place for this reason alone. Other tourism issues regarding the well-being of the environment include fishing and resort development. Those topics are discussed in detail in other sections of the report.

2.5 Development

Many of the same reasons Puerto Rico is such a popular tourist destination also make it a great place to live and work. These reasons have resulted in an increasing amount of development, especially on coastal regions. While this development may have positive effects in terms of improved living areas, more tourist attractions, and increased commercial space, it aids in the degradation of marine corridors.

2.5.1 Urban Sprawl

In order to examine the effects of development, more specific terminology will be defined and utilized to explain various urban phenomena. The scope of development investigated in this report deals mainly with urban sprawl, which is defined as a "spread-out development that consumes significant amounts of natural and man-made resources, including land and public works infrastructure of various types" (Transportation Research Board, 2000, Preface). While this definition still seems to encompass a broad range of expansion, there is a differing view of sprawl which concentrates on spread out growth and the specific necessity of the automobile. It specifically includes large commercial areas that are built in strips or clusters that are located further away from each other or from residential areas (Jackson, Frank, & Frumkin, 2004).

By creating large clusters of developments, it is necessary to use a car instead of walking or riding a bike, and the large distances between clusters makes it difficult to implement a public transportation system. The commercial properties created, as well as the increased automobile use cause additional pollution and limit the amount of green spaces (Jackson, Frank, & Frumkin, 2004). While there are some positive aspects of commercial and residential growth, sprawl creates a disproportionate use of fragile agricultural and marine land relative to population growth (Transportation Research Board, 2000, Modeling Sprawl and Its Impacts).

2.5.2 Resort Development

In addition to the creation of commercial and residential property, development in Puerto Rico has also led to an increase in tourism and the need for increased accommodation of tourists on the island. While commercial property may be built

anywhere, the building of resorts and hotels is generally limited to places where tourists want to visit. In Puerto Rico, these places are constructed generally on the coast and infringe greatly on marine ecosystems.

2.5.3 Marine Pollution

In Puerto Rico, the urban sprawl and resort development has lead to an increase in marine pollution levels. There are many laws and regulations to control water pollution, but "despite 30 years of progress, including significant progress in reducing pollution from ocean dumping, waste treatment facilities and toxins such as DDT, our coastal waters remain in very serious peril" (Lubchenko, 2001, p. 2). The pollution in marine areas stems from specific coastal development including road construction, port development, and dredging. These processes are devastating to marine corridors as they impart dangerous chemicals into the water, as well as physically destroying acres of coral reefs, mangroves, and sea grasses. Additional pollutants in marine areas that are a direct result of development include runoff from urban streets, lawns, and agricultural areas in developed land on coastlines. These pollutants deliver harmful nutrients and chemicals to coastal estuaries and wetlands which kill fish and plant life and can stimulate harmful algae blooms (Sanchirico, Emerson, & Cochran, 2002).

Pollutants can have grave effects on marine wildlife and ecosystems, and due to the nature of these chemicals, it is slow and difficult to recuperate from the ill effects caused by them. These issues must be addressed in order to assess and heal the environmental condition of a marine ecosystem. If the pollution is allowed to run rampant, it may lead to serious problems as seen in other places on the United States

coast and bays such as Chesapeake along the East Coast and the Santa Monica on the West Coast, places notorious for pollution (Agardy, 1999).

When evaluating pollution, there are two main types to be considered. The more obvious source of pollution is called point source pollution. Point source pollution encompasses readily identifiable input sources such as a pipe or drain that is directly dumping chemicals into a body of water (EPA Victoria, 2005). Most companies end up dumping their waste into the sea in this fashion, but the amount and contents of the waste that is dumped are controlled by the Environmental Protection Agency, and limits and regulations are easily imposed. Companies are often inspected to ensure adherence to these limitations.

The second type of pollution, non-point source, is much harder control and far more harmful to the environment than point source. Non-point source pollution consists of pollution spread over a wide area and cannot be attributed to any one source. Specific examples of non-point source pollution include seepage from septic systems, runoff of road debris and oil during rainfall, smog caused by factories and automobiles, and farming chemicals and byproducts. Stopping non-point source pollution requires identifying large-scale sources and creating public policy and awareness to stem the flow of harmful pollutants into coastal environments (EPA Victoria, 2005).

2.5.4 Laws and Regulations Regarding Marine Areas and Activities

While the U.S. has enacted many laws for environmental protection, the Clean Water Act, the Pollution Act, and the Endangered Species Act, which are enforced and administrated by the Environmental Protection Agency, have the most relevance to marine ecosystems.

The first act to establish regulations for the dispersal of pollutants into waters in the United States was The Clean Water Act of 1977. In addition to establishing regulations for pollutants, it set water quality standards for contaminants and made point source pollution illegal without a permit (U.S. Environmental Protection Agency, 2005, The Clean Water Act). The act also funded sewage treatment plants and funded planning to address non-point source pollution issues.

Another act vital to the protection of marine ecosystems, the Pollution Prevention Act of 1990, involved the government in reducing the amount of pollution in the United States. To effectively do this, it focused on changes in production, operation, and the use of raw materials. The idea behind this act was to control pollution at the source, instead of focusing on treatment of disposal. This source reduction was seen to be "more desirable than waste management or pollution control" (U.S. Environmental Protection Agency, 2005, The Pollution Prevention Act).

The Endangered Species Act, passed in 1973, is another law that will help to protect marine ecosystems in Puerto Rico. This act helps to protect endangered species of plants and animals and the habitats in which they live. Also administered by the United States Environmental Protection Agency, this law prohibits any actions that may harm or adversely affect these species (U.S. Environmental Protection Agency, 2005, The Endangered Species Act).

2.6 Organizations

The concern for environments such as marine corridors is not a new phenomenon; there are many organizations putting forth various efforts in order to help preserve them. The major environmental groups active in Puerto Rico include the Caribbean Fisheries

Management Council (CFMC), the National Oceanic and Atmospheric Administration (NOAA), the Environmental Protection Agency, (EPA), and the Department of Natural and Environmental Resources (DNER).

The Caribbean Fisheries Management Council is a key player in the creation and regulation of fishing in and around Puerto Rico (CFMC, 2005). It was established in 1976 and consists of members from fishermen, scientists, and members of government. Once those members develop a set of regulations, they are enforced by the United States Coast Guard. The CMFC is a good resource in finding out more about what kinds of factors go into creating the regulations and how well they are enforced.

The Department of Natural and Environmental Resources is a government agency (Departmento de Recursos Naturales y Ambientales, 2005) that was established in 1972, its mission is to protect, conserve, and administer the natural environment and its resources to ensure the next generation's benefit and to stimulate a better quality of life. They reach these goals by promoting sustainable use of the resources, creating plans for resource management, and educating Puerto Ricans on the benefits of conservation.

The Conservation Trust of Puerto Rico, Surfrider, and CORALations are also important organizations active in Puerto Rico and more information concerning them can be found in appendix M.

2.7 Conclusion

The health of seagrasses, coral reefs, and mangroves continues to decline due to factors such as changing environmental conditions, commercial and residential development, and the tourism and fishing industries. Despite the fact that marine corridor conditions are still worsening, if it were not for the environmental organizations

previously mentioned, the well-being of marine corridors would be considerably worse. However, there is still much that can be done to help those organizations in order to reverse the trend of marine corridor health deterioration, and in the next chapter we have discussed how we went about collecting data to create and evaluate possible solutions.

3 Methodology

Achieving our goal of providing recommendations for the preservation of marine corridors in Puerto Rico depended upon the successful completion of individual objectives. While some objectives, such as examining the economic effects of marine corridors on Puerto Rico and determining the basic types of fish in marine corridors were completed by research before leaving for Puerto Rico, others were achieved only through interaction with the local communities and fieldwork. To obtain insight into the fishing and tourism industries and their effects on marine corridors, we obtained information from local fishermen, dive shops, and government officials. Quantitative data about fish catches and the current state of marine corridors were obtained from the National Oceanographic and Atmospheric Administration and compared and analyzed against remote sensing images of marine corridor ecosystems in Fajardo, Puerto Rico. Through this combination of qualitative and quantitative data collection and analysis, we obtained a clearer representation of the current state of near shore marine ecosystems in Puerto Rico and the necessary steps to alleviate the problems they are experiencing.

3.1 Observation and Interviews

Interaction with local communities in our area of study brought a social aspect to our research. Contrary to scientific research where data may be analyzed systematically, social research yields data with added complexity due to bias. In our project, we needed to determine what fishermen, dive shop managers, and government officials knew about marine corridors and the ecosystems within them. The connection between coral reefs, sea grasses, and mangroves has only recently been studied, and it was unknown whether

people in Puerto Rico had realized the connection between the three ecosystems and the correlation between marine corridor health and Puerto Rico's economy.

Academic resources were an important part of discovering what data were available to us from previous studies. They also aided us by providing us with contacts among the fishermen, SCUBA divers, and government officials. By interviewing experts in different fields and organizations, we were able to obtain different viewpoints from different locales. Our list of academic resources included Graciela Garcia, Manuel Valdez Pizzini, Richard Appeldoorn, and Ernesto Diaz.

Graciela Garcia works for the Caribbean Fishery Management Council (CFMC) within the National Oceanic and Atmospheric Administration (NOAA) and coordinated our work in Fajardo. She arranged for us to meet the DNER contact, Jesus León, in Fajardo to facilitate our meetings and interviews with fishermen in three fishing villages. She also provided data on fish catches from 1983 to 2005 on the four species we were studying. Moreover, Graciela Garcia helped us find dive shop managers to interview and provided us with the names of government officials with whom we could speak.

Manuel Valdez Pizzini is an anthropologist at the University of Puerto Rico – Mayaguez and is an expert in applied social science research concentrating mainly on marine ecosystem management. Richard Appeldoorn is another professor at UPR – Mayaguez and focuses his research on coral reefs and fisheries. Ernesto Diaz works with land based sources of coral reef deterioration in the Department of Natural and Environmental Resources (DNER). His knowledge of Puerto Rico's government, regulations, and enforcement helped us determine the current efforts and the role of the government, specifically the DNER, in marine corridor preservation.

To determine what local communities knew about the connection between fish catches and the health of marine corridors we visited the Fajardo area. Through Graciela Garcia's contact, we had access to three of the fishermen's villages in Fajardo and took two field trips there. The purpose of our trips was to interview some of the fishermen and dive shop managers. Our interviewees were not selected randomly from each fishing village, but were chosen based on their availability during our visits to Fajardo. The sample included at two fishermen from Maternillo, two from Sardinera, and five from Las Croabas. This sample included commercial fishermen, retired fishermen, subsistence fishermen, and commercial divers. To retrieve qualitative data that could be analyzed, we used a standard interview protocol that can be found in appendix B for fishermen and appendix C for dive shop managers containing both categorical questions and open-ended questions. It was important to translate all of the questions into Spanish and to pretest them to avoid confusion. These trips to Fajardo aided us in completing the objective of determining fishermen's current practices and their knowledge of marine corridor deterioration.

The majority of the information we received from dive shop managers and fishermen was oral history. Oral history is the recording of people's memories and as such, we recorded fishermen's and divers' memories about the changes in fishing levels and marine corridors. It provided qualitative data and allowed us to understand the changes in marine corridors from the point of view of people who see the area every day. Oral history aided in the completion of all of our objectives, whether directly through what we were told or indirectly through our analysis of what we saw and heard.

We analyzed fishermen's and divers' responses to our open-ended questions to determine their attitude about recreational boaters, marinas around Fajardo, and factors affecting marine corridor health. Interviews were an important part of our project because they enabled us to interact with local people and to determine their attitudes and opinions on marine corridor connectivity. Our various interviewees provided several points of view so we were able to make accurate conclusions. Since we conducted multiple interviews, we had a strong indication of how much knowledge most of the fishermen had on the subject. Our first few questions provided us with details concerning where they fish, the type of boat they use, the gear they use, and how often they go out to fish, while our other questions provided insight into problems that the fishermen and divers have noticed such as decreases in fish catches and changes in marine corridors. We also invited them to share any opinions they have on the causes of marine corridor deterioration and we were able to make several recommendations based on their knowledge.

3.2 Ecological Studies

General observation and oral history provided us with a general idea of the health trends of the mangroves, coral reefs, and seagrass beds, but it was not enough to give us a full understanding of the subject. We used existing information from ecological studies and fishing surveys conducted by the Caribbean Fishery Management Council to understand the status of marine populations over time. The types of studies we analyzed included fish catch data from 1983 to 2005 as well as remote sensing images from satellites and airplanes also taken from this period. After collecting these data, we

developed a specific plan for the analysis of both the raw fishing data and remote sensing images.

3.2.1 Remote Sensing

Remote sensing is a method that involves capturing data using any device not in direct contact with the person collecting the data. Specifically, we used high-resolution pictures of Fajardo taken via government satellite and airplane, as shown in Figure 3-1. The older pictures, which were obtained by our liaison from government agencies in Puerto Rico, were of lower resolution but still provided a clear view of changes in corals, mangroves, and seagrasses as well as showing growth and sedimentation around the area. These aerial photographs allowed us to determine the level of developments and marine corridor habitats in Fajardo and how the area has changed over the last forty years.

Figure 3-1 - Remote Sensing (NOAA, 1999)

3.2.2 Fish Catches

In order to find the relationship between marine corridor health and its effect on the fishing industry, we obtained information regarding the fish catches over the years for comparison. The specific species used in our analysis included queen conch, Caribbean spiny lobster, yellowtail snapper, and red hind. According to our contact in the CFMC,

these are indicative species and their analysis in the Fajardo area provided an adequate representation of the fishing trends throughout the rest of the Puerto Rican coast.

3.2.3 Analysis

We compared the fish catch trends to changes in surface area of marine corridors in order to make conclusions about the health of marine corridors and its effect on fish populations. We organized the fish catch data using Microsoft Excel and created graphs displaying the fluctuations of fish catches of yellowtail snapper, queen conch, spiny lobster, and red hind from 1983 to 2005. These were originally separated by fishing village and then combined to provide an overall trend in Fajardo. To take into account the variation of the number of fishing trips that each fishing village made, we used the "Average" function in Excel to obtain graphs of the average number of pounds per trip each year and we added trend lines to visualize the general trends of the data for each species. In drawing these conclusions, we assumed that a decrease in fish catches was a sign of decreasing fish populations in that area, making qualitative exceptions for the implementation of fishing bans during certain times, as well as taking into account years with major hurricanes.

To determine changes in marine corridor health, we analyzed several remote sensing images from the past forty years. Dr. Maritza Barreto, professor of Geography at the University of Puerto Rico – Rio Piedras, trained us in the qualitative examination of satellite and aerial photographs of the Fajardo area. The training consisted of learning techniques for proper comparison of different sized images, orientation of images with set references in Puerto Rico, and the ability to determine which areas represented coral reefs, mangroves, and seagrasses. After training, we studied each habitat's area over time

to determine the changes that have occurred and we examined the changes in human impact on the area, such as construction, marinas, and sediment levels. The analysis of these data provided us with the basic information needed to make an association between marine corridor health, fish catch trends, and human impacts on the area.

3.3 Conclusion

Our methods, varying from observation and interviews to reviewing raw numerical data, helped us determine the trends of marine environments around the coast of Puerto Rico. Observation of and interviews with fishermen and dive shops allowed us to achieve our objectives of determining fishermen's and dive shop owners' knowledge of marine corridor health. Interviews with expert resources allowed us to complete our background research and offered solutions to other questions. Analysis of remote sensing images and fish catch data provided us with the information we needed in order to provide a sound basis for our recommendations.

4 Results and Analysis

This chapter introduces the data and our analysis of it. The negative trends in the fish catch data and areas of marine corridors became obvious during our investigations. Interviews of fishermen and dive shop owners provided insight into their practices and problems. We received and interpreted information concerning the causes of marine corridor deterioration from our interviews of fishermen, dive shop owners, professors, and government officials.

4.1 Connection between Marine Corridor Health and Fish Populations

In order to properly achieve our goal, we needed to evaluate the possible relationship between the health of marine corridors and the abundance of fish in the area. As previously stated, this was done by qualitatively analyzing aerial photos of Fajardo and creating graphs of the fish catch data we obtained from NOAA. Figure 4-1 is a graph showing how the average fish catch of each species we studied has changed over time from 1983 to 2005. It shows that both the yellowtail snapper and red hind have been experiencing a steady, moderate decrease in population ever since 1983. The other two

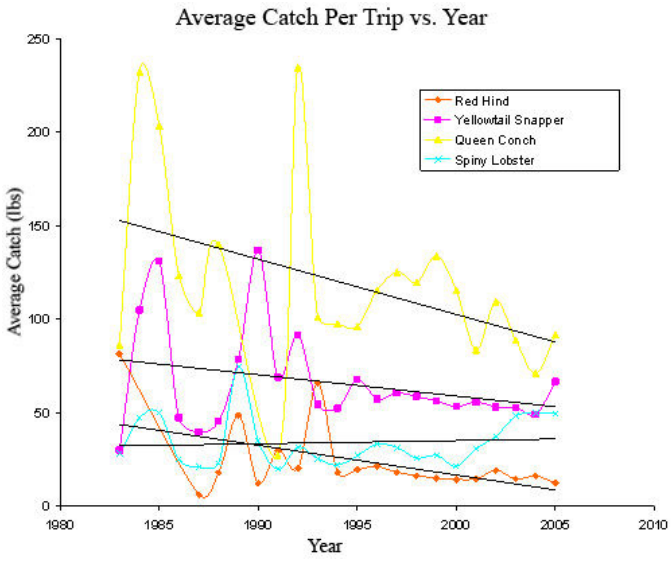

Figure 4-1 – Average Fish Catches in Fajardo from 1983 to 2005

species we were concentrating on, the spiny lobster and queen conch, have significantly different trends. The queen conch data show a steep downward trend in population, and the spiny lobster's numbers are actually increasing (CFMC, 2005, p. 98). However, according to Professor Appeldoorn (Personal communication on Apr. 6, 2006), this phenomenon is easily explained by two simple facts - the population of spiny lobster predators (mainly sharks, octopuses, rays, skates, crabs, dolphins, and turtles) is decreasing, and the spiny lobster is a predator of the queen conch, thus as the spiny lobster population increased the conch population decreased due to predation by lobsters. Upon reflection, the only data trend that seemed to initially be positive, spiny lobster population, is actually a result of a negative trend in its predators. It must be said these data cannot necessarily be taken as being completely reliable; it is possible that the fishermen failed to report all of their catches to NOAA. In examining these data, we concentrated on trends over time. Thus, assuming that biases in data have existed over time and been biased in the same direction throughout this period, our analysis should represent valid trends.

After analyzing the fish catch data, we needed to evaluate the aerial photos of Fajardo from 1962 to 2004 in order to see if we could possibly attribute these decreases in fish populations to certain marine corridor health trends. The results of that evaluation

Percentage of Initial Habitat Area Remaining

Habitat	Year 1962	1983	1994	1999	2004
Seagrasses	-	100%	80%	75%	74%
Mangroves	100%	0%	0%	0%	0%
Coral Reefs	-	100%	75%	68%	65%

Table 4-1 - Analysis of Marine Corridors through Remote Sensing Images

are summarized in Table 4-1. In every single category, qualitative evaluation indicated that trends are moving in negative directions (e.g. the area of coral reefs is decreasing). The small area of mangroves found in the 1962 aerial photograph of Fajardo disappeared by 1983 while seagrasses and coral reef areas appear to be diminishing. Also contributing to these trends, sedimentation, development, and the number of marinas are growing rapidly as seen in Table 4-2, which will only accelerate degradation of marine areas.

Number or Percentage of Human Factor Present Beginning in 1962

Human Factor	Year				
	1962	1983	1994	1999	2004
Sedimentation	-	100%	200%	250%	325%
Marinas	2	5	5	5	7
Development	-	100%	105%	105%	107%

Table 4-2 - Analysis of Human Impact through Remote Sensing Images

There are no specific data for seagrasses, coral reefs, and sedimentation in 1962 because there is a significant amount of glare on the water in the aerial photograph rendering these habitats unreadable. There are no data for development in 1962 because it was almost non-existent. Now it is near its peak since almost the entire coastal Fajardo area is occupied by residential and commercial buildings. Another observation from the aerial photos worth mentioning is that the

Figure 4-2 – Sedimentation (NOAA, 2006)

source of almost all the sedimentation comes from the rivers, as can be seen in Figure 4-2. We interpreted this to mean that although the development near the shore is close to its peak, there is still much inland construction causing erosion into the rivers that eventually finds its way to the sea.

From the analysis of both the fish catch and remote sensing data, the connection between marine corridor health and fish populations is obvious. Mangroves in the area have completely disappeared and seagrasses and coral reefs are deteriorating quickly all while sedimentation and development are on the rise. Although there are almost surely other factors regarding the relationship between marine corridor health and fish populations, we believe the negative trends in each are directly related.

4.2 Harmful and Beneficial Practices of Fishermen

Assessing the negative impacts of marine corridors requires consideration of the positive and negative contributions of commercial fishermen and divers in the area In addition to examining the effects the fishermen and divers have on the corridors, we also utilized their everyday exposure to these corridors to ascertain their knowledge concerning changes and other essential factors in these marine ecosystems. To obtain this information, we visited the Fajardo area with Mr. Jesus León from the DNER, who has working relationships with the chairmen of several fishing villages in the Fajardo area, as well as contacts with many dive shops. With Mr. León's help, we were able to interview nine fishermen and two dive shop owners in the area.

Throughout all of the interviews, fishermen expressed the desire and willingness to protect marine areas and the juvenile fish living in them. The practices utilized by the fishermen in these areas reflected their concern for these fragile ecosystems. The majority of the fishing that was done by the fishermen interviewed took place along the eastern shelf of Puerto Rico and North of Culebra (see Appendix C). By traveling further out to sea, the fishermen not only find larger, more mature fish, but also avoid depleting the inhabitants of marine corridor areas. The majority of fish capture by fishermen was done using rod and reel, nets, traps (see Figure 4-3 for an example of a trap), vertical lines, or SCUBA diving (see Appendix C). While nets are utilized in open water areas, the remaining types of equipment are used in off shore areas that may contain reefs. According to the fishermen, the greatest amount of care is taken when fishing near reefs. Due to their experience, they know exactly where these fragile areas exist and can navigate their boats through known channels to avoid hitting them. They drop their anchors only in sand and position their boats so they are downwind from the reefs, thus avoiding the destruction that can be caused by dragging an anchor through one of these areas.

Figure 4-3 – Traps (Taken by Caitlin Slezycki)

In addition to the expert navigation and experience obtained through numerous years of fishing, the fishermen have also developed practices to avoid harming juvenile fish. They utilize equipment that is designed to allow the release of smaller fish and traps

that will disengage if abandoned. When fish are caught, they are measured and released if they are below a certain size, varying from species to species. They recognize the importance of this size difference, as smaller fish have yet to mature and replenish the stock for the upcoming years. SCUBA divers searching for Queen Conch and Spiny Lobster use devices called lassos to snag them, and they measure them before they take them to the surface. Other equipment is designed so that it is less likely that smaller fish are included in the catch. This includes larger hooks on vertical lines and rod and reels and larger holes in the nets. In addition to the equipment employed, they use larger bait that will attract the specific fish they are trying to catch. Fishermen's adherence to regulations is vital for the health of the marine corridors.

When interviewing the fishermen, rather than directly ask whether or not they were adhering to regulations and risking false information, we asked more indirect questions. These questions, such as type of fishing gear used, fishing location, and additional open-ended questions, provided us with the information needed to assess their adherence.

Upon review of the data collected from fishermen interviews, it is evident that overall they are following the regulations. The type

Figure 4-4 – Map of Fajardo (Mapquest, 2006)

of gear used and areas where they are fishing comply with the restrictions that have been established. Fishermen are also not fishing during the prohibited take periods of certain species, as they feel that these are necessary for populations to replenish, and that they will eventually benefit from it. They also understand that marine corridor ecosystems are vital for the growth of juvenile fish, and encourage and utilize practices that emphasize their preservation.

Although the fishermen have been adhering to regulations, they often mentioned issues with several regulations in place. Fishing licenses have been a continuing problem for the fishermen. Depending on the species fished, additional licenses are sometimes required. These licenses are issued separately from one another, resulting in an inconvenient number of licenses that must be carried at all times. Moreover, renewals of licenses are required on a yearly basis and often times take a period of three to four months to be completed. This inconvenience may make fishermen less likely to comply with the regulations.

The three fishing villages in Fajardo where we conducted fishermen interviews were Maternillo, Sardinera, and Las Croabas. Though there were similarities among the three, each village was unique. To better analyze interviews and catch data, we have provided a brief summary of each village.

Figure 4-5 – Maternillo (Taken by Caitlin Slezycki)

Maternillo (See Figure 4-5) is located on the southern shore of Fajardo (See Figure 4-4). This village is comprised of around twenty-four fishermen who fish mainly for yellowtail snapper using vertical lines.

Figure 4-6 – Abandoned Boat (Taken by Caitlin Slezycki)

Directly off the southwest coast of Maternillo there is an abundance of abandoned boats in a boat graveyard. These boats have been left behind by both recreational and commercial owners without proper disposal of wastes such as sewage and gasoline that have harmful effects on the environment. An example of an abandoned boat can be seen in Figure 4-6.

Figure 4-7 – Sardinera (Taken by Caitlin Slezycki)

Sardinera, as shown Figure 4-7, is located on the central shoreline of Fajardo (See Figure 4-4). A village of around twenty-four fishermen, Sardinera's fish capture consists of mostly spiny lobster, grouper, and other reef fish. Fishing here is done mainly with traps, and the indiscretion of these traps in catching fish results in a wide range of fish caught.

Las Croabas (See Figure 4-8), located on the north shore of Fajardo (See Figure 4-4), is also a village of around twenty-four fishermen. The fishermen catch a range of species including queen conch, spiny lobster, and grouper using SCUBA techniques.

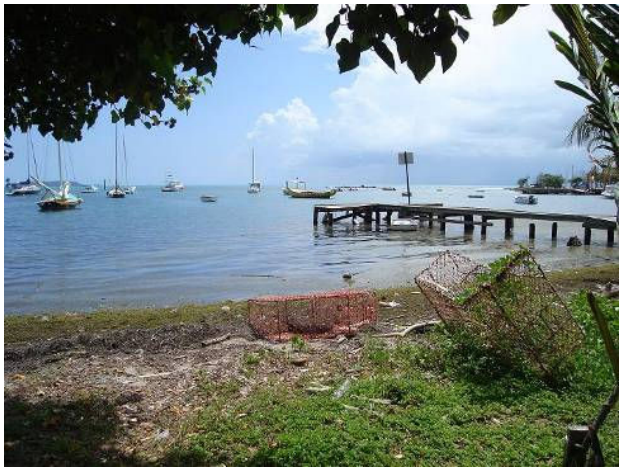

Figure 4-8 - Las Croabas (Taken by Caitlin Slezycki)

4.3 Harmful and Beneficial Practices of Divers

Interviewing fishermen was an essential part of determining factors affecting marine corridors in Fajardo, but we were also able to utilize information provided by dive shop owners to further our knowledge of marine ecosystems. The environmentally friendly practices of SCUBA shop dive masters are vital in preserving marine corridors. Dive masters understand the importance of the protection of marine ecosystems, and their concern is reflected in their instructions to and supervision of clients.

In order to rent diving equipment, customers must have proof that they have obtained an Open Water SCUBA certification. For those who are not certified, shallow water dives can be done in small groups with a dive master. Comprehensive training courses to gain certifications are also offered by many dive shops. These classes are taught in sandy areas to maintain diver attention and prevent accidental contact with corals. To reach many of the diving areas, groups go out in boats (See Figure 4-9).

Dive masters have established some rules to protect not only the divers they are obligated to instruct, but also the vital marine ecosystems around them. To ensure their safety, divers are not allowed to touch anything while on a dive, as any contact with coral is damaging. In order to discourage divers from touching reefs or breaking off pieces of coral, many dive masters do not even allow the use of gloves, as a diver is significantly less likely to touch and damage a coral with bare hands.

Figure 4-9 - Dive Boat with Equipment (Taken by Caitlin Slezycki)

4.4 Observed Changes in Marine Corridors

Through the direct interaction they have with marine corridors every day, fishermen and dive masters were able to provide first-hand observations concerning the changes these ecosystems are undergoing. The majority of the fishermen said that they noticed a great deal of change in marine corridors throughout the past twenty-five years. They said that the current condition of the reefs and seagrasses in the Fajardo area is poor and getting worse. While there were mangroves lining the coast of Fajardo in the past, there exist practically none in the area today, as they have all been cut down for development or were cut down in the 1970's because they were breeding grounds for

insects and thought to be ugly. Due to the lack of mangroves, the connection among the three main components of marine corridors is disrupted in this area. Though there are few mangroves in the area, the fishermen still recognized the importance of this connection. They talked about areas of shallow water whose entrances were protected by mangroves, providing safety for juvenile fish in these areas, as predators cannot enter. Consistent with our findings, they also recognized the importance of seagrasses and coral reefs as havens for young fish.

The changes in the marine corridor areas noted by the fishermen were also corroborated by our remote sensing data. The fishermen said that while the mangroves were relatively unaffected by sedimentation and pollution, the reefs were a fragile ecosystem that could be easily affected and destroyed. All of the SCUBA diver fishermen who were interviewed reported areas of bleached and dead coral. They also said that they often found trash or other foreign objects in seagrasses or on reefs.

As with most social research, the opinions of the fishermen were not unanimous on all topics. While most fishermen agreed that fish catches and marine corridor health are both declining, observations consistent with our other data, the two fishermen interviewed in one fishing village said they noticed absolutely no changes in either of these areas. Due to the large amount of data we have collected to the contrary, we believe these opinions to be biased, but they were included to ensure a comprehensive representation of the data we acquired. This contrary opinion was explained by other resource persons, who noted that fishermen may be apprehensive about being blamed for problems with marine corridors and fear additional restrictions.

Unlike fishermen, who frequent specific areas for the fish contained in them, the dive masters concentrate on the health and appearance of the marine environments in which they dive. Their regular observation of these marine habitats makes them useful sources of information about the current state of these ecosystems. In the areas in which dives take place, noticeable changes have occurred. Reef size is diminishing and bleaching is apparent in many areas. An increased amount of sedimentation was also observed as one of the main causes of this deterioration. Despite changes in the coral reefs, the same number and types of fish were still said to be observed.

4.5 Additional Detrimental Factors

Many people come to Puerto Rico to enjoy the available water activities, including fishing, SCUBA diving, snorkeling, and pleasure boating. Throughout our interviews, we obtained information regarding these topics along with development, which includes both sedimentation and water pollution.

Recreational boaters and fishermen are prevalent throughout the island, trying to enjoy the environment despite their lack of familiarity with the areas. There are hundreds of boats and yachts moored at the marinas in Fajardo that are used only by recreational fishermen and boaters. According to Richard Appeldoorn (Personal communication on Apr. 6, 2006), fish catches from recreational fishermen are approximately equal to those from commercial fishermen despite the fact that species vary slightly. Unfortunately, there are no official data on this so it makes it difficult for the DNER to provide regulations regarding species that are often sport fished. Additionally, the commercial fishermen have complained that the government ignores the actions of recreational fishermen and that the seven marinas in Fajardo do not provide any economic advantage

to the local fishermen. The fishermen have also noted that recreational boaters do not know where the coral reefs are located and often unknowingly drop their anchors on top of the reefs or scrape their bottoms along them, breaking the delicate corals. While commercial fishermen have moved farther and farther out to fish, many charter boats have been moving closer to shore for convenience and to avoid seasickness in their customers, therefore encroaching on marine corridors and juvenile territories. The local fishermen have noticed that sport fishermen often go into seagrass beds and coral reefs to use spear guns to kill fish, including juveniles.

Development is occurring all over Puerto Rican coasts, in the form of apartment complexes, high-rise condos, and resorts. According to a fisherman in Maternillo, one particular resort is even attempting to force the fishermen from their homes in order to make room for another hotel. These high levels of construction and development around the area are also causing run off into the rivers, which eventually reach the ocean, leaving up to eight inches of sedimentation in the water near Maternillo, which can be seen in the aerial photograph in Figure 4-10. Unfortunately, sedimentation drastically decreases water clarity, rendering coral dead as it makes it impossible to carry out photosynthesis. Another consequence of development is wastewater, which is supposed to go through two treatment plants before reaching the ocean. According to the owner of

Figure 4-10 – Sedimentation around Fajardo (NOAA, 2006)

a dive shop in Fajardo, the second plant is currently not functioning due to its inability to meet OSHA requirements. The number of marinas has also been greatly increasing in the area, mainly due to the high traffic of recreational fishermen and boaters. The intrusion of marinas into the water is driving fish, lobster, and conch into deeper water due to both the increased traffic within the bay, boat waste dumping, and sedimentation from construction.

As we expected from the beginning, many factors are negatively affecting the health of marine corridors but we could not evaluate all of them. We have determined recreational boating, development, and water pollution to be major problems and will be an important part for our conclusions and recommendations.

4.6 Conclusion

By collecting comprehensive data concerning marine corridors, we have been able to examine the major causes of their degradation and the steps necessary to prevent this degradation. We began by examining fish catches over time and comparing them to remote sensing images of marine ecosystems to get an idea of their changes over time. By interviewing people who regularly interact with these areas to obtain first-hand views regarding changes in reefs and the major interactive contributions concerning these corridors, we learned the reasons behind degradation and the necessary steps to stop it. Using these results and analysis, we were able to make conclusions and recommendations in the next chapter to reduce the degradation of marine corridors.

5 Conclusions and Recommendations

Our goal throughout the project has been to provide recommendations to the University of Puerto Rico and to other organizations regarding how they can decrease the negative impacts on marine corridors. After review of the data we have collected, we are making conclusions and recommendations in several different areas, concentrating on the possible changes that can be made to alleviate the stresses on the marine near shore ecosystems around Puerto Rico. To alleviate one of the main factors, damage done by commercial and sport fishermen, we provide recommendations for further regulations and enforcement. Additional areas of significant damage come from land-based sources, so recommendations to developers and lawmakers are established to lessen the effects of sedimentation and pollution. We have identified education as one of the most practical and effective ways to implement marine corridor protection, and as such, we have developed several recommendations for expansion of education to both boaters and the general population. We conclude with ideas for future research to be done by the University of Puerto Rico, Worcester Polytechnic Institute, and other parties interested in supplementing the results of our project, in an attempt to obtain truly comprehensive data about all factors influencing marine corridors.

5.1 Recreational Overuse

With Puerto Rico's coastline of crystal clear water rich with coral reefs and marine life, recreational activities are frequent. These activities are vital for the tourism industry on the island but, unfortunately, are also detrimental to the natural surroundings,

making these types of tourism unsustainable as they are currently practiced. With the implementation of our recommendations, we hope to improve the health of the marine corridors and the sustainability of marine recreation tourism.

Recreational boating includes both tourists and locals participating in any activity involving the use of a boat for pleasure. Boats can range from small kayaks to 150-foot yachts, but all of their users can damage the marine ecosystems in similar ways. As mentioned previously in the report, one of the biggest problems is anchoring in improper locations such as coral reefs. Anchoring buoys (Figure 5-1), which are simply buoys that boats can tie on to rather than use an anchor to stay in place, are currently implemented to prevent this problem. These are helping to a certain degree, but we recommend that more research be done on which reefs and what parts of them are being affected most by anchors. A greater quantity of buoys should be placed in areas that are desirable for boaters to visit in order to ensure the highest usage. The outcome of this would be a significant reduction in the amount of damage caused by anchors in Puerto Rican reefs.

Figure 5-1 – Anchoring Buoy (Taken by Marina Gurbanov)

To help with recreational boating, we also recommend a survey of the coral reefs and seagrasses be done in popular coastlines around the island. This information could

then be used in making detailed maps of these areas including anchor buoy locations that could be distributed at all the marinas and boat ramps around the island. The implementation of this recommendation would result in an increase in boaters' knowledge of the area, allowing them to safely navigate around shallow reefs, and would provide them with information concerning buoys so they could visit beautiful reef areas without having to drop anchor.

In addition to mechanical damage caused by these recreational boats, they often harm marine ecosystems while they are in marinas. This damage comes about by pollution through spillage from boating chemicals and oil, or from leakage or dumping from onboard bathrooms. Although the US Coast Guard and EPA have regulations regarding the restriction of this dumping, it does happen occasionally. We recommend that marinas be required to prevent this contamination through readily available waste removal assistance. With the assistance of marina operators, contamination caused by moored boats would be reduced significantly.

Another recommendation regarding marinas is a restriction that could be implemented by the government on where marinas can be built and how many boats they are allowed to moor. This would lead to a reduction in the current trend of coastal overdevelopment and also reduce the number of boats in the water.

5.2 Fishermen

A more specific type of recreational boating is sport fishing. As previously mentioned in the report, sport fishing is suspected to be responsible for approximately half of the catches around the island, but that is only an estimate. To get a more exact idea of the scope of this type of fishing, we suggest random samples be done by DNER

rangers at different marinas to better evaluate the numbers and species being caught, similar to the practices employed with commercial fishermen. With this information, regulations created to protect specific fish populations can be improved to account for the considerable portion of marine life being fished by sport fishermen.

In addition to gaps in data collection concerning fish caught by sport fishermen, there are also gaps in the licensing system that allow all sport fishermen to fish without fishing licenses. Although the law that requires all fishermen to have licenses to fish was passed in 2004, the licensing process for non-commercial fishermen has yet to be implemented. The implementation of this process has been postponed until the DNER can find a system to create, distribute, and administer over 100,000 recreational licenses per year (E. Diaz, personal communication, April 12, 2006). This has caused a loss in revenue that could have been used for funding other marine preservation acts. For example, if each license application costs $25 and there are 100,000 applications every year, that is $2,500,000 of revenue that the government is not receiving. We recommend that this system be implemented as soon as possible to prevent further sport fishermen from catching fish without licenses, as well as increase revenue that can be used to protect marine environments. With this implementation, there should be a wide range of licenses available from daily licenses for tourists to yearly licenses for local, non-commercial fishermen. We also recommend that these licenses be sold at local marinas and equipment stores to facilitate the acquisition of these licenses.

Marine corridors in Puerto Rico are being affected by commercial fishermen as well as recreational fishermen. Although the data collected from our interviews with commercial fishermen suggests that they are complying with regulations, improvements

could be made to better protect juvenile fish populations. New gear technologies that promote environmentally friendly catch and release of species should be made available to fishermen. The DNER should require a minimum level of technology present in their equipment for the release of juvenile fish. While the main responsibility for purchasing this equipment should belong to the fishermen, the government should offer financial assistance in keeping up with new technology. In addition to improved fishing gear, existing regulations should be altered to take into account the life cycles of certain species. For instance, the queen conch reaches maturity at about 2.5-3 years and their first reproduction cycle occurs at age 3-4 years during the month of July. However, the acceptable market size is 7 inches, which is usually reached around 2.5 years of age. This particular regulation allows for the catch of queen conch before they are able to reproduce, causing a decrease in juveniles. Regulations should be made based on the life cycles of species to allow for a more sustainable ecosystem.

The implementation of additional regulations could only be effective through proper enforcement. Currently, there are approximately 200 marine rangers responsible for enforcing all laws protecting marine ecosystems in Puerto Rico. With the implementation of a sport licensing process, this number will need to be increased, but can be paid for through the revenue gained from selling the licenses. This increased presence of rangers in coastal areas will support compliance with regulations.

Fishermen of Puerto Rico depend on the health of the marine corridors for their livelihood. Their dependence on this ecosystem has made them proactive in its preservation. The government should help maintain the fishing industry to help continue their contribution to the conservation of marine corridors by assisting them with

maintenance of their facilities and waterways. Additionally, there is currently a law forbidding minors under the age of eighteen to be able to fish with commercial fishermen. The inability for fishermen to take minors fishing prevents them from teaching new generations how to fish and has contributed to a lack of interest in the field. While this law is important for child labor reasons, it could be adapted to include times that minors interested in fishing could go out and learn to fish with parental consent.

5.3 Land-Based Impacts

Land-based sources have increasingly detrimental effects on marine corridors. There are several recommendations we have made in order to decrease the negative impacts from land-based causes.

Most of coastal Puerto Rico is already developed; as such, future and current construction needs to be planned out carefully to minimize its affect on marine corridors. Environmentally sensitive land use planning should be mandated by the government and imposed on developers to plan new construction and to utilize and expand the wastewater treatment system as the demand increases. In planning new construction, environmental policies and procedures developed by the DNER need to be followed to minimize non-point sources of pollution and sediment. Sediments are produced through dirt, concrete, and other construction debris and reduction of impervious surfaces like pavement will help reduce run-off and non-point sources of pollution. When it rains, these sediments are carried through the rivers into the ocean and spread out over marine ecosystems, stopping the natural photosynthetic processes of the coral reefs and causing bleaching.

The Department of Natural and Environmental Resources is researching land-based sources already, but they do not have enough funding to complete all of the

necessary research quickly enough to make a difference if the deterioration of the coral reefs continues at the current rate. We believe that more financial support can be obtained by concentrating on marine corridors' natural ability to break waves created by storm surges and hurricanes. By marketing the prevention of coastal hazards offered by coral reefs, mangroves, and seagrasses to those with coastal infrastructure, the importance of marine corridors can be demonstrated. We believe that by advertising this information, the DNER can obtain more funding for preventative measures.

5.4 Education

The biggest factor in establishing safe, sustainable practices concerning marine ecosystems is, undoubtedly, education. According to Ernesto Diaz, the administrator of Coastal Management in the Department of Natural and Environmental Resources, "Educating the general population to use sustainable practices would definitely lead to conservation and effective management of coral reefs" (E. Diaz, personal communication, April 12, 2006). In order to effectively protect marine corridors, this education must reach not only those directly influencing marine corridors, but also those indirectly influencing them. While education is already a component in the action strategies concerning reefs in Puerto Rico, it must be expanded to include coral reefs, mangroves, and seagrasses.

One of the biggest pieces of education concerning those directly affecting marine ecosystems concerns fishermen, both commercial and sport, and recreational boaters. By concentrating on education and other preventative measures, less money will be required for punitive measures. The most effective way to educate fishermen would be through a brief orientation session at the time fishing licenses and boat registrations are issued.

This orientation session would include specific information concerning fish species and the restrictions concerning them, including species' size, no take periods and zones, quota, and required release. For other recreational boaters, including those who fish and those who do not, distributed information would concern the specific locations of reefs and other marine ecosystems and how to locate and identify them. This information would also include procedures for interacting with corridors and how to properly anchor in the sand, with the wind blowing away from reefs to prevent additional anchor damage.

Currently, there are guides available to fishermen detailing specific fish types and the minimum sizes required (see Appendix O), though there is nothing relating to reefs or protection of marine ecosystems. We recommend the development and distribution of a guide to all boaters regarding locations of and regulations concerning marine corridors, as well as their importance to the environment and information about their life cycles; a sample mangrove page for this guide is also shown in Appendix O. Other visual materials and posters, such as the ones in Las Croabas shown in Figure 5-2, show fishermen information concerning fish as well as marine corridors and should be displayed at marine areas and boat ramps throughout the island. All materials to be distributed should be mostly visual in nature, making it easier to understand and limiting barriers in literacy and specific terminologies. Other

Figure 5-2 - Posters in Las Croabas (Taken by Caitlin Slezycki)

educational materials should be in multimedia forms such as pictures, and videos concerning coastal resources. The DNER has already made a video, but distribution is limited and could be expanded.

Distributing information to fishermen and other boaters would greatly reduce mechanical damage to reefs, but to stem the majority of damage to marine corridors, education must be targeted to people in all segments of society in Puerto Rico. This can be accomplished over time by educating students in public schools about the importance and fragility of marine ecosystems and the steps that must be taken to protect them. When these students become working members of society, they will support marine-friendly legislation and will take marine ecosystems into account when making decisions in their jobs and behaviors. Currently, the education of students regarding coral reefs is included as part of the 9th grade biology curriculum. This education should be expanded to include the importance of all three major corridor components, and should be taught, both formally and informally, in additional years in school.

5.5 Additional Research

Although this report provides recommendations for the preservation of the marine corridor ecosystem, there is always more research that could be done in order to supplement those recommendations. Further scientific research could include conducting a quantitative remote sensing data analysis using GIS software, thereby providing reinforcement for the recommendations. It is also important to research how global warming is affecting marine corridors, as it seems to be a significant factor in marine health from what we heard throughout our interviews.

Science only plays a partial when considering how to manage an entire ecosystem; the rest of the information must be obtained through social research. Interviewing marina owners would provide a better understanding of what kinds of boats most people have, what they use them for, and how well they think regulations are being followed and enforced. Going one step further, interviewing sport fishermen to find out how often they fish, where they go, what species they are specifically trying to catch, and how much they catch would provide a more complete and less biased evaluation of fishing in Puerto Rico. It would also be valuable to interview developers to determine their techniques for minimizing sediment runoff as well as their thoughts on implementing more sustainable development. Finally, visiting various public elementary, middle, and high schools to evaluate how students are being informed of marine ecosystems would prove worthwhile since existing curricula could be improved to better provide information about Puerto Rico's natural habitats.

5.6 Conclusion

With our recommendations and possible suggestions that come from future research, we hope that the marine corridors of Puerto Rico can once again reach a healthy state. In developing these recommendations, we took into account information obtained from government agencies, members of the scientific and academic communities, and local fishermen and divers, who all provided their own opinions of the situation. Through analysis and comparison of the information provided by all groups, we have been able to draw conclusions about what is really happening in marine corridors in Puerto Rico and what should be done to protect them. If followed, our recommendations should lead to an improved state of marine corridor health, helping to restore the natural

balance of the Puerto Rican environment and aiding its people both commercially and recreationally.

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Appendix A – Academic Resource Interviews

Richard Appeldoorn Interview Protocol

1. Can you describe reef fish movement and the effects of habitat distribution on species diversity and abundance?

2. Have you done any research involving the connection between mangroves, coral reefs, and seagrasses? If so, please elaborate

3. What is the impact of fishing on reef-associated habitats?

4. Do you feel that coral reefs are in danger of being destroyed? Please explain.

5. Are commercial fishermen the major negative factor in marine corridor destruction, or are there other major factors that overshadow them? (ex. Development, recreational fishermen)

6. Do you feel that regulations are strict enough for recreational fishermen and/or developers?

7. Have you done any work specifically in the Fajardo area?

8. Do you think it differs from other areas around the island? How?

Richard Appeldoorn Interview Summary

Attending: Jim Doucet, Dave Giebenhein, Marina Gurbanov, Caitlin Slezycki
Location: Room 603
Time: 11:45am
Date: Thursday April 6, 2006

1. Can you describe reef fish movement and the effects of habitat distribution on species diversity and abundance?

A significant number of species important to commercial fishermen have changed their locations and the vast majority move from shallow areas to deeper areas. Some species use each part of the marine corridors. Some make big shifts while some make smaller moves. The data that we have for most species is observational data and it only shows what fish are doing in a certain spot, not a generality

2. Have you done any research involving the connection between mangroves, coral reefs, and seagrasses? If so, please elaborate.

A lot of species live in marine corridors because of the variety of habitat. Sea grasses, have different forms, the deeper ones are not a good habitat for fish. Adult distribution does not vary much from juvenile. Queen conch use short grass beds for a nursery habitat, with clean sand and not too dense grass. Most of those are between the east coast of Puerto Rico and Vieques because many other areas are too close to shore.

3. What is the impact of fishing on marine environments?

Fishing has had a large toll on the environments, there are examples all over PR. One example is the spiny lobster because most of its predators are gone it has been increasing, but lobsters are predators of the queen conch which is affecting that population very drastically.
Recreational fishermen catches are equal in pounds to commercial fishermen's, but the species they catch vary. Recreational fishermen are more likely to take the juvenile queen conch, while commercial fishermen know not to take it, even though the same regulations apply to both kinds of fishermen.
There is a lot more that can be done to preserve marine environments.
Puerto Rico needs a network of marine reserves around the island to make sure that we retain the fish population, but we need to see what the ecosystem would look like without fishing. This is difficult because there are no areas where fishing is not occurring. Implementation of management regulations is a problem, but involving the local people would alleviate that.
People should stop fishing in near shore environments.

4. Are commercial fishermen the major negative factor in marine corridor destruction, or are there other major factors that overshadow them? (ex. Development, recreational fishermen)

The shelf of Puerto Rico is narrow so the fishing locations are limited. Sedimentation is also a big problem.

5. Do you feel that regulations are strict enough for recreational fishermen and/or developers?

No, the regulations are not strict enough for recreational fishermen.

6. Have you done any work specifically in the Fajardo area?

Interviews with fishermen around Puerto Rico which included Fajardo.
Appeldoorn also did conch surveys all over the east coast of Puerto Rico.
He mentioned we should contact Edgardo Ojeda at eojeda@uprm.edu

7. Do you think it differs from other areas around the island? How?

It is as good as any location, but the eastern platform is different than other shelf width. There is also much more recreational fishing in Fajardo than other areas.

Ernesto Diaz Interview Protocol

NOTE: Although we had this interview protocol prepared, we decided to go another route during the interview due to his expertise in areas other than fishing

1. Do you think the fishing regulations reflect good marine management in terms of fish life cycles, juvenile habitat protection, minimum sizes, etc…?

2. How much consideration of species life cycle goes into developing new regulations?
    a. For some species, there are size regulations that conflict with breeding age. For instance, the queen conch reaches maturity at about 2.5-3 years and their first reproduction cycle occurs at age 3-4 years during the month of July. However, the acceptable market size is 7 inches which is usually around 2.5 years of age.

3. How are fishing regulations enforced?
    a. Who enforces the different fishing zones?
    b. Are sport and commercial fishermen regulated in the same way?
    c. Do they both need licenses?
    d. How do they obtain licenses?

4. Are safe/environmentally friendly boating exercises enforced on a daily basis (such as anchoring on reefs, etc.)?

5. How are dumping laws enforced at marinas?

6. What is the best way to protect marine corridors in your opinion?

7. How would you describe the relationship between the DNER and commercial fishermen?

8. In Maternillo, we noticed several vessels offshore that were left abandoned. Are their any plans to clean these up/prevent this from happening?

Ernesto Diaz Interview Summary

Attending: Jim Doucet, Dave Giebenhain, Marina Gurbanov, Caitlin Slezycki

Location: Department of Natural and Environmental Resources, Coastal Zone Management, Conference Room
Time: 10:00 am
Date: Thursday April 12, 2006

On Wednesday, April 12, 2006 James Doucet, David Giebenhain, Marina Gurbanov, and Caitlin Slezycki interviewed Ernesto Diaz at Puerto Rico's Department of Natural and Environmental Resources (DNER) office in Rio Piedras. Diaz works with land based sources of coral reef deterioration in the DNER. Recently, he has moved from fieldwork to working more with math models of watersheds to reduce sediment loading and land impacts on marine environments.

Diaz provided us with information that he felt would be useful for out report. He recommended visiting www.usgs.gov to download the Scientific Investigations Report 2005-5206 "Water, Sediment, and Nutrient Discharge Characteristics of Rivers in Puerto Rico and their Potential Influence on Coral Reefs." He said that there are 14 different classifications of reefs, they are listed on the CD we received. He said that we should also visit www.coralpr.net and follow the Publicaciones link and look at the links on the left side, especially Vol. 1, 2 and 3. The U.S. Coral Reef Taskforce was begun by President Clinton as an executive order. The Coral reef conservation law is a mandate to map, monitor, and use local action strategies to conserve coral reefs. He also recommended that we research 'local action strategies'. Local action strategies include land based sources, overfishing, recreational overuse (anchoring, boating, extraction, overfishing in reefs, spills, vessel groundings), and education & outreach programs.

Although Diaz stated that marinas are not the largest problem, he feels that the recreational boaters that occupy them are. There have been great mechanical impacts from recreational boaters by shipwrecks, propellers, groundings, anchors, and diving

(breaking off coral). Another type of impact is chemical, when people fish by putting chlorine in the water, but that does not happen around Puerto Rico. The recreational boaters also have played a huge part in overfishing.

When asked about laws and regulations, Diaz stated that marine safety laws are the same for recreational and commercial fishermen. Currently there are 490 DNER rangers for enforcing the regulations, 200 of them are for marine environments. These rangers are in charge of marine safety, marine regulations, marine trust, and enforcement. This amount of rangers is not nearly enough to effectively regulate the 57,000-60,000 recreational vessels registered (13,000 of those are jet skis). Of that amount, 75% of the recreational vessels are in the Northeastern coast, especially Fajardo.

There is currently a problem with the licensing system that was mentioned by Diaz. Although there was a law requiring fishing license that was implemented in 2004, it has not yet been enforced. The company that is supposed to make the licenses has not set up a good system yet. This has resulted in a gap between the law and the capabilities of the processing company. The new company is also issuing licenses in 19 coastal states and will now be doing Puerto Rico. Although the plan should be implemented by next year, there have been 100,000 applications for licenses every year and the DNER is losing money. This loss of profits could have been spent on the preservation of marine corridors. In addition to the above, there is a need for a wider range of available licenses in terms expiration. There should be licenses for recreational fishermen that vary from a one-day license (tourist) to a year-round license.

When asked about the abandoned boats that we saw in Fajardo, Diaz was concerned about this issue. Diaz mentioned that abandoned vessels in coral reef areas

need to be removed because in a hurricane they can move around and hit the coral reefs. He attributed these boats to people that leave their boats on purpose so they sink in a hurricane so that they can file an insurance claim. A good recommendation might be to add a clause to insurances that require owners to remove their sunken boats as part of receiving the claim.

When asked about possible recommendations that he felt were important to make regarding our project, Diaz had a lot of ideas. Diaz felt that education was very important. The rangers of the DNER deal with all of the regulations and enforcement, but if there is more education, there will be less need for enforcement. An investment in funding effective enforcement and education as preventative actions would be more ideal than prosecution since prosecution occurs after damage has already been done. Diaz felt that there is a great need to increase awareness through education for recreational boaters, including more visual and multimedia information.

There is a booklet for commercial fishermen with pictures and regulation sizes of different species. Diaz thinks that there should be a similar booklet for coral reef species and that both booklets should be more widely distributed free to people. This would help recently purchased boat owners who do not know enough to tell the difference between a rock and a coral reef and do not pay attention to what they are fishing, whether it is juveniles or inedible fish.

Diaz also stated that upon issue of fishing licenses, an educational program for all of the fishermen should be required. In addition to education for commercial and recreational fishermen, Diaz felt that education in school curriculum is important. Currently, the 9th grade curriculum for biology is all about marine biology and is taught

in both formal and informal ways. He felt that additional education including more in depth information on marine corridor preservation would be a positive addition to curriculum. Diaz mentioned anchoring buoys that have been put around the island. These buoys are anchored in environmentally friendly areas of the ocean floor (such as the sand) so boaters can tie up to them instead of dropping anchors. Up to three small boats (less than 22 feet long) can tie up to one buoy. Diaz suggested adding more buoys around the island.

Diaz discussed the need for better management of land based sources. Land based sources and mechanical impacts make up 85-90% of the impact on coral reefs. If we want to preserve reefs, we need to decrease land-based impact.

An additional recommendation Diaz felt is important is to make companies aware of the necessity for marine corridors. The DNER want allies for protecting the reefs, they are marketing reefs as protection against natural disasters. They are a good investment for banks, insurance companies, developers, tour operators, marina owners, hotel owners, and other landowners because they decrease the damage to their buildings during storm surges. Diaz suggests that they all be educated to protect their investment, funding, and wealth.

After providing us with all this information, we asked Diaz if he could provide us with some contacts that we could interview in the future. He suggested that we speak with Aida Rosario and Daniel Matos from the fisheries lab, Walter Padilla from the Department of Agriculture, and Edgardo Ojeda from the University of Puerto Rico. We then thanked him for his time and left.

Graciela Garcia Interview Protocol

1. What is the name of the contact from NOAA whom we are meeting in Fajardo?

2. Do the fishermen in Fajardo mainly do commercial or subsistence fishing?

3. Where exactly are the fishermen fishing in Fajardo? How close to shore?

4. Can you define 'coral reef' fish for us?

5. Can you look at our questions and translations for fishermen and dive shop managers?

6. Could you set up contacts for us with dive shops or at least give us a list of shops in Fajardo?

7. Do you have any contacts in the government (local, federal, NOAA, coast guard, etc) that are concerned with marine environments?

Graciela Garcia Interview Summary

Attending: Jim Doucet, Dave Giebenhain, Marina Gurbanov, Caitlin Slezycki, Maritza Barreto
Location: Caribbean Fishery Management Council Office
Time: 2:00 p.m.
Date: Thursday March 23, 2006

On Thursday, March 23, 2006 James Doucet, David Giebenhain, Marina Gurbanov, and Caitlin Slezycki performed an interview with Graciela Garcia, our National Oceanic and Atmospheric Administration (NOAA) and Caribbean Fishery Management Council (CFMC) contact. This interview, held at Puerto Rico CFMC's headquarters in Hato Rey, helped provide with a great deal of information that will help us complete several of our objectives leading us to completion of our final goal.

Initially, we were provided with fish catch data from different fishing clubs in Fajardo. We were informed that we would be focusing on three fishing clubs (Maternillo, Las Croabas, and Sardinera) and four types of species including the Yellowtail Snapper, Red Hind, Queen Conch, and Spiny Lobster. Research on data

trends will help us determine the connection between marine corridor health and fish populations from 1986 to present. Graciela Garcia recommended that we first determine the trends in catches of the chosen species and then present them to fishermen when we interviewed them. She recommended that we find out where the fishermen are fishing exactly. It was suggested that we take charts of the waters surrounding Puerto Rico to interviews so that interviewees could color on the maps and show the areas they have been fishing. She also mentioned that our contact in the Fajardo area fishing villages was port agent Jesus Leon. Jesus was assigned to take our group around to both fishing villages and SCUBA shops where we could conduct our interviews.

We were also given an abundant amount of information on individual species, laws and regulations, SCUBA diving, and marinas to help support information presented in our report.

In addition to providing us with documents, Graciela Garcia mentioned several people that we could contact for further information regarding our project. She recommended that we speak with Professor Hernandez and Professor Pizzini of the University of Puerto Rico.

After Graciela Garcia graciously gave us many documents to review and research she agreed to look at our questions and translations for fishermen and dive shop managers. We thanked her for her time and left.

Manuel Valdes Pizzini Interview Protocol

1. What type of studies have you performed on coral reef health in Puerto Rico?
2. What is the current status of coral reef health in Puerto Rico?
3. What is the current status of coral reef health in Fajardo?
4. What do you feel is the importance of the connection?

5. In relation to our project, what groups, associations, etc. that are knowledgeable about c oral reefs do you feel would be helpful in contacting or researching?
6. How will changes in these ecosystems affect the people of Puerto Rico?
7. Do you have any recommendations on possible ways of educating the fishermen or developers?
8. Do you have any additional recommendations?

Manuel Valdes Pizzini Interview Summary

Attending: Jim Doucet, Dave Giebenhain, Marina Gurbanov, Caitlin Slezycki
Location: La Tortulia book store in Rio Piedras
Time: 11:30 a.m.
Date: Thursday April 4, 2006

On Monday, April 4, 2006 Jim Doucet, Dave Giebenhain, Marina Gurbanov, and Caitlin Slezycki interviewed Professor Manuel Valdez Pizzini, Associate Dean of College of Arts and Science at the University of Puerto Rico – Mayaguez. His area of expertise is anthropology in the field of marine ecosystems.

After meeting at a bookstore near the University of Puerto Rico – Rio Piedras campus and going over introductions, we got into the bulk of the interview. The first question asked was what he thought the current status of coral reefs in Puerto Rico was. He replied that although he is not an expert on the scientific aspect of the reefs, he was feeling very pessimistic. Recently there have been large amounts of coral bleaching and reductions in overall reef areas. He thinks that the reason for this is the proximity of the reefs to the highly developing coastal regions. The sedimentation and silt associated with development and construction erodes into both the Caribbean itself as well as many rivers that flow into it. There is a report of sedimentation and its effects on Puerto Rico that he sent us via email. Increased development also brings increased waste and sewage, which also often flows into Caribbean bound rivers. One main reason development has become

such a problem is the Puerto Rican laws regarding the topic. Most of these laws concentrate on the preservation of the land during development and do not take the surrounding marine habitats into account. In addition, the tax system favors home owners due to the fact that interest owned is tax deductible, which catalyzes beach from condo and home construction.

In response to the question of whether or not fishing has had a dramatic impact on the marine habitats, he had a wealth of information. He thought that the industry had much less of an impact than many publications make it out to be. Although it does contribute to the problem, it is much less of a factor in comparison to unsustainable development and sedimentation among others.

Professor Valdez-Pizzini also noted that our data almost surely is not completely accurate. Regarding the fish catch data, it does not include any recreational fish catches, and it is also very possible that the commercial fishermen skew the data before they send it to the CFMC.

The professor also had numerous recommendations on who to educate and what they need to know. As previously mentioned, the developers and lawmakers are the biggest deciding factor for the future well being of marine corridors and must somehow become educated. Also, despite the fact that he did not think that fishermen were the big problem, he did not think it could hurt to provide for them some educational devices. The main problem is that these groups do not fully understand and must learn the mechanics of how ecosystems work, how they can be affected, and the value of sustainable development.

Throughout the interview, professor Valdez-Pizzini also gave us numerous other contacts that might be good sources of information. The first was Richard Appeldoorn - a professor at Mayaguez. He also recommended we contact Evelio at the DNER. He has an intern that has developed a plan similar to what we are working on. Aida Rosario is the head person at the fisheries lab in Mayaguez. The final possible source that the professor gave us was Ernesto Diaz – the administrator of the DNER. After some closing remarks, we thanked professor Valdez-Pizzini and left.

Appendix B – Fishermen Interviews

Questionnaire for Fishermen

1. What kind of fishing do you do?
    a. commercial full-time
    b. commercial part-time
    c. subsistence (for food)
    d. pleasure

    1. ¿Qué tipo de pesca realiza?
    a. comercial a tiempo completo
    b. comercial a tiempo parcial
    c. solo para sustento, no para vender
    d. para divertirse

2. How long is the boat that you fish on?
    a. 0-20 feet
    b. 20-50 feet
    c. 50+ feet

    2. ¿Cuántos pies de extensión tiene su embarcación?
    a. 0-20 pies
    b. 20-50 pies
    c. 50 o más pies

3. What type of fishing gear do you use? (circle all that apply)
    a. Cast nets
    b. SCUBA diving
    c. Other nets
    d. Pots
    e. Rod and reel
    f. Seines
    g. Vertical lines

    3. ¿Qué tipo de equipo de pesca utiliza? (circule todos los que apliquen)
    a. redes
    b. SCUBA
    c. otras redes
    d. olla - pot
    e. caña y carrete
    f. seines????
    g. línea vertical

4. Where do you fish? (circle all that apply). Show on the chart.
    a. Shoreline
    b. Continental shelf
    c. Shelf edge

d. Beyond the shelf

4. ¿Dónde usted pesca? (circule todos que apliquen). Marque en el mapa.

a. cerca de la orilla
b. plataforma insular
c. Veril
d. Fuera del área del veril

5. How often do you fish?
   a. Every day
   b. 5-6 days a week
   c. 3-4 days a week
   d. 1-2 days a week
   e. 1 day every two weeks
   f. Less (specify)

5. ¿Cuántos días en la semana usted pesca?

a. todos los días
b. 5-6 veces por semana
c. 3-4 veces por semana
d. 1-2 veces por semana
e. 1 día por cada dos semanas
f. menos (específique)

6. Have you seen changes in coral reefs, sea grasses, and/or mangroves over time? If so, please explain.

6. ¿Ha visto cambios en los arrecifes de coral, hierbas marinas, y/o mangles a través del tiempo que usted pesca? (Por favor, explique).

7. Is there any decrease in fish catches that is abnormal?
   a. If so, how long has this been going on?
   b. Are specific species being affected more than others are?
   c. Is this occurring in a specific location?

7. ¿A identificado usted alguna reducción en la captura pesca que sea anormal *en los pasados años*?

a. Si hay, ¿cuándo ocurrió?
b. ¿Hay especies que sean afectado más que otras?
c. ¿Está reducción está ocurriendo en un lugar específico?

8. Where do juvenile fish live? Do you fish there?

8. ¿Dónde se ubican mayormente los peces juveniles? ¿Usted pesca allí?

9. Have you noticed any connection between coral reefs, mangroves, and/or sea grasses? If so, please explain.

9. ¿Ha notado alguna conexión entre arrecife de coral, mangle, y/o hierbas marinas? Si hay, por favor explique.

Fishermen Interview Summaries

Maternillo (1)

3/30/06

Fisherman for 25 years
Commercial Full-Time
Fishes on a boat less than 20 feet
Fishing Gear: cast nets, SCUBA, rod and reel, vertical lines
Fishing Locations: Shelf edge, beyond the shelf
Fishes 3-4 days a week

Fishes for lobster/queen conch to approximately 120 feet using SCUBA, multiple tanks at a time. Also fishes from 20-60 feed by skin diving. Uses a device called a lasso to grab lobsters by the tail.

Measures all fish when caught or trapped, releases if they are too small.

Changes in corridors:
Sport fishermen and pleasure boats doing a large amount of damage to reefs. They do not know the areas where there are corals so they drop anchor on them, destroying them. There are seven marinas in the area, all used by pleasure boating or sport fishing. Fishermen know locations of reefs/other vital areas. Fishermen drop anchor in sand and drag anchor through sand.

Sees trash near reefs when diving.
Some corals are taking over other corals. Lots of bleached/white/dead coral.
Mangroves that were growing are often cut to add hotels or marinas.

Boats in marinas and old, abandoned boats leaking oil/gasoline/diesel. Can see the spillage floating in the water. Island across from Maternillo has many abandoned boats "boat graveyard."

Lots of sedimentation on reefs. Floats in from nearby river. In walking there are about 8 inches of sediment in areas near the river. Lots of construction upstream that is feeding it.

Changes in fishing:
New marinas causing decrease in fish in area. Great decrease in the number of fish caught in the area over the past 25 years. 25 years ago there were only two marinas.

Fish/bait much further out than before. Fish moving away from shore areas toward open waters.
Lobsters and queen conch still plentiful though you need to go further out.

Every year there is a 3 month period when you cannot fish QC. Other periods for other fish. Thinks this is a good thing so stocks can replenish.

Yellowtail snapper huge decrease in close areas. Need to travel 5-10 miles out.
Kingfish moving out with bait.

Juveniles:
Lots of smaller fish in mangroves/reefs. Juvenile lobsters live in mangroves.

Sport fishermen spearfish in reefs/seagrasses. Will spear anything they see, even if they are juveniles. They do this mostly for enjoyment and rarely eat the fish they catch.

Crabs live good amount of mangroves. Crabs disappearing not from overfishing but from lack of habitat.

Other notes:
Many problems with the system.
Must be 18+ to go out on a fishing boat. Could not take his son out fishing because he was not old enough.
Takes 3-4 months to get a license renewed. Renewals must be done every year.
Need separate license for fish/carrucho/lobster

Recursos naturales are supposed to safeguard areas. They bother fishermen who are obeying rules but do nothing to sport fishermen who are doing all the damage. Attributed this to money.

Building another marina in the area for resort use/sport fishermen.

Messed up dock in Maternillo, government will not fix. Broken since hurricane George.

Trying to move fishermen out of area to add another resort.

Sardinera (2)

3/30/06

Commercial Full-Time
Fishes on a boat 20-50 feet.
Fishes using SCUBA only.
Fishes on shelf edge.
Fishes 3-4 days a week.

Changes in corridors:
Has not noticed any change.

Marinas kill mangroves and reefs in the areas.

Anchors from boats cause great damage to reefs.

Changes in fishing:
Has not noticed any change.

Juveniles:
Many juvenile fish in shelf edge.

Recognizes the importance of connection or marine corridors.

Mangroves offer shelter from larger fish. Also act as entrances/exits to cays. Offers protection of smaller fish from predators. They grow up then the water rises and the fish are able to leave. Most of the cays in Fajardo are protected by mangrove entrances.

Other notes:

Las Croabas (3)

3/30/06

Commercial Full Time
Fishes on boat of 24 feet.
Fishes with nets, cages, boxes.
Fishes close to the shelf, approximately 78 miles from shore.
Fishes 2 nights per week.

Changes in corridors:
Development has changed corridors greatly over the past 30 years.

Mangroves are cut down to develop/add marinas.

Marinas are not affecting reefs.

Very few mangroves left in areas.

No connection exists between corridors due to the destruction of the mangroves.

Changes in fishing:
No noticeable changes.

No change in location for QC/lobsters.

Juveniles:
Live in mangroves/reefs.

Sharks are eating the juvenile fish.

Other notes:
Angry about new regulation that requires them to throw away dead fish.

Hurricanes destroy boats, but if your boat makes it you get lots more fish.

Croabas (4)

3/30/06

Has not fished for approximately 1-2 years.
Works in the fishing center of the village.
Was a Full Time Commercial fisherman
Worked on a boat of 20-50 feet.
Used nets, traps.
Fished on shelf.
Fished 3-4 days a week.

Changes in corridors:
Great deal of change.

Many changes in reefs.

Changes in fishing:
Lobster virtually disappeared from original area.

Less fish in the last 10 years.

Juveniles:
Living in reefs.

Other notes:
Did not think there was a connection between fish populations and mangrove health.

Made most of the traps used in the fishing village.

Showed us a shark.

Croabas (5)

3/30/06

Commercial Full-Time
Chairman of fishing village in Las Croabas
Fishes on a 22 foot boat.
Fishes using lines and traps
Fishes on shelf near Culebra
Fishes 3-4 times a week.

Changes in corridors:
Has noticed changes.

Mangroves pretty much unaffected by pollution.

People lie about the levels of contamination.

Private boat owners breaking corals, government does not do anything. Giant boats drag anchors across corals. Fishermen know to anchor in sand.

Many marinas in the area.

Corals need to be in clean water to live.

Changes in fishing:
Amounts of some species have decreased.

Caused by contamination/pollution from marinas dumping chemicals into the sea.

Good corals have lots of fish. Fish move if corals are damaged.

Overall, the state of fishing is pretty good.

Juveniles:
Smaller fish near the shore. Fish are moving away from shore areas.

Living in the grasses and the corals.

Other notes:
Does not think there is a connection between marine corridors as mangroves are mostly on land.

Was in a movie about fishing in the 50's. Could not remember the name of it though.

Croabas (6)

3/30/06

Commercial Full-Time
Fished in a boat of 20-50 feet
Fished mainly using boxes
Fished outside of the shelf area.
Fished 1-2 times per week.

Changes in corridors:
Has not noticed many changes.

Changes in fish catches:
Lots of change. 700lbs before 400lbs now.

Change occurring in all of Puerto Rico.

Lobsters slowly decreasing.

Fish in the sea are disappearing.

Lobster 20 years ago 150-200 lbs. Now 40-50 lbs.

Juveniles:
Living in corals. He takes people out on boats to see corals/fish.

Not many fish living in mangroves.

Other notes:
We are in the final time. World War III is coming to end it all.

DNER (7)

3/30/06

Only sport fisherman
Fishes on a boat less than 20 feet.
Fishes using nets, rod and reel, vertical lines.
Fishes outside of the shelf area.
Fishes approximately once every two weeks.

Changes in corridors:
Has noticed changes.
Mostly from contamination from boats.
Also from contamination from rivers.

Changes in fishing:

Juveniles:

Other notes:
Did not notice a large connection. Some species enter mangroves for protection while others use reefs for protection. Seems to be more of a connection with reproducing fish than with fish seeking protection.

Works in DNER office.

Maternillo (8)

4/21/2006
Chairman of Maternillo Fishing Village
Part time commercial fisherman
Fishes on a boat 22 feet
Fishes near shelf area

Changes in corridors:
Reefs are deteriorating. Has seen many bleached reefs. Dying or already dead.
Most problems in past 10 years.

Being damaged around Fajardo area.
Also being damaged around keys by recreational boats.

Large marinas have taken over coast.
Ferry to Culebra and Vieques also pollutes water, forces fish further out to sea.

On holidays like fourth of July many boats go out to keys. Around 5000 anchors being dropped doing damage.
Many recreational fishermen fishing in reefs.

There are mangroves there but they are more land based than usual.
Construction project still destroying mangroves
The DNER should do more to stop the destruction of mangroves by development.

Changes in fishing:
Fishing further away from shore because of contamination, coastal problems.
Could find many more fish near Icacos, Palomino, Palominito before.
Have to go out five or more miles.

Showed him DNER fishing booklet. Said he had seen it many times and had one. Most information was correct except for Chillo. Said they should be able to catch it at 11 inches and the book says 16 inches. He says there are a large number of fish in between this range.

Beda on conch works really well. Should increase the amount of time these last and increase the quota for the number of conch that can be taken on each trip. Currently only allowed 50 per day.

Other notes:
Connection between marine corridors is important.
Fish reproduce in mangroves, they protect them. Mangroves are connected with keys and seagrass.

Many more sediments along river.
Maternillo has more exposure to waves, could be reason for sediment.

Rising sea temperature is not a noticeable problem.

Area for dead boats, Isleta Marina, used to be completely surrounded by yellow mangroves. Two islands were joined together by humans, hurricanes separated them again. First marina on island.

Information book about reefs/mangroves/seagrasses would be a great help.
Wants to make it possible to allow people under 18 to learn to fish. Need to be trained while they are younger.

Possibly have licensing process certified by administrators of fishing villages to prevent people who really are not commercial fishermen to receive their benefits. Many people lie about this.

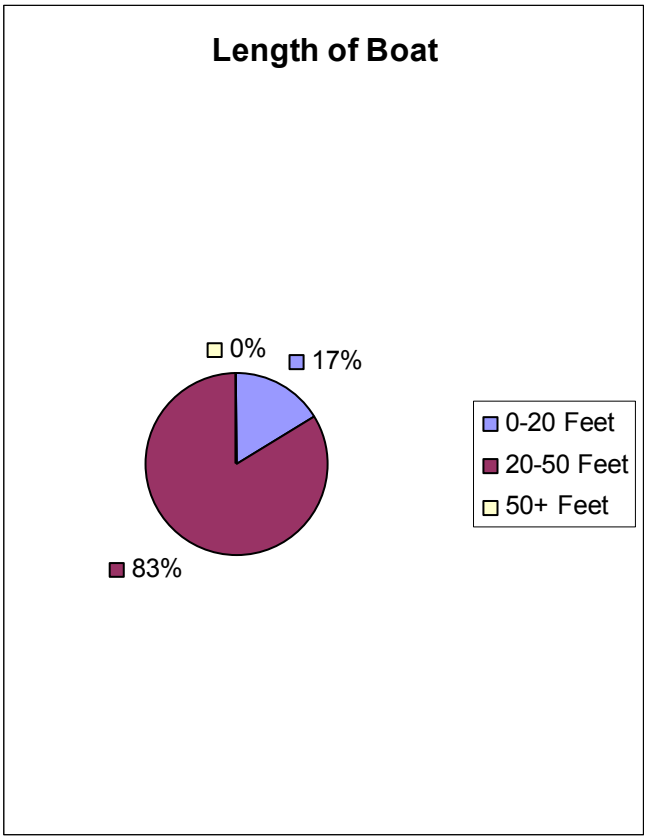
Appendix C – Visual Representation of Fishermen Interviews

Question 1: What kind of fishing do you do?

	Maternillo	Sardinera	Las Croabas	**Total**
Commercial Full-Time	1	1	4	**6**
Commercial Part-Time	1	0	0	**1**
Subsistence (For Food)	0	0	0	**0**
Pleasure	0	0	1	**1**

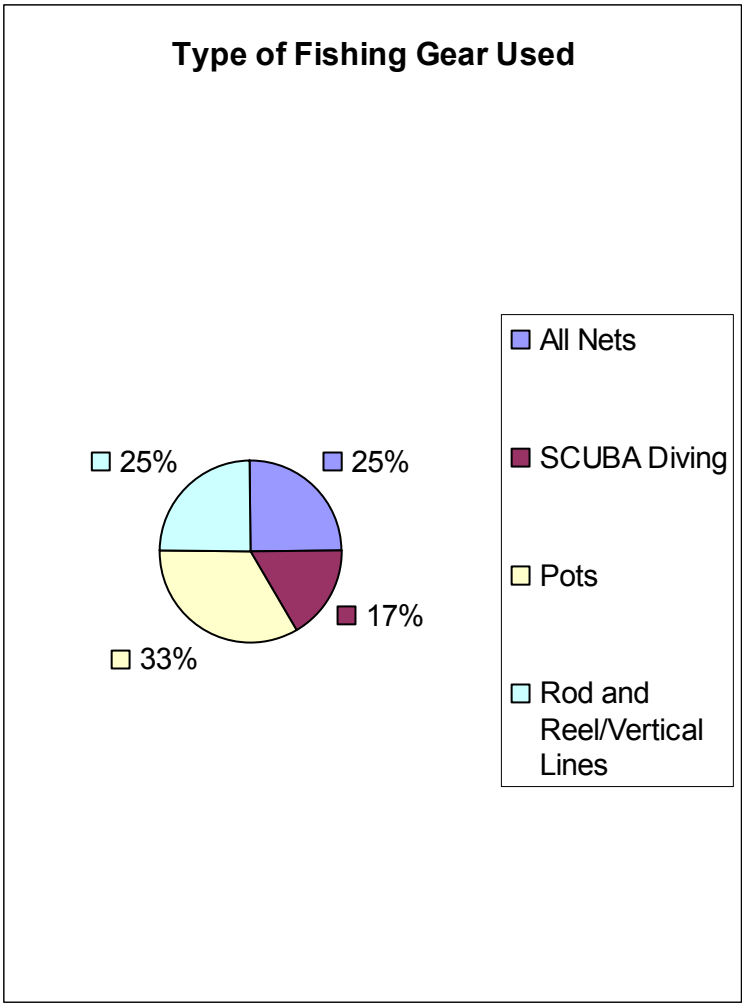
Question 2: How long is the boat that you fish on?*

	Maternillo	Sardinera	Las Croabas	**Total**
0-20 Feet	1	0	0	**1**
20-50 Feet	0	1	4	**5**
50+ Feet	0	0	0	**0**



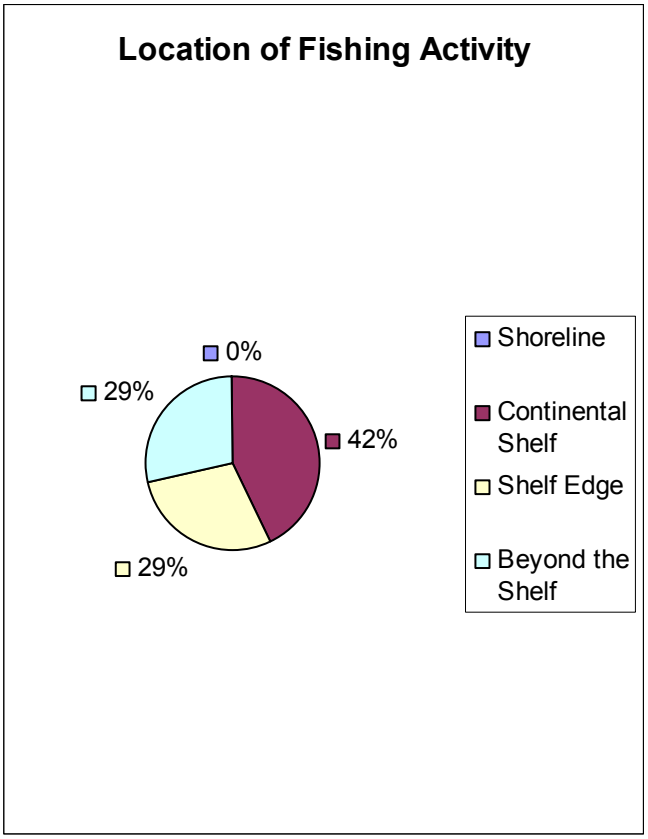
Question 3: What type of fishing gear do you use?*

	Maternillo	Sardinera	Las Croabas	**Total**
All Nets	1	0	2	**3**
SCUBA Diving	1	1	0	**2**
Pots	0	0	4	**4**
Rod and Reel/Vertical Lines	2	0	1	**3**



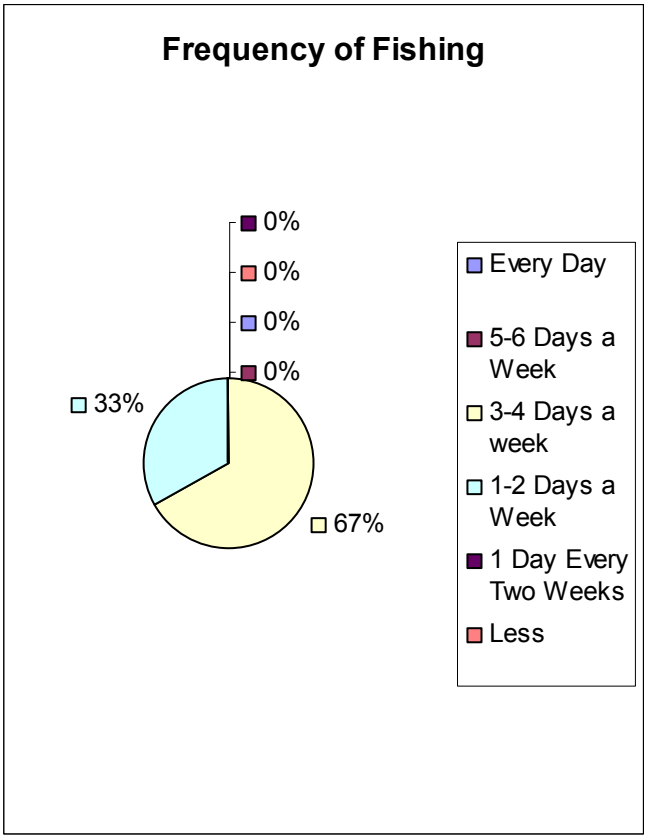
Question 4: Where do you fish?*

	Maternillo	Sardinera	Las Croabas	**Total**
Shoreline	0	0	0	**0**
Continental Shelf	0	0	3	**3**
Shelf Edge	1	1	0	**2**
Beyond the Shelf	1	0	1	**2**



Question 5: How often do you fish?*

	Maternillo	Sardinera	Las Croabas	**Total**
Every Day	0	0	0	**0**
5-6 Days a Week	0	0	0	**0**
3-4 Days a week	1	1	2	**4**
1-2 Days a Week	0	0	2	**2**
1 Day Every Two Weeks	0	0	0	**0**
Less	0	0	0	**0**



*Note: Data analyses of questions 2-5 are based on the responses of only full-time commercial fishermen (6 Fishermen Total) from Maternillo, Sardinera, and Las Croabas. Graphs are based on the totals from Maternillo, Sardinera, and Las Croabas.

Appendix D – Dive Shop Interviews

Questionnaire for Dive Shops

1. Do customers have to be SCUBA certified before a dive? Explain.
   -If not, how do you prepare them for the dive?
   ¿Los clientes necesitan tener una certificado de SCUBA antes de bucear? Si no, ¿como usted se lo prepara?

2. What kind of other instruction do you provide?
   ¿Qué otros tipos de adiestramientos usted proporciona?

3. Do you also provide snorkeling equipment and instruction?
   ¿Usted también proporciona equipo y adiestramiento para snorkel?

4. What are your rules for interaction with coral reefs and other marine ecosystems?
   ¿Cuáles son las reglas que usted sigue cuando interacciona en arrecifes de coral y otros ecosistemas marinos?

5. How do you enforce the rules?
   ¿Cómo hace cumplir las reglas?

6. Do you send a guide/diver with the customer?
   ¿Usted envia un guía o buzo con los clientes?

7. Do you let certified divers dive without a guide?
   ¿Permite que los buzos certificados buceen sin un guía?

8. In what locations do you have dives?
   ¿En qué lugares usted realiza buceos?

9. Do you offer any pleasure fishing activities?
   -If so, where do you fish and what rules are in place to protect marine ecosystems?
   ¿Ofrece actividades de pesca recreativa?
   -Si contesto sí, ¿dónde pesca y qué reglas sigue para proteger los ecosistemas marinos?

10. Have you seen changes in coral reefs over time? What are they?
    ¿Ha identificado cambios en los arrecifes de coral durante el período que lleva buceando? ¿Cuáles son?

11. Do you think coral reefs need to be protected? What can be done to protect them?
    ¿Piensa usted que los arrecifes de coral necesitan ser protegidos? ¿Qué se puede hacer para protegerlos?

Dive Shop Interview Summaries

Dive Shop (1)

3/30/06

Dive instructor/runs dive shop.
Diver for 20 years, instructor for 15.

People can not dive without certification. He does teach a training class. For uncertified people, for each people that go down for a dive, one must be an instructor. There are 43 different levels of certification. He trains people in groups of 4-6. Takes them all out to areas in the sand, not to places with corals. They are not allowed to touch anything.

When he goes with certified people, they are very strict about not touching or standing on corals. He does not let people wear gloves because it tempts them to touch more things.

Protection of corals and respect for the environment is very important.

Rents equipment only to people with SCUBA certification cards. Will take groups of certified people out or they can go out on their own.

There are corals down to 120 feet.

Lobsters move to and from shore with changes in water temperature. During summer they go deeper and they come shallower in the winter.

Noticed lots of sedimentation and bleached corals in many areas. He still noticed lots of fish living in these areas.

Works at marinas in his free time. Notices water flowing down from construction into the sea. The amount of pollution is regulated by the EPA but not enforced. Affects reefs more than other things.

Talked about water treatment facilities. Had a second stage plant but it was not working properly. Now the water is not filtered properly. New development, but nothing done about the treatment facilities. Again, EPA doing nothing.

Dive Shop (2)

4/21/2006

All divers must be certified before they can rent equipment on their own.

He teaches a brief class to teach divers then goes along with them. He teaches them basic things like hand signals.

Customers are not allowed to touch reefs or fish. There are several poisonous fish.

Never allows the use of gloves to prevent people touching reefs.

Does offer advanced classes to get certification. PADI diving class.

Rents snorkeling gear as well as SCUBA gear.

Never anchors boat on reefs, only in sand. In areas with reefs, uses buoys to hold boat in place.

Will rent equipment to people to dive alone if they are certified and know the area.

Has noticed changes in reefs. In past year has seen more bleached coral than ever before.

Noticed changes in temperature of the water.

Appendix E – Interviews Done Before Coming to Puerto Rico

Lauren Mathews Interview Protocol

1. What type of studies did you perform last year in Puerto Rico?

2. Could you define for us, your understanding of what the term "marine corridors" means?

3. Are you aware of the connection between coral reefs, mangroves, and sea grasses?

4. What do you feel is the importance of the connection, specifically in Puerto Rico?

5. Are there any specific methods for establishing a relationship between coral reefs, mangroves, and sea grasses?

6. What are the social implications with regards to this topic?

7. Do other Caribbean islands have similar problems?

8. Are there any resources you can recommend?

9. Do you have any suggestions for us for what we should do/who we should talk to in Puerto Rico?

10. Could you provide us with additional maps or data concerning marine corridors?

Lauren Mathews Interview Summary

Attending: Jim Doucet, Dave Giebenhain, Caitlin Slezycki
Location: WPI SL 211
Time: 1:00 pm
Date: February 10, 2006

On Friday, February 10, 2006 Jim Doucet, Caitlin Slezycki, and Dave Giebenhain interviewed Lauren Mathews, assistant professor of biology at WPI. We thought she would be a good resource as she has studied marine environments in the past and was also an advisor for the Puerto Rico IQP center last year.

The interview started with our IQP group introducing ourselves and stating our problem and goals. Following this, we got into the bulk of the interview. We found out that within the field of biology, Professor Mathews is specifically an ecologist, usually studying the genetic differences between populations of shrimp to analyze their evolutionary relationships.

In asking Professor Mathews about what she thought the term "marine corridor" might mean, she related it to what corridor usually meant – a pathway for plants and animals to travel from one habitat to another. Conclusively then, a marine corridor is a pathway of the sea that allows species to travel from one location to another without leaving its natural environment.

In doing many studies in marine environments, Professor Mathews had some insight on the connection between mangroves, coral reefs, and seagrasses. To her knowledge, those habitats are not isolated at all. Usually they border one another. Non-fish species usually move from one to another via ocean currents; because of this, it is hard to quantify how interrelated ocean ecosystems are. Although she is admittedly not an expert on fish, her thoughts are that most coral reef fish spend their entire lives there, and the connection between habitats may not be as strong as we think. Mangroves and seagrasses are known nurseries, but not necessarily for coral reef fish. One idea she had for determining the level of connection that exists was to compare which species use mangroves and seagrasses as nurseries and which species live their adult lives in coral reefs.

Professor Mathews also had some insight on what the social aspect of the project might be. She thought that the term corridor meant that there was some concern that fish

were not able to make the connection between the habitats and that the possible cause for this was anthropogenic. The social part that we could concentrate on would be that if this is really happening, how acceptable to the locals it would be to try to implement restrictions on these environments to aid preservation.

She did not know of any other good resources in the area who we could interview. However, she did recommend that we look at the MPA IQP that was written last year. We told her that we have done this already, and she suggested that we should then talk to Marty Driggs, one of the authors of the IQP. That brought the interview to a close. After some closing remarks, we thanked her and left.

Lauren Mathews Interview Transcript

Date: Friday, February 10, 2006
Time: 1:00 pm
Location: Worcester Polytechnic Institute, Salisbury Labs, Room 209
Interviewers: James Doucet (J); Dave Giebenhain (D); Caitlin Slezycki (C)
Interviewee: Lauren M. Mathews (L), Assistant Professor of Biology and Biotechnology, Worcester Polytechnic Institute

C: My name is Caitlin, and this is Jim and Dave. Do you mind if we tape the interview?

L: No, not at all.

C: OK, we are going to Puerto Rico for our IQP and the problem that we are trying to address is to find the correlation between coral reefs, mangroves, and seagrasses and determine how they affect each other and the relation that they have in forming marine corridors. We are also concerned with how aware the people of Puerto Rico are of the marine corridors and their importance in the environment.

J: A lot of research has been done on each of the topics individually but nothing has really been done under one uniform term between the three.

L: OK, so is this purely an ecological study or tell me what the social part of this project is as you see it now.

J: Well, I think our liaison in Puerto Rico is going to concentrate more on the biology aspect but since it is an IQP I think we are suppose to concentrate on the social aspect as well.

L: Right.

J: so, we're going to try to interview fishermen and people in the area and try to figure out if their aware of what they need to do to preserve these things and if they're aware of the importance of them.

L: OK, who is your liaison?

J: Maritza Barreto.

D: Are you familiar with her at all?

L: No, is she a UPR?

J: Yes, UPR Rio Piedras.

L: OK.

C: Professor Peet, our advisor, mentioned you and that you went to Puerto Rico last year and that you might be familiar with some of the stuff that we are researching. We were wondering what kind of studies that you did last year in Puerto Rico.

L: Um, I am assuming that you mean outside of IQP advising, my own research.

C: Yes.

L: Um, so I am an ecologist in general and the project that I was working on down in the Caribbean is a marine ecology project looking at population genetics and population connectivity of some tropical marine shrimp. So Puerto Rico is one of my study sites in the Caribbean. Mostly I was doing collections down their and then I bring them up here and I analyze them genetically and find out how populations are related to each other in an evolutionary sense. That was that project essentially.

C: Dave, do you remember that project that you researched for the IQP review?

D: Yes.

C: She might be familiar with it and I was wondering if you had any questions on the information.

D: Well, I read an IQP that we had to review and mine was on the marine protected areas around Puerto Rico.

L: Was the project from last year?

D: Yes.

L: OK, that was one of my groups, yeah.

D: We found a lot of similarities so I guess, I don't know, I guess I didn't think about any questions to ask specifically but, um, do you have any people that they interviewed that you though were especially helpful or anything? How familiar you are with it, I do not know.

L: I mean you may want to contact those students and their very good students. You would probably want to contact, you could contact any of them, but probably Marty Driggs.

C: Yes, Mary Driggs, I have already discussed that with him.

L: Yeah, so, uh, if you can get him to give you half an hour or something, he might be helpful.

D: OK.

J: How do you think we could use the study of different populations in this area to come up with a correlation between the three.

L: Well, so, I am still a little unclear on, this looks like a very biological project to me and I know that your advisors are going to push you guys on the social components. So I do not think that you will be trying to answer that question. I think you will be more dealing with the local communities. So, why do not I… I have taken a look ahead at some of your questions… um, I will tell you, let me try to address number two, the meaning of marine corridors. This is an interesting question. Um, in the field of ecology the term "corridor" is usually used in a management sense and I have only ever seen it applied to terrestrial habitats basically and the idea is that as people start doing more development, we start fragmenting habitats quite a bit, as I'm sure you're all aware it happens quite often here in Massachusetts. And most species, most native species of plants and animals do not like to be near human development, obviously there are exceptions (robins and squirrels and whatever is living in your backyard) but generally most native species do not like to be near development. And they also do not… well that is another topic. But, so, if you have a habitat that has been fragmented so that what use to be one big forest is now entirely developed except for two little tiny patches, those two patches now are going to be completely isolated from one another. And if, there are all sorts of things that can go wrong when you have patches that are completely isolated that I don't want to get into too much technical detail but if you just think about what happens if some disaster happens to one patch and wipes out all the individuals there, then that patch is essentially useless 'cause no individuals can get to the other patch from the one

over here because there is no place that they can go. They cannot cross over the mini-mall, they are not going to do that. So, the concept of a corridor, um, is that when we plan development, we plan it such there are areas that we set aside to be naturally habitats, any sort of preserve, those are always connected by some, what we call corridor of appropriate habitat so if you have a species that wants to live in a forest and it does not want to come out of that forest it can then migrate between two patches through this area of corridor. This is not necessarily, I am not sure how the term is being using in marine habitats because marine systems are different in marine systems most species have complex life history where they have larval stages. So juveniles are in the form of larvae that are what we say, what we call pelagic, so they live in the water column and they are generally moved by currents or they can potentially swim actively. So, if you have a seagrass bed over here that is separated from a coral reef over here, it may look like there is big stretch of empty sand there but those two populations are not isolated because individuals will move as larvae between the two freely as ocean currents move them around. So, in a marine system it is a lot harder to quantify how connected populations are. And generally we think that populations are highly connected unless they are very, very, very far apart. So, that brings me to my question, what is your understanding of the term marine corridor?

J: From what our liaison said, I think she was using the term as a general collective term from coral reefs, mangroves, and seagrasses.

D: Like an overall ecosystem, you know, saying all three, because there are a lot of species of fish that might breed in one habitat and then they move into coral reefs as they get older and so they are obviously connected in that way. And she just is using marine corridors I think as something to encompass that.

J: Maybe in specific to the juvenile fish populations, you know, if the marine corridors are a place where they are safe from maybe larger predators or something like that.

L: OK, so she is probably, almost certainly thinking entirely of fish.

J: Yes.

C: It seems like it.

D: I think, it kind of seems like it.

L: Yeah, um, and that is outside my personal area of expertise. So, um, I know that mangroves and probably grasses as well are generally what we call nursery grounds for a lot of fish but, um, that is where my knowledge kind of ends because um, I would have guessed, I would have not guessed that they would be nursery ground for fish that were ultimately going to live on a coral reef. But, I may be wrong about that, I do not know. I would guess that the species that live on coral reefs probably spend their whole lives there. But, again she would know more than I do.

J: Well, we do not know that is why we are trying to find out.

L: Yeah.

J: So you are saying that that is probably not as related, like the seagrasses and mangroves.

L: Well, they are certainly are important spawning and nursery ground but I am not sure where those individuals then spend their adult lives. I guess that is the limit of my knowledge, so you have got to find that out.

C: How important are the mangroves and seagrasses to other things, such as larvae and shrimp, in helping support the coral reef fish in the ecosystem?

L: Um, well everything is interconnected. It sort of depends on the answer to the question we just came up with. So, um, I do not know what is growing up in mangroves and seagrasses. If it is larger fish that are not necessarily associated with coral reefs that does not mean that they are not affecting coral reefs because they could be transient predators that come in and eat coral reef species. I am not sure, so basically the answer to that question depends on what is actually growing up in there. Um, but I am almost certain that the connection is important, it is just a question of how far removed it is.

C: OK, do you have any recommendations on trying to find and establish relationships between those from your past experiences?

L: Um, I think, I think that this is important even if you start, even if you end up doing a project that involves mostly working with people, with the locals, I think you need to understand what the ecology is. So, um, I think you should probably either; you need to find out what species are using mangroves and grasses as nursery beds. Um, you may find somebody to interview for that, I am not sure. Um, but certainly you should be able to find that out, um by researching literature and that'll tell you a lot because then you can follow up on those species and find out how they are associated with coral reefs. And I suspect that you are going to find very different stories for lumping mangroves and seagrasses, but those are very different habitats so you are going to have to go to a few different places.

D: I found a few examples so far.

L: OK, um, species are using them?

D: Yep, and then they moved to coral reefs. I do not know, it was Caribbean Parrotfish and there was another one that was not Caribbean specific, I think it was in the Red Sea that was doing the same thing.

L: OK, do you remember the common name?

D: I have no idea.

L: Well, the only thing that I know is that Parrotfish are a coral reef species as adults. I am sort of surprised to hear that, but…

J: As an IQP advisor you were concentrating more on the social aspects of the projects, right?

L: Um, well the projects are, I mean the projects are really supposed to be focusing on all aspects.

J: Well, how can we, is there any way that we can take this project to concentrate more on the social implications? How would you recommend that?

L: Well, just from the… here is what my interpretation is of what the project probably is and have you interviewed your liaison yet?

D: Yes.

L: OK, the term 'corridors' implies to me that there is some evidence, whether it's empirical or just a concern that fish are not making it from the nursery grounds onto coral reefs. So, or the adults are not making it into the nursery grounds to spawn. One of the two, maybe both. Um, so I suspect that somebody is looking into the establishment of literally corridors where probably not boat traffic or no fishing or something that would connect those two habitats so that fish can actually migrate between those two areas. Um, so it is probably analogous, very much, to a terrestrial corridor. Um, and if that's the case, if I'm right about that, then your liaison, well the social component of your project would probably be, you know, looking at how likely is it that that's going to be, that that's going to happen and that that's going to be acceptable to the locals and so that would be my expectation. I think that you should probably, did you liaison communicate with you by email?

J: Yes, we called her on the phone and we have also been in contact through email. Everything that she sent, like she sent us maps of marine corridors and it is just a map of Puerto Rico with the coral reefs, mangroves, and seagrasses highlighted.

L: OK.

D: It is mostly all biology stuff that she sent us.

J: Yeah.

L: Yeah, so is she, she is a biologist clearly.

J: She is a marine biologist.

L: And she is going to be pushing heavily the science-y part of your IQP and your advisors are going to be pushing, pulling heavily in the other direction. So, yeah, I can tell you are prepared for it and um…

D: She is actually a marine geographer.

L: Oh, ok, interesting, maybe you will get to do some GIS or something. Um, so, you know, I am sure your advisers are telling you that she needs to understand that you need to think about the social component of this.

D: Yes.

L: But, I suggest you, you know, any of you biology majors?

C, D, J: No.

L: No, I did not think so. You should probably confess to her that you do not know anything about biology and she needs to explain to you more clearly what a marine corridor really is.

C: Yes.

J: That is one small problem that we have been having is that she…

L: Speaks biology and…

J: She speaks biology Spanish. I mean she does speak English but…

L: Are any of you fluent in Spanish?

J: Not fluent.

D: Three of us did our sufficiencies in Spanish, but we are not fluent by any means.

L: OK, so you can speak in English with her?

D: Yes.

L: OK, will not be two barriers there. You will get it, you will get it.

C: Um, with the different project sites that you worked at, we kind of asked this earlier but um, is there anyone at like UPR that you are familiar with that we should try to contact?

D: You might have some insight on this.

L: Um, you probably want to ask your liaison that. Have you asked her?

J: Yeah, she said she is also making connections for us with, what is it the Caribbean Fisheries Council, so we can speak to some fishermen.

L: Um, I am trying to think of the MPA project last year, if you want to talk to any of those people. Um, I really do not know, you probably really want to take a good look at that project. There is probably a lot of overlap there that you may want to talk to some of those people. People outside of the area, um, no you probably want to stick to people in the area because you are really interested in the social component, not the biology component.

C: How about any other people in the Worcester area that you are familiar with?

L: Um, yeah, not really, I do not think so.

C: OK.

L: This is a largely, a topic that you are going to find more useful people in Puerto Rico I think because it's very Puerto Rico specific.

C: Are you familiar with Woods Hole?

L: I am familiar with it, do not have any contacts.

C: Do you think that they might anybody?

L: If they have any ecologists on staff, you can send them an email anyway.

C: OK.

L: That might be worth it, you never know when you will find a true expert.

C: That is true.

D: I think that is about it.

J: Do you have anything else that you would like to add or recommend?

L: Um, do you know if anybody is looking into this in any other places in the Caribbean? I see that is one of your questions here.

D: She says there are.

L: There are.

D: She says there has been studies in pretty much everywhere else in the Caribbean but there has not been any in Puerto Rico and that is kind of why she has been studying this.

L: OK, um, I have, I mean I have some, I could possibly give you references but they're all going to be bio references that I don't know how useful would be to you, but I'm happy to look through my files and see what I can find.

C: That would be great.

J: Thank you.

C: You could just email those to me.

L: Yeah, sorry I just have your email , but I will send it to you.

C: Yeah, that is fine.

L: OK, and if you, if I send you anything that you think might be very useful and you want some help interpreting it from a biologist, feel free to come ask me.

C, D, J: Thank you.

L: You are welcome.

Tim Downs Interview Protocol

1. What is your experience in socio-ecological systems approaches, natural resource management, watershed stewardship, water supply and sanitation?

2. Has your research ever been applied to the Caribbean? If so, where and how?

3. What are the effects of poor water sanitation, particularly in Caribbean areas?

4. How have you used risk analysis, vulnerability and adaptation, impacts assessment in Latin American region and transitional countries in the past?

5. What have you found from these studies (causes/effects)?

6. What are the social implications with regards to this topic?

7. What have government agencies, such as NGOs and CBOs, done in attempt to solve and help prevent environmental issues?

8. Have the government agencies been cooperative in providing solutions?

9. Do you have any recommendations on approaching government agencies regarding their policies?

10. What types of science, technology, and policy tools have been adapted in transitional countries?

11. What type of science, technology, and policy tools do you feel might be useful in regards to our project?

12. Do you have any additional suggestions/thoughts/comments?

Tim Downs Interview Transcript

Date: Thursday, February 23, 2006
Time: 3:00 pm
Location: Clark University, Worcester, MA 01610-1477
Interviewers: Marina Gurbanov (M); Caitlin Slezycki (C)
Interviewee: Timothy J. Downs (T), Assistant Professor of Environmental Science & Policy, Clark University

C: I am Caitlin Slezycki and I am an electrical and computer engineer major at WPI and this is Marina.

M: I am a biomedical engineering major at WPI.

C: Do you have any questions for us to start out with?

T: Um, the project that you are doing, this is sort of part of your practical training?

C: Yes, yeah because we have a project based curriculum at WPI and this is the second one, it has to do with connecting science and technology to the society.

T: Uh huh.

C: It is part of the requirements in order to pass.

T: Alright.

C: So, we are just going to start with the problem statement. It is relatively the same as what I said in the original email. We are studying near shore marine corridors in Puerto Rico and how they are being negatively impacted. In specific, we are studying mangroves, sea grasses and coral reefs and the connection between the three of them and

trying to find what is causing their destruction, whether it be pollution, disease, tourism, urban sprawl, fishing industry as you can see there.

T: Uh huh.

C: So, we've been conducting a lot of background research regarding this topic and um, mainly focusing on those causes that I just mentioned and the goal of our project is to supply suggestions regarding how to decrease the problem and um, whether it be to government officials or to people who are in the fishing industry as you can see there. Do you want to add to that at all Marina?

M: Um, I think the focus of our project is trying to connect the people to the science, like what is happening in the marine corridors and trying to see if they understand what is going on and the relation between the three different habitats that is how we are pulling in the social aspect.

T: Uh huh, OK, good. That helps, now I can see where I can speak to that better.

C: To start off with, after reading your bio online, I saw you had experience with socio-ecological systems approaches, natural resource management, watershed stewardship, water supply and sanitation. Can you briefly explain what you have done in the past with those; in relation… you know if there is anything that strikes you as being related to our project?

T: Um, yeah maybe I can just talk about the general approach that I use for more or less any kind of project that I am involved with whether it is heath related or natural resource related. Um, it is really about bringing different stakeholder groups together, um which is certainly community sector, in your case it might be fishermen, or, you know, coastal communities, local government agencies, non profit organizations, researchers, sometimes private sector, and donor organizations that are often driving different types of development projects. So, how do you bring those different types of people together creates bases where they can actually collaborate in several different stages of a project. So, if we envision a project consisting of typically four different stages, you may have like an assessment stage trying to figure out: so, what is going on, what are the kinds of problems that are being experienced, what may be causing those problems… the sort of research um kind of assessment piece. That is the first opportunity to bring people together because more and more we recognize that there is so much complexity involved. There are cultural aspects like political, social, ecological, economic aspects. These need to be understood sufficiently and therefore we need to involve these different groups I have mentioned in really trying to understand the nature of the problem right from the beginning.

C: Uh huh.

T: And then once you can build that sufficient understanding through different types of maybe collaborative research or different methods you may use for exchange of

information and bringing information together, which very much includes indigenous knowledge of local expertise. Uh, once you have built that understanding then that can lead to planning, strategic planning. So, this is… these are kinds of problems we're dealing with, um, what are the different ways we can solve these problems, um, and what are the advantages and disadvantages of each one of those alternative approaches or solutions. So that also, you know, the planning aspect of things necessarily means that you have to consider trade off between different solutions cause there is no such thing as an ideal solution. So, you look at thing like, um, economic… you also look at economic, social, ecological impacts of different solutions and they would be both positive and negative types of impacts. Um, you are trying, you are trying to fully appreciate, um, what the implications are of choosing a particular solution, um, instead of some other solution and that is also something that needs to be done with those different groups participating. Um, so both the assessment and planning piece bring people together and foster an environment off collaboration and communication and you actually start to get to know each other and often times it opens up lines of communication that didn't exist before particularly between like government agencies and community groups, for example. And then, you know, in your planning process you're also considering, um, 'OK, so let's say we're going to, um, choose this particular solution, um, to the problem', what kinds of capacity do we need to build in order to make that solution sustainable over time and adaptive to changing conditions over time. So, the work that I do also very much involves, um, different types of capacity building. So, capacity building basically means trying to strengthen the ability of the different groups to contribute to the solution of the problem. Um, so, that's sort of built into planning and then you, you know, the next stage would be implementation and actually implementing some change in policies or practices um and then monitoring the impact of that over time. Again ideally, the monitoring links back up to assessment so that you are in an adaptive learning loop, if you like. So in general, that's the type, those are the kinds of projects that I do, you know, independent of the topic you know whether it's: we have a local project here in Worcester in environmental justice, environmental health also you know we have projects that we work on in Mexico in terms of water supply and sanitation and health risks um, we also work on natural resource management issues in East Africa and the relationship between how you change, um, maybe changing land use practices, um, and poverty and how land degradation leads to other types of development problems and environmental problems.

C: In areas like Africa or Mexico, how have you gone about approaching the locals and getting their opinions? What have you found to be the most successful in doing that?

T: Yeah, that is a very important question, it is sort of one the key challenges. Um, what we tend to do is we work through, um, local community based organizations where they exist, um, and often times they do exist in some form or another. Other times we'll actually engage in what are called participatory appraisal methods where we invite members of the community to like a town hall type meeting to discuss, in your particular case it would be the marine corridors and the negative impacts on them – so, what do people think about that, what are their opinions on it, what are their concerns about it. And they'll very often they'll maybe talk about that issue but they'll also talk about

things that they think are more important, so they'll, that's a way of brining people together just to talk about what is most important to them and listening to them. Then you listen and that's sort of like a first encounter and then what you might do based on that is structure some kind of, um, you know, focus groups or some interviews, um, maybe even begin to talk about setting up some kind of, um, working, working groups with, um, representatives of the community who are interested in this particular topic. That's where you are trying to get to the point where you have sort of a community based working group that you can be part of, that you're not leading it but you're contributing you're particular knowledge of your particular expertise, um, to their planning process, their assessment planning process. So a lot of it is, it's getting to know people, you know, meeting people, um, spending enough time talking to people so they know who you are and basically you're building trust and opening lines of communication which takes time. And that's, and that's the most precious, you know, resource you have is time and I know for you guys it's fairly short so, um, that's another reason for you know trying to identify community based organizations that already has, is well connected with residents and with people who are effected by problems and working through them maybe to set up interviews or focus groups.

C: Have you ever…

T: I may have covered a few questions through my general statements about what I do.

C: How about your communication with government agencies, have they been helpful? Are they willing to, particularly in East Africa and Mexico, are they helpful and do they want to participate in helping to prevent environmental issues?

T: Yeah. Um, the way I usually approach it is, again, I will, um, find out, uh, who are the government agencies that are responsible for these kind of issues or have a strong interest in these particular issues and try to find the best person in that organization to talk to. Often times, you know, the head of a certain division may not be the best person to talk to. So that is again where you would rely on sort of the local knowledge. I mean, I would anticipate that you would go in and you would be working with some sort of local organization, you are not being sort of plopped down there without any kind of network of any kind, hopefully.

C: We are working with the University of Puerto Rico and we also have contacts in the Caribbean Marine Fisheries Council.

T: Yeah, OK. Right, so they would be able to tell you who to talk to in different government agencies. Who the, you know, who are the government agencies to talk to and who in particular is the person to talk to. And then I would, um, I think it is just really important to be, uh, to structure your… in the way you've done this (interview protocol), have a short questionnaire, um, where you're trying to understand their perceptions of a particular issue, um, because it's almost certain they'd be different from the community sector, they're coming from a different place. Um, what are the things that they're most concerned about, what do they feel that they… what are the challenges

that they currently face as an organization, what kinds of capacity would they like to have that they don't have. In other words, um, instead of putting them in a defensive position of saying "well, why aren't you doing what you are suppose to be doing?" you… it is much more productive to, you know, what they need, what they feel, how they feel they need to be strengthened in order to do the job, um, of maybe regulating the resources usefully or something like that, what do they need as an organization that they don't currently have. And then they're kind of, they're in a more positive kind of frame of mind and you're also then getting at this capacity building issue that, you know, it's not simply that, it's too simplistic to say that the agencies don't want to respond. Often times they just don't have the capacity to respond and so you're trying to be sympathetic to that and find out if that is the case then what particular types of capacity need, need to be strengthened in order for them to be able to do their job more effectively. Um, and I would also ask them about how they work with other stakeholder groups, you know, and the challenges they face with working with community based organizations and um, other, other stakeholder groups. Because government agencies have a hard time figuring out how to do that, it is hard enough for us who, you know, are supposedly experienced in it but government agencies, that's a difficult thing for them to figure out how to do. And so you get this disconnect between the community organizations and the interest of the community and the government agencies which breeds mistrust and, you know, that is part of the political, social and political problem that exists.

C: How, um, do you have any recommendations on tying the research, governmental agencies, and community based organizations? Like how to tie them all together and get everybody on the same page, do you have any recommendation on how to go about doing that?

T: Yeah, I mean I would just, I would pull back on what I said before with thinking about, if you really want to solve this problem, um, first of all recognizing that you need to work together to actually figure out the nature of the problem because it's so complex and people do naturally understand that it's complex and so if you're expecting just one social group to solve it, it's an unrealistic expectation. And so by creating a sort of environment where your saying, you know, here's a shared problem, let's share finding a way to solve it, um, because that's the only… only by pulling our resources are we going to be able to make much process. And then you bring people in, um, to sit around a table where everybody has something to contribute and often times it's something different and then together you begin to build a sufficient understanding. And right there, as soon as you get people doing that, then the assessment, the sort of first piece of the project cycle, the assessment piece, as soon as you get people doing that, communicating with one another, sharing information, it's kind of transformative. You know, you've actually changed the dynamic and, um, my experience has been that even in societies where there is sort of a lot of mistrust, like Mexico, mistrust between social groups, um, we were able to mobilize people around issues of common urgency like water supply and sanitation and how, and by not putting them on the spot and blaming them, bringing them in and saying this is a shared problem and let's try to figure it out, and by the way we can build capacity for you as an organization then, um, then that sort of broke the usual um, cycle of sort of, um, conflict and nonproductive work. A lot of this is just basic "how do you

get people to work together in teams", people with diverse interests and they really need to invest time in understanding what those types of diverse interests are and having spaces where people can actually hear where other people are coming from. So that is sort of the people skills aspect of it.

C: Marina, do you have any further questions?

T: Actually there is one of your questions here which is about types of science and technology policy tools, um, there are, you know, a sort of assessment piece that I emphasize a lot because it has, that is where you bring people together first of all. Um, there you are using a whole range of different, what we would call research methods or research tools. Um, you know some may be more qualitative others might be more quantitative if you are looking at existing data, actually just getting a sense of what is the existing data. Often times it's going to be in different places, actually doing an inventory of, so what is it that we actually, you know, as a group of different stakeholders, what information does each person have and let's bring that all together and see what we have together collectively. Um, and then you see where the gaps are, um, and then you can think about how you fill those gaps. You know, you really want to be filling those gaps up be doing some kind of primary data gathering um, but you want to make sure that every unit of effort that you expend in that data gathering is going to yield valuable information for the planning process. So again you're approaching this from a very strategic point of view and you're using different types of techniques to gather information that my be existing or gather original information from the field and then put it together and put it in, you know, analyze it and interpret it in such a way that it's informative and helpful because often times, you know, you may spend a lot of time producing a wonderful GIS map of different health indicators or something like that but it may not be accessible to indigenous people. So how do you make these information resources speak to different audiences and so presenting the data is also very important, presenting information and having ways to discuss it. So we have to climb down off of our sort of scientific high-horse in a sense in so to make it, make the information accessible. And the way you write about things, also, um, you need to be writing, writing anything, you know, in a very simple form. You know, not with complex words and you need to be, you know, mindful of the needs of everybody to be able to understand the information you gave to them.

M: Have you ever had any trouble with communication or like different languages?

T: Um, not really. I mean, I went, when I do my work in the field I spoke Spanish, um, I had, I was well equipped in that sense. And where I've worked in areas where there are indigenous dialects spoken, again I'm working along side a local partner organization that has that local dialect skills, the local language skills just to bridge that gap. Um, so again it comes back to partnering and who you partner with. So they have, they have never been, I mean they are a challenge; they are actually a challenge for us here in Worcester where we have a lot of different ethnicities in these neighborhoods, these local neighborhoods. Um, but again we approach it by working with people who have those

language skills. So people who speak Albanian, Vietnamese, and uh Portuguese, um French, West African French and things like that.

C: Do you have any additional questions for us?

T: Um, well I just wanted to ask you, what's, what is the next step for you? Are you going to go there, when are you going, how long are you going for?

M: We are going March 11 actually.

T: Oh, OK.

M: And we are staying for about seven, seven and a half weeks.

T: Oh, good, OK. So that is quite a nice long period of time.

C: The main goal is not really to implement things; it is more to come up with suggestions to the community.

T: So it is that, the piece I was emphasizing on the assessment and beginning to do some planning. That sounds like where you could make progress.

C: So we are going to try to get that done in seven weeks.

T: Great.

C: Anything else at all?

T: No, no it sounds like a very interesting project and by the way when you were talking about causes, you know the marine corridors, possible causes pollution, disease, tourism, etc. um, it's almost always the case that there is sort of multiple causes. But, it may well be that there are certain things that are driving the degradation, maybe it is just one or two things. You know, maybe it is a particular fishing policy or a particular tourism policy that is encouraging degradation. So, um, also when you're doing that assessment piece you're gathering information on existing conditions and you're tying to understand, um, several different types of causes but also being mindful that some of them are going to be more dominant, some of them are going to be dominant perhaps um that is almost always the case when we look at environmental degradation issues. Um, they are being driven by just a small number of things and often it is policy choices that are being made by certain groups.

C: Thank you very much for your time.

T: You are welcome.

C: Nice to meet you.

T: Nice to meet you too, good luck.

Maritza Barreto Interview Protocol

1. What are your thoughts on our problem statement?

   -¿Qué piensa usted de nuestro declaración del problema?

2. What is the big societal issue behind the project?

   -¿Qué es el grande asunto para sociedad con ese problema?

3. How does the big issue manifest itself in Puerto Rico?

   -¿Comó esto asunto le manifesta en Puerto Rico?

4. What are some of the signs that show that there is a problem?

   -¿Qué son algunos indicios que hay problema?

5. What has been done to date?

   -¿Qué había hecho al día?

6. What has been the outcome?

   -¿Qué había sido el resultado?

7. What has <u>not</u> been done?

   -¿Qué no había sido todavía?

8. How could more progress be made?

   -¿Comó se podría hacer más progresos?

9. What does the future of this issue look like if nothing is done?

   -¿Qué podría ocurrir si nada sea hecho/cambiado?

10. What kind of assistance will we have in Puerto Rico?

    -¿Qué tipo de asistencia tendrémos en Puerto Rico? – coche, equipo, otra persona

11. Where does the funding come from?

    -¿Dondé los fondos son de?

12. Will we have any type of budget?

    -¿Tendrémos algun presupuesto por nuestros investigaciones?

13. What type of research will we be doing in Puerto Rico? Field work?

    -¿Qué tipo de investigaciones harémos en Puerto Rico?

        -trabajo en el campo, entrevistas, etc

14. What is your role in the organization?

    -¿Qué es su puesto en la Universidad de Puerto Rico?

        -en el programa Sea Grant?

15. Are there any resources you can recommend?

    -¿Puede recomendarnos otros recursos?

16. Do other Caribbean islands have similar problems?

    -¿Hay otros isles caribeñas con problemas similares?

17. Could you provide us with additional maps or data concerning marine corridors?

    -¿Puede darnos mapas adicionales o datos en relación con los pasillos marinos?

18. Will there be space provided for us to work?

    -¿Será un lugar donde podríamos trabajar o escribir?

19. Is there a computer lab where one of the other WPI groups could work?

    -¿Hay una habitación donde uno de otros grupos podrían trabajar a veces?

20. What is the typical dress code for women? For men?

    -¿Qué son los normas sobre la ropa que debemes llevar?

-Thank you

Maritza Barreto Interview Summary

Attending: Jim Doucet, Dave Giebenhein, Marina Gurbanov, Caitlin Slezycki
Location: WPI IGSD Hallway
Time: 4:00 pm
Date: February 6, 2006

On Monday, February 6, 2006, an interview with our liaison, Maritza Barreto, was conducted. This interview provided us with a great amount of information thus adding to our knowledge of our project. This information was useful in updating our problem statement and our sponsor description.

We began the interview by presenting our problem statement and goals. We stated that, "Near shore marine corridors in Puerto Rico are being damaged and our goal is to determine the causes of the damage around Puerto Rico and to introduce a set of recommendations for solving the problem." Maritza agreed with this statement and recommended areas where we could improve it. She emphasized that we focus the project on the connection between the coral reefs, sea grasses and mangroves.

Maritza mentioned that our research will be conducted primarily on two areas of Puerto Rico, rather than on the island as a whole. Our research will be performed by a combination of research at the University of Puerto Rico (UPR) and by taking trips to sites of interest in either her personal car or a van that UPR would provide. While at the university, we will have access to a computer and accessories in her personal office along with access to labs on campus. A teaching assistant will also be available to us. Additionally, Maritza has established connections with the Caribbean Fisheries Management Council who will provide us with fishermen to interview, observe, etc.

Maritza provided us with further details regarding our sponsor. Toyota is providing funding for our research although we are completing the project through UPR. This was initially a concern to us, as we thought this might effect our sponsor description. However, this will not effect our current sponsor description of UPR.

Overall, the interview with Maritza was very helpful. A phone conversation provided us with necessary detail in regards to what our project is, how research will be performed, and what materials and assistance will be available.

Maritza Barreto Interview Transcript

Date: Monday, February 6, 2006
Time: 4:00 pm EST
Location: Worcester Polytechnic Institute, ISGD Conference Phone
Interviewers: James Doucet (J); Dave Giebenhain (D); Marina Gurbanov (M); Caitlin Slezycki (C)
Interviewee: Project Liaison, Maritza Barreto, PhD (S), University of Puerto Rico, Marine Geologist and Geographer

S: Hello?

M: Good afternoon Dr. Brown.

S: Am I talking to a student from WPI?

M: Yes.

S: Hi, nice to meet you, you are?

M: Marina.

S: Marina, nice to meet you Marina.

J: We are all here, the four group members.

S: Dave, James, Caitlin, and Marina.

M: Yep.

S: OK, first thing my English is bad, if you do not understand something that I say, please let me know, OK?

M: OK.

J: OK, same with us, if you need us to repeat anything.

S: (laughter) OK.

D: So far so good.

M: Do you mind if we tape the conversation?

S: Yes definitely, yes.

M: Um we will begin with the problem statement, what we understand of it.

S: OK

M: So we decided that it would be: near shore marine corridors in Puerto Rico are being damaged.

S: Yes.

M: OK and our goal is to determine the causes of the damage around Puerto Rico and to introduce a set of recommendations for solving the problem.

S: Yes, this is like I read here in the email that you sent me last week.

M: Yes.

S: Yes.

D: Is that fairly correct?

S: Yes, I want, OK, I have here that the main problem is the destruction of marine corridors near Puerto Rico shores and the goal is to determine the underlying causes of marine corridor ecosystem destruction around Puerto Rico. That is the thing that you told me now.

M: Yep.

S: Yes, one of the recommendations… I do not know if you have the copies of the maps that I send to the professor?

M: Yes we do.

S: Yes, it is a map that shows different marine corridors in the near shore waters. I do not know if you know, you had, you have been to Puerto Rico before though, some of you?

M: Yes, I have been there.

S: Yes I do not know how many things that you know about Puerto Rico geography and different locations, but in this map you can see different corridors some of them in the north side of the island other in the east on the south and the west coast.

M: Mhm.

S: I don't know exactly how many marine corridors we have in the map but it's something like 10 or 11 and we call the corridors the line, eh, each side that is a line mangrove coastline with a coral reef and with a sea grass bed. These three different ecosystems are aligned and these, each time that I found this alignment, it's one corridor. Um, for your project I suggest to, I suggest for professor… I'm so bad with the names, eh, the chairman from the WPI project.

M: Peet?

S: Excuse me?

M: Professor Peet?

S: Uh, no, Susan.

J: Yes.

S: Susan, I don't remember the last name, Susan?

M: Yep.

S: I recommend her that we select older corridors around the island, we can, and I propose you, in studies with me, we can select maybe two corridors or three corridors in the northeast of Puerto Rico.

M: OK.

S: In this way, we can visit the corridor, we can interview the fishermen that I saw in your proposal, part of the email that you sent me that you want interview the fishermen or see the reason. Personally, they know about the corridors and check where with, in that you can identify a few causes of the destruction of the corridors and I feel that from all these corridors we can select maybe one or two sides in the northeast and we can work in details.

M: OK.

S: Yeah, are you agreeing with this approach?

M: It sounds good.

S: Yes, OK. First thing, you will be, all of you will be stay on San Juan city?

M: Yep.

S: And the area that I purpose for visit and talk with the fishermen is in the northeast point of the island, it is something like 45 minutes from the place where you work.

M: OK.

S: The other place, well it's not so far but as a little more difficult to visit. And I make a contact with people from Caribbean Fisheries Council and they had plans to support all things, help us to identify the fishermen and these things and they suggest me to select this specific side because it will be better to conduct research with fishermen.

M: OK.

S: But, I agree with your goal the only other thing that I suggest that is instead select all the marine corridors, maybe concentrate maybe in one, in one site at San Juan and one marine corridor at Fajardo city. Fajardo city is exactly located in the northeast point of Puerto Rico.

M: OK.

S: That's my suggestion in terms of the overall… but I agree with your approach with the goal. Yes.

M: OK, we were wondering what research has been done up to now about those?

S: Yes, well in terms of marine corridors, that's the other thing. The concept of, you know, the concept of a corridor is more used in terrestrial ecosystems, forests and land and terrestrial ones. This time it is now used many times in marine environments. I have some previous research that I don't, I'm not sure if, I sent out an email last week, I send one today, but I don't know if Dave receive it. Dave?

D: Yeah, I got it.

S: Which one? The paper in PDF format?

D: Yep.

S: OK. I start to send some papers. Some papers from some professional journals related with marine corridors that were conducted in other places. In Puerto Rico, we had a lot of research done in coral reef ecosystems, in fish populations, in mangrove but all of this research is doing apart. It's not integrated in terms of marine corridors. We just started like two or three years ago to use this concept, to apply, not to use, to apply this concept in Puerto Rico. I have a report that I done to the Caribbean Council, Caribbean Fisheries

Council, I try to send you the copy by email but it's too big. It don't go through. But, I am planning to take some images and try at least send you the writing, OK?

M: OK.

S: And then if you can send me by email your address, I can mail it as CD with the complete report.

M: OK.

S: OK? But in Puerto Rico, our, as I told you… Do you access to journals databank in your college?

M: Yes.

S: You can make a search using, for example proquest or applied sciences, are differing searches, are different databanks for sciences, applied sciences.

M: OK.

S: That you can make a search using the keyword 'marine corridor' or a 'coral reef, Puerto Rico', 'marine corridor, Puerto Rico' – you will find nothing, but you can at least go there and I have some papers that I can send you by email.

M: OK.

S: OK?

M: Mhm.

S: But, in terms of marine corridors in Puerto Rico, a few of them is one that I done work marine for the Caribbean Council. And I connect to other friend from marine science department and try to search other where because they don't use the term but ordinarily see that they… it's possibly marine corridors.

M: OK.

D: What terms do they use?

S: What?

D: What kinds of terms do they use?

S: What kind of what?

D: Terms, words.

S: Well, they, they, the thing that they've done is when they make a research with coral reef and they're just talking about coral reef ecosystems, the thing is that they, if maybe I have these two papers that analyze in their work the importance of the connection of the connectivity of the sea grasses, the mangroves, and the and the coral reef, they talk about connectivity. But the thing they don't use, the term marine corridors. The term marine corridors I took from a paper from some scientist and I don't remember the name actually now, that they done research in the Caribbean and they say marine corridors – and he define it – marine corridors are the areas where you can find a mangrove coastline that is connected with a coral reef area and it's connecting also with a sea grass bed.

M: OK.

S: That's the first paper that I really saw the use of the concept of corridors applied to marine environment. Because before I saw it for terrestrial, and it's the same thing. Terrestrial corridors are a place where ecosystems are connecting, are aligned, and are connected between them and some destruction in one of these ecosystems can affect the other ecosystems because are connected between them. But, I don't know, Dave if I send you this paper, I don't remember now, but I will recheck again my databank because one of the papers defines and applies marine corridors for marine environments.

D: Yep, I think you did send me that one.

S: Yes, OK, this paper is so important. It's very, very important. And I really found few papers that really use the term applied for marine ecosystems.

D: Maybe just to make sure you can resend that?

S: What?

M: Can you resend that?

J: Can you send that to us again maybe?

S: Yes, definitely, definitely. No, problem.

J: Thank you.

S: Yes, I will recheck again and send you again this paper and other papers that I already get from a search that I made like six months, starting six months ago.

J: OK.

S: Yes. One of the, not a chairmen, but a scientist from the Caribbean Fisheries Council told me that they know about marine corridors but not many people use the concept.

M: OK.

S: Why? I don't know, I really don't know, maybe we can check why, but I don't know. Maybe you ask to some fishermen, "OK, what do you think about marine corridors?" maybe they will tell you, "What, what's this? I don't know what you're talking about.", maybe.

D: We'll see.

S: Mhm. Yes.

M: I was wondering what kind of assistance will we have in our research.

S: What? What kind of what?

M: Assistance, like will we have access to a car, computer labs…

S: OK, OK. In terms of the UPR I have a small office. Well, it's not so small but it's not too big. Yeah, I have an office for research. And I don't have a many equipment but I have a computer eh… I have a desktop computer, a scanner, I have a portable computer that you can load DVD and you can write DVD. I have my own computer, portable that if you need in some moment record any, record a DVD, we can do it. This portable, it's using for other student also but we can, if you need it, we can organize and use it. But in my office, it's a desktop portable, we have line for internet eh… I make a contact with a Caribbean… well, we have our office, our physical office. In terms of move around, for example, when you go to the seas, with a group in my car. We are in the UPR, we will be how can I say this in English…

J: Together?

S: It's a play, I don't know how to say this in English.

M: Can you describe it in Spanish?

S: What?

M: Can you describe it in Spanish using simple words?

S: I don't understood.

J: We speak a little Spanish.

S: It's called something, a field day?

J: Field day, a field day is exactly what it is.

S: OK, you get it. OK, we have this celebration in April, and we had a van, a local van in UPR for you four move around and with a chauffeur. How can I say chauffer in English?

J, D, M, C: It's the same, chauffeur.

S: OK, with a chauffer and… I would like you to send me your schedule, when you arrive… Do you know already when you arrive to Puerto Rico?

M: Yes, March eleventh.

S: Eleventh?

M: Yes.

S: OK, because, I can't, OK on March seventeenth, this is Friday, I have planning go to a field. I would like that you or those who can go, you are, the group are four students, that's right?

J: Yes.

S: OK, I would like then, on March seventeenth, if you can go with me, I already, I have a van and I invite some other of my students. I have planning visit the southwest coast of Puerto, no, the west coast of Puerto Rico to visit a place that is a corridor.

J: OK.

S: And in this visit, maybe it's a first, you can see you know the sea grasses and the connection between this. But, eh, if you, eh, I know that you, when you be in Puerto Rico on Fridays, this is the day for the meetings, is that right?

M: What's that?

S: Each week, when you start the WPI project at Puerto Rico, you need make a, how can I say a…

J: Yep, a presentation.

S: Make a presentation weekly, that right, that's right or am I wrong?

J: OK, yeah, I think that's right. Yeah, I think we have to do that for our advisor.

S: Well, at least, that's my general agree I think with WPI.

J: OK.

S: My last time was like three years ago, and now I come back again, but I remember that my students, weekly, need to make a presentation to their professors from WPI.

J: OK.

S: And I remember it was on Friday.

M: OK.

S: But I don't know if it will be again, but based on this, we can arrange the week in the way that maybe… for us to go visit the fishermen. For me, the best day is on Friday, because on Friday I have completely free.

J: OK.

S: I can go, we can go very and stay all day, it is necessary. On Wednesday, that's my worst because I am teaching from seven to four o'clock.

J, M: OK.

S: But Friday, I want, in terms of the cars, we don't have cars. But, we be visit in my own car, you'll go with me in my car, or the arrangement that I can make with UPR, that they can wait for us. We can fix this but I can tell you for now that on April will be a bad, bad month for the UPR vans because they have a compromise already with the sports, or something like that. What more… OK, I have, we have, if you need, OK, Caribbean Fisheries told me they have planning help us connect us to make the contact with the fishermen. They have a lot of static data of fisheries from the area and they planning get all the information that you need about fisheries statistics, OK, about fish species, statistics. For example, you need, maybe you want check how species are in this area, how are the population; this kind of thing they have it. Eh, all kind of fisheries of management related questions, we have the expert there, that can tell us and they have, they make the compromise with me to help. Eh, which other things. Eh, we have a, we have a, a lab with eh… for the moment with this project we don't need to use it but it's something, if you need some geographic information assistance software or maybe some email or some photo, we have our lab. And we have our other lab that they use for statistic. We have a lab in the first floor of the building that have this information. Eh, other interesting… Tell me any other things that you need for some sort of information or space.

M: Um, we need to have a section about the sponsor and information about them. So we were wondering where the funding comes from.

S: OK, the funding from this project?

M: Mhm.

S: Well, it's not coming from the UPR.

J: It's not coming from UPR?

S: Excuse me?

J: It's not coming from UPR?

S: No, no, no. UPR's support is the mentoring and we're the logistic help of logistics move with the group to the places, but the money support is really for, like I understood it's coming from Toyota, or from some other people, not from the UPR.

M: OK.

S: We have planning to support, OK, we don't have, we are not in the money, we are not making the support for this group but if you need transportation to the places or we can help taking some photo copies… you know this kind of thing we can help.

M: OK.

J: Where will we be working on a daily basis? Will we be at the university or…

S: Daily basis? Well the main, something like the main research center like, no not a research center, the main office will be UPR.

J: Yeah, OK.

S: Yes, will be in my research office. You will be, this office, you will be stay there with my assistant research eh… she will be working also in her thesis, in her undergrad thesis. But the main office will be there. We, we can fix… I will be available. I will be there all week and we can fix, based on my classes' time, we can fix if you want to… you can do it every day, anytime that you need it, OK? I will be there. And if you want to make arrangement that a specific day will be meet, an hour/two hour, we can do it also.

M: OK.

S: A specific time, make up like a schedule. We can say like, example, Tuesday or Monday at ten o'clock we can meet this time, if you think it's necessary.

M: OK.

S: But that is in terms of what do you think you need, is necessary.

M: Um, may I ask what is your role in the university? You're in the geography department?

S: I'm marine geology and I'm really an oceanographer. A geological oceanographer and my main specialty is coastal processes and fish evolution. And I'm teaching for geography department specific in the physical geography area. In my Ph D also, I took classes in electrical engineer. I'm no engineer, but I took the classes in electrical engineer because I'm working also with remote sensing techniques.

M: OK.

S: Yeah, that's more or less my background. And the last part I'm doing related with people from Caribbean Fisheries Council.

C: Is remote sensing something that we might consider on working on down there for what we're studying?

S: Excuse me, I hear you very far away.

C: Is remote sensing a possibility for what we're studying?

S: Well, this is not the main goal, but we can, we can, we can check… I think would be important, especially that you are not from Puerto Rico, would be good to see and talk on using remote sensing techniques, but it's not the main, main goal of the project and the question that you are underline, no? But we can work with it, if you want, if you're interested, we can use part of the design, too, yes.

C: I was just curious because two of us are electrical engineers.

S: Excuse me, I hear so far away.

C: Two of us are electrical engineers so if that's a possibility, maybe we could help out with that, I don't know…

S: Yes? Ah, OK. Yes, well one of the things is that we are, the main important thing is that all of you will be during this process about the specific questions that the group can, wants to answer. And based on this question, we'll be, I forgot how to say, define or underlining the specific methodology that already I saw in your emails, that you are, you are in the right direction. But also, that still means that we can, in these processes, if you have interests to know about a specific technique or maybe answers other questions, we can do it, we can do it. The main, the important thing that we are very clear about, what we want to find, will be the right line that we want to follow. I think this is very important in this research project.

C: OK, thank you.

M: We had one more question.

S: Mhm.

M: What is the typical dress code?

S: The typical what?

M: Dress code? How should we dress at the university?

S: I don't know that one.

J: The clothes that we're wearing.

S: Ah, OK, how we're wearing. Well, you can, many students go in jeans, OK, jeans. But you can use also shorts as you feel, a T-shirt, the main student go very, um, sports? T-shirts, jeans, they use a lot of jeans, it's as you feel comfortable.

J: OK.

S: Yes, but more or less, yes they… eh… that's only, you do that in the normal process, but when they have plans to make a presentation for that there is a difference. They go a little more…

J: Formal?

S: Well, it's not formal, but they go… they don't use jeans.

J, M: OK.

S: But that's it.

M: Thank you very much for meeting with us and we look forward to working with you in Puerto Rico.

S: Yes, I'm sorry for my English.

J, M: It's OK.

S: I hope that I can improve my English and that you can understand.

J: We hope to our Spanish as well. So, hopefully we'll be able to.

S: Well, well, but, but the important thing is that anytime that you… I have… first thing, I have plans now to sit down and start to send you other papers, references, please if you can send me your address, I can send you by mail a CD with the report of the mangroves, marine corridors that I done for Caribbean Fisheries. And if you need call me, please call me anytime, I send you my cellular number also. Or if you need send me emails making

specific questions please do it. For me will be… I like that when I make research with students they can ask me and have communication between the group, OK?

D, M: OK.

S: Well, nice to meet all of you.

J, D, M, C: You too.

S: For me, will be a pleasure to work with all your group.

J, D, M, C: Thank you.

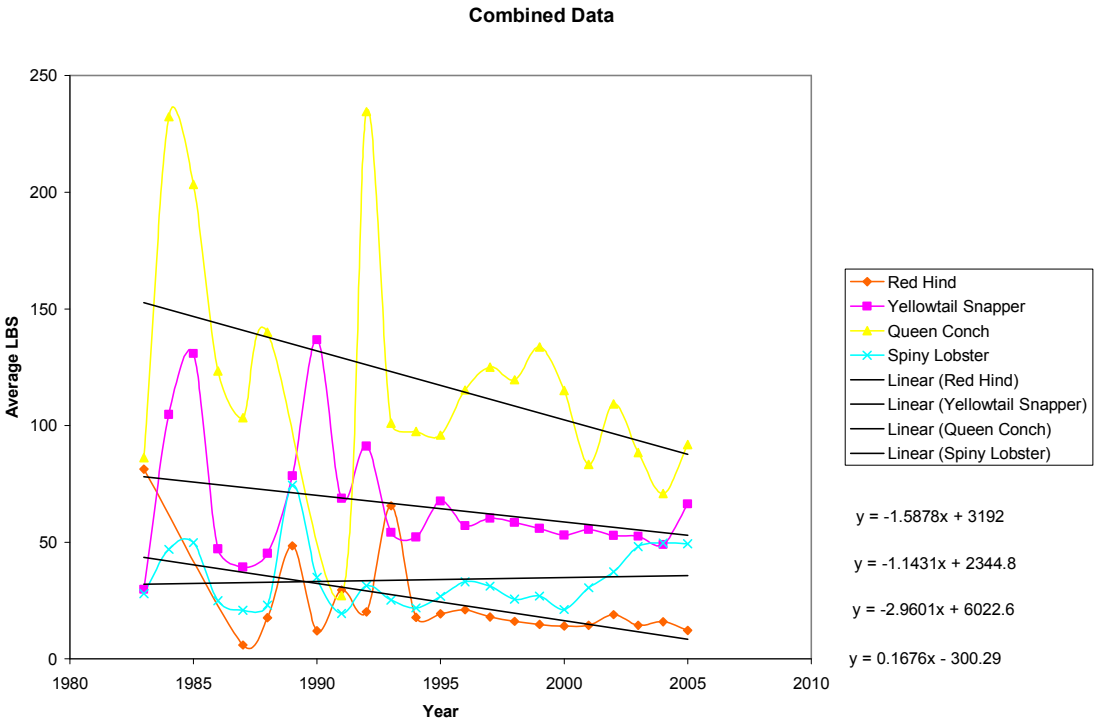
S: OK.

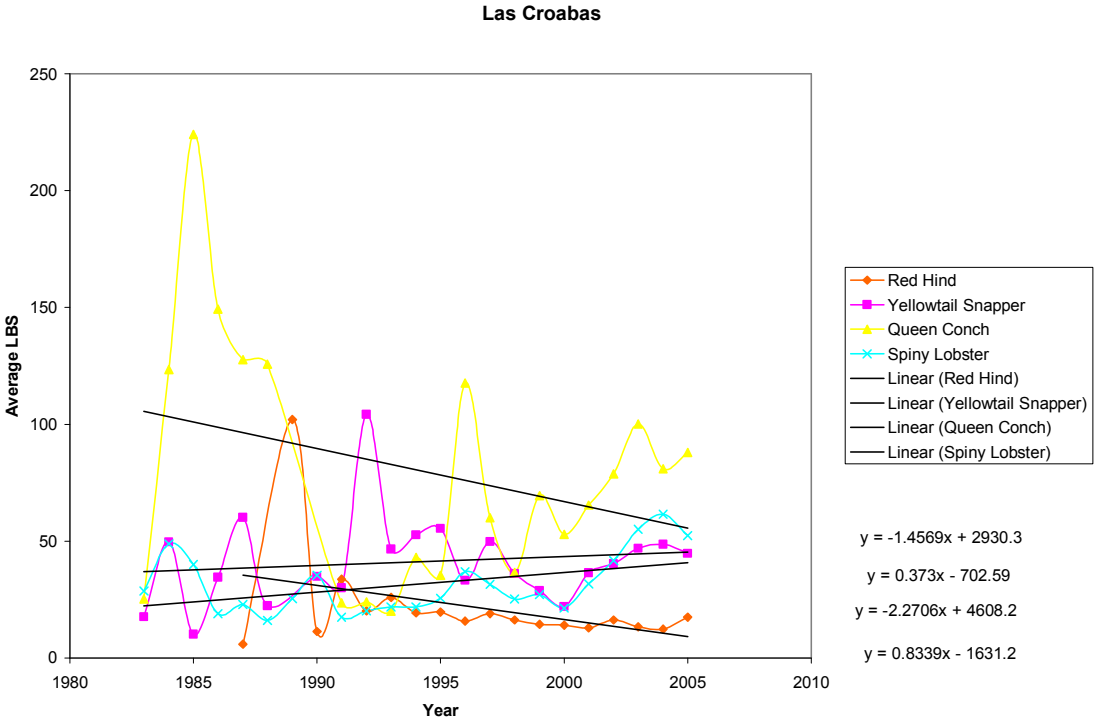
M: Have a good evening.

S: OK, same for all of you, OK.

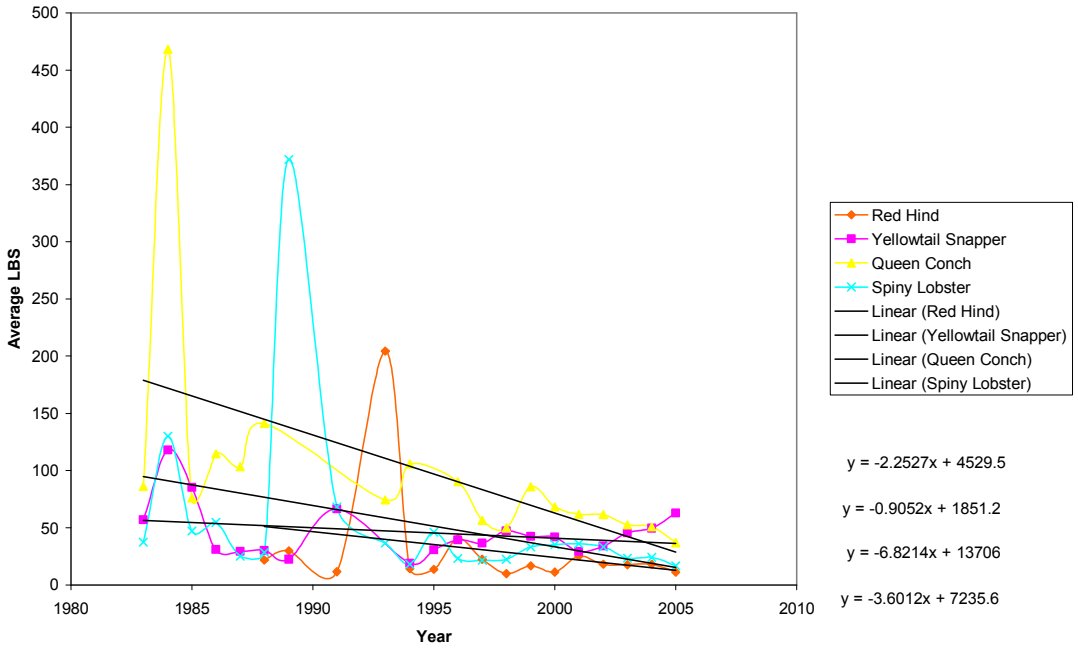
J, D, M, C: Bye.

Appendix F – Fish Catch Data

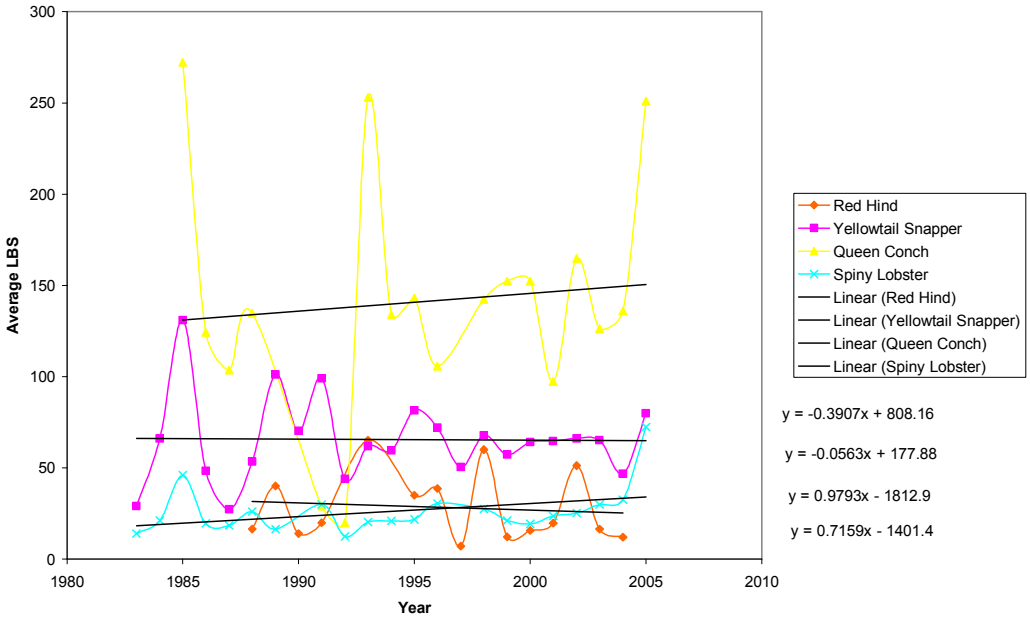


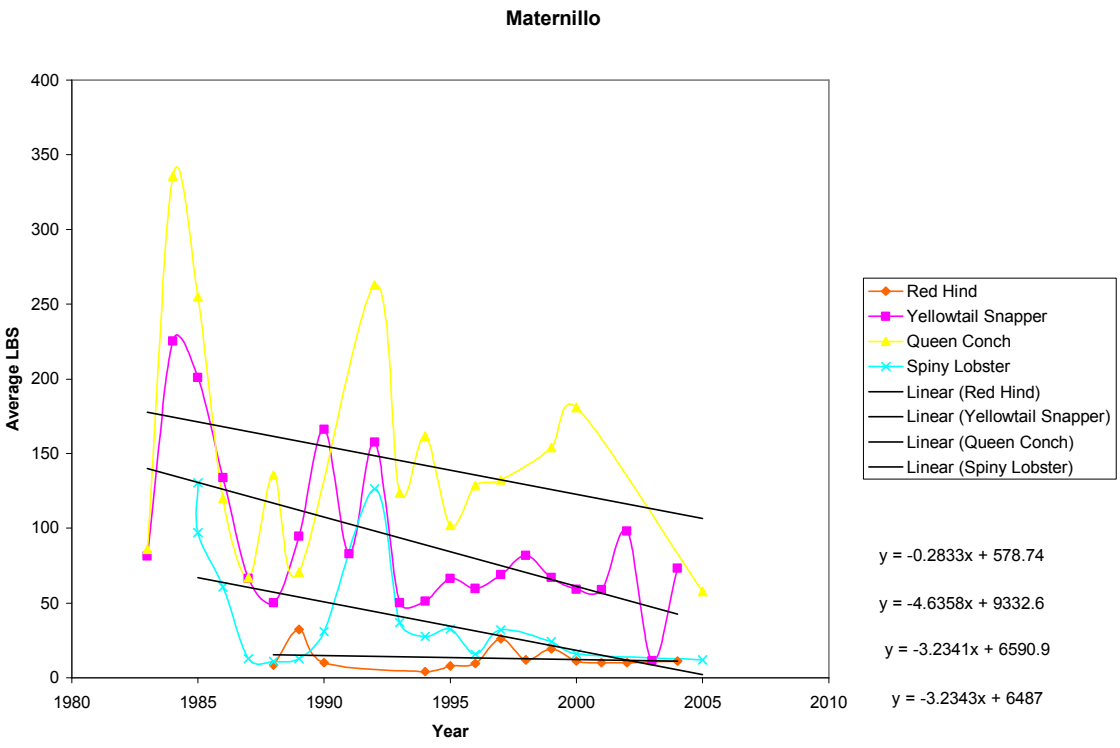


Sardinera



Puerto Real



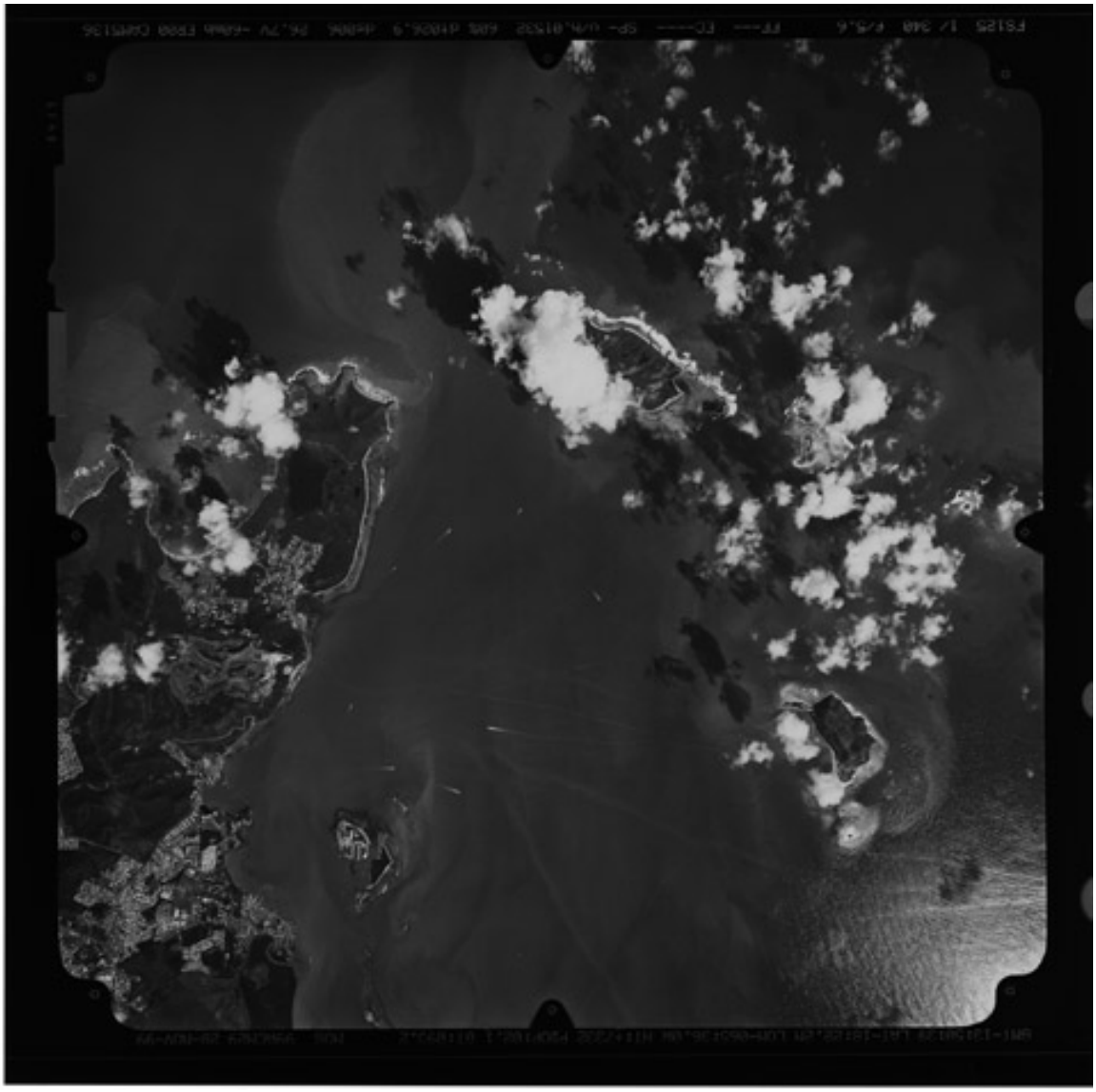

Maternillo
Average LBS
Year
400
350
300
250
200
150
100
50
0
1980
1985
1990
1995
2000
2005
2010
Red Hind
Yellowtail Snapper
Queen Conch
Spiny Lobster
Linear (Red Hind)
Linear (Yellowtail Snapper)
Linear (Queen Conch)
Linear (Spiny Lobster)
y = -0.2833x + 578.74
y = -4.6358x + 9332.6
y = -3.2341x + 6590.9
y = -3.2343x + 6487

Appendix G – Aerial Photos

Fajardo 1962, (Autoridad de Carreteras y Transportación, Oficina de Fotogrametría, 2006)

Fajardo 1983, (Autoridad de Carreteras y Transportación, Oficina de Fotogrametría, 2006)

Fajardo 1994, (Autoridad de Carreteras y Transportación, Oficina de Fotogrametría, 2006)



Fajardo 1999, (Autoridad de Carreteras y Transportación, Oficina de Fotogrametría, 2006)

Fajardo 2004, (Autoridad de Carreteras y Transportación, Oficina de Fotogrametría, 2006)

Appendix H – Fishing Regulations and Management Plans

Fishery Management Plan for the Spiny Lobster Fishery of Puerto Rico

*Taken from Caribbean Fishery Management Council (2005, May). *Comprehensive Amendment to the Fishery Management Plans (FMPs) of the U.S. Caribbean to Address Required Provisions of the Magnuson-Stevens Fishery Conservation and Management Act.*

The Council's Spiny Lobster FMP (CFMC 1981; 49 FR 50049) was implemented in January 1985, and was supported by an EIS. The FMP defined the Caribbean spiny lobster fishery management unit to include *Panulirus argus* (Caribbean spiny lobster), described objectives for the spiny lobster fishery, and established management measures to achieve those objectives. Primary management measures included:

- The definition of MSY as 830,000 lbs per year;
- The definition of OY as "all the non-[egg-bearing] spiny lobsters in the management area having a carapace length of 3.5 inches or greater that can be harvested on an annual basis," which was estimated to range from 582,000 to 830,000 lbs per year;
- A prohibition on the retention of egg-bearing (berried) lobsters (berried female lobsters may be kept in pots or traps until the eggs are shed), and on all lobsters with a carapace length of less than 3.5 inches;
- A requirement to land lobster whole;
- A requirement to include a self-destruct panel and/or self-destruct door fastenings on traps and pots;
- A requirement to identify and mark traps, pots, buoys, and boats; and
- A prohibition on the use of poisons, drugs, or other chemicals, and on the use of spears, hooks, explosives, or similar devices to take spiny lobsters.

Amendment 1 to the Spiny Lobster FMP (CFMC 1990a; 56 FR 19098), implemented in May 1991, added to the FMP definitions of overfished and overfishing, and outlined framework actions that could be taken should overfishing occur. The amendment defined "overfished" as a biomass level below 20% of the spawning potential ratio (SPR). It defined "overfishing" as a harvest rate that is not consistent with a program implemented to rebuild the stock to the 20% SPR. That amendment was supported by an Environmental Assessment (EA) and a finding of no significant impact (FONSI).

Fishery Management Plan for the Queen Conch Resource of Puerto Rico

*Taken from Caribbean Fishery Management Council (2005, May). *Comprehensive Amendment to the Fishery Management Plans (FMPs) of the U.S. Caribbean to Address Required Provisions of the Magnuson-Stevens Fishery Conservation and Management Act.*

The Council's Queen Conch FMP (CFMC 1996a; 61 FR 65481) was implemented in January 1997, and was supported by an EIS.

The FMP defined the queen conch fishery management unit (Table 1), described objectives for the queen conch fishery, and established management measures to achieve those objectives. Primary management measures included:

- The definition of the MSY of queen conch as 738,000 lbs per year;
- The definition of the OY of queen conch as "all queen conch commercially and recreationally harvested from the EEZ landed consistent with management measure set forth in this FMP under a goal of allowing 20% of the spawning stock biomass to remain intact;"
- A prohibition on the possession of queen conch that measure less than 9 inches total length or that have a shell lip thickness of less than 3/8 inches;
- A requirement that all conch species in the fishery management unit be landed in the shell;
- A prohibition on the sale of undersized queen conch and queen conch shells;
- A recreational bag limit of three queen conch per day, not to exceed 12 per boat;
- A commercial catch limit of 150 queen conch per day;
- An annual spawning season closure that extends from July 1 through September 30; and
- A prohibition on the use of hookah gear to harvest queen conch.

Fishery Management Plan for the Reef Fish Fishery of Puerto Rico

*Taken from Caribbean Fishery Management Council (2005, May). *Comprehensive Amendment to the Fishery Management Plans (FMPs) of the U.S. Caribbean to Address Required Provisions of the Magnuson-Stevens Fishery Conservation and Management Act.*

The Council's Reef Fish FMP (CFMC 1985; 50 FR 34850) was implemented in September 1985. The FMP, which was supported by an EIS, defined the reef fish fishery management unit to include shallow water species only, described objectives for the shallow water reef fish fishery, and established management measures to achieve those objectives. Primary management measures included:

- The definition of MSY as equal to 7.7 million lbs;
- The definition of OY as "all of the fishes in the management unit that can be harvested by U.S. fishermen under the provisions of the FMP...This amount is currently estimated at 7.7 million lbs;"
- The specification of criteria for the construction of fish traps, which included a minimum 1 1/4-inch mesh size requirement and a requirement that fish traps contain a self-destruct panel and/or self-destruct door fastening;
- A requirement to identify and mark gear and boats;
- A prohibition on the use of poisons, drugs, and other chemicals and explosives to take reef fish;
- A prohibition on the take of yellowtail snapper that measure less than 8 inches total length for the first fishing year, to be increased one inch per year until the minimum size limit reached 12 inches;
- A prohibition on the take of Nassau grouper that measure less than 12 inches total length for the first fishing year, to be increased one inch per year until the minimum size limit reached 24 inches; and
- A prohibition on the take of Nassau grouper from January 1 to March 31 each year, a period that coincides with the spawning season of this species.

Amendment 1 to the Reef fish FMP (CFMC 1990b; 55 FR 46214) was implemented in December 1990. That amendment was supported by an EA with a FONSI. Primary management measures included:

- An increase in the minimum mesh size for traps to 2 inches;
- A prohibition on the take or possession of Nassau grouper; and
- A prohibition on fishing in an area southwest of St. Thomas, USVI from December 1 through February 28 of each year, a period that coincides with the spawning season for red hind (this seasonal closure would later become a year-round closure with the implementation of the Hind Bank Marine Conservation District through Amendment 1 to the Coral FMP).

Amendment 1 also defined overfished and overfishing for shallow water reef fish. "Overfished" was defined as a biomass level below 20% of the spawning stock biomass per recruit (SSBR) that would occur in the absence of fishing. For stocks that are overfished, "overfishing" was defined as a rate of harvest that is not consistent with a program that has been established to rebuild a stock or stock complex to the 20% SSBR level. For stocks that are not overfished, "overfishing" was defined as "a harvesting rate that if continued would lead to a state of the stock or stock complex that would not at least allow a harvest of OY on a continuing basis."

A regulatory amendment to the Reef Fish FMP (CFMC 1991; 56 FR 48755) was implemented October 1991. The primary management measures contained in this amendment, which was supported by an EA with a FONSI, included:

- A modification to the mesh size increase implemented through Amendment 1 to allow a mesh size of 1.5 inches for hexagonal mesh, and a change in the

effective date of the 2-inch minimum mesh size requirement for square mesh to September 13, 1993; and

- A change in the specifications for degradable panels for fish traps related to the required number of panels (required two panels per trap), and their size, location, construction, and method of attachment.

Amendment 2 to the Reef Fish FMP (CFMC 1993; 58 FR 53145), implemented in November 1993, was supported by an SEIS. That amendment redefined the reef fish fishery management unit (Table 2) to include the major species of deep water reef fish and marine aquarium finfish. Primary management measures implemented through this amendment included:

- A prohibition on the use of any gear other than hand-held dip nets and slurp guns to collect marine aquarium fishes;
- A prohibition on the harvest or possession of Goliath grouper (formerly known as jewfish);
- A prohibition on the harvest, possession, and/or sale of certain species used in the aquarium trade, including seahorses and foureye, banded, and longsnout butterflyfish;
- A prohibition on fishing in an area off the west coast of Puerto Rico (Tourmaline Bank) from December 1 through February 28 each year, a period that coincides with the spawning season for red hind;
- A prohibition on fishing in an area off the east coast of St. Croix, USVI (Lang Bank) from December 1 through February 28 each year, a period that coincides with the spawning season for red hind; and
- A prohibition on fishing in an area off the southwest coast of St. Croix, USVI from March 1 through June 30 each year, a period that coincides with the spawning season for mutton snapper.

Existing definitions of MSY and OY were applied to all reef fish within the revised FMU, with the exception of marine aquarium finfish. The MSY and OY of marine aquarium finfish remained undefined.

A technical amendment to the Reef Fish FMP (59 FR 11560), implemented in April 1994, clarified the minimum mesh size allowed for fish traps.

Finally, an additional regulatory amendment to the Reef Fish FMP (CFMC 1996b; 61 FR 64485) was implemented in January 1997. That action, supported by an EA, reduced the size of the Tourmaline Bank closure that was originally implemented in 1993, and prohibited fishing in two areas off the west coast of Puerto Rico (Abrir La Sierra Bank (Buoy 6) and Bajo de Cico) from 1 December to 28 February of each year, a period that coincides with the spawning season of red hind.

Appendix I – Shallow Water vs. Deep Water Fisheries

The shallow-water reef fish fishery exists within the exclusive economic zone and the shoreline, limited to a depth of 40 fathoms (240 feet) or less. The majority of commercially caught reef fish reside within this area. Unfortunately, statistics show a decrease in the number of young fish in this portion of the reef; most species are highly vulnerable to capture during spawning season. This dilemma is currently being remedied by the closing of different sites during spawning season to increase reproductive capacity (CFMC, 2004).

The deep-water fishery is home primarily to adult reef fish. This area ranges from the outer reaches of the shallow-water fishery (approximately 73 meters) to depths up to more than 550 meters. Those habitats are characterized by rocks, ledges and corals (CFMC, 2004).

Although fishermen use similar techniques for fishing in shallow-water and deep-water fisheries, differences do exist. Each habitat has a unique environment, requiring different gear for increased landings.

Appendix J – Species in the Caribbean Conch Resource Fishery Management Units

*Taken from Caribbean Fishery Management Council (2005, May). *Comprehensive Amendment to the Fishery Management Plans (FMPs) of the U.S. Caribbean to Address Required Provisions of the Magnuson-Stevens Fishery Conservation and Management Act.*

Atlantic Triton's Trumpet, *Charonia Variegata*	Milk Conch, *Strombus Costatus*
Cameo Helmet, *Cassis Madagascarensis*	Queen Conch, *Strombus Gigas*
Caribbean Helmet, *Cassis Tuberosa*	Roostertail Conch, *Strombus Gallus*
Caribbean Vase, *Vasum Muricatum*	True Tulip, *Fasciolaria Tulipa*
Flame Helmet, *Cassis Flammea*	West Indian Fighting Conch, *Strombus Pugilis*
Green Star Shell, *Astrea Tuber*	Whelk (West Indian Top Shell), *Cittarium Pica*
Hawking Conch, *Strombus Raninus*	

Appendix K – Species in the Caribbean Reef Fish Fishery Management Units

*Taken from Caribbean Fishery Management Council (2005, May). *Comprehensive Amendment to the Fishery Management Plans (FMPs) of the U.S. Caribbean to Address Required Provisions of the Magnuson-Stevens Fishery Conservation and Management Act.*

Acanthuridae -- Surgeonfishes
- Ocean surgeonfish, *Acanthurus bahianus*
- Doctorfish, *Acanthurus chirurgus*
- Blue tang, *Acanthurus coeruleus*

Antennariidae -- Frogfishes
- Frogfish, *Antennarius* spp.

Apogonidae -- Cardinalfishes
- Flamefish, *Apogon maculatus*
- Conchfish, *Astrapogen stellatus*

Aulostomidae -- Trumpetfishes
- Trumpetfish, *Aulostomus maculatus*

Balistidae -- Leatherjackets
- Scrawled filefish, *Aluterus scriptus*
- Queen triggerfish, *Balistes vetula*
- Whitespotted filefish, *Cantherhines macrocerus*
- Ocean triggerfish, *Canthidermis sufflamen*
- Black durgon, *Melichthys niger*
- Sargassum triggerfish, *Xanthichthys rigens*

Blenniidae -- Combtooth blennies
- Redlip blenny, *Ophioblennius atlanticus*

Bothidae -- Lefteye flounders
- Peacock flounder, *Bothus lunatus*

Carangidae -- Jacks
- Yellow jack, *Caranx bartholomaei*
- Blue runner, *Caranx crysos*
- Horse-eye jack, *Caranx latus*
- Black jack, *Caranx lugubris*
- Bar jack, *Caranx ruber*
- Greater amberjack, *Seriola dumerili*
- Almaco jack, *Seriola rivoliana*

Chaetodontidae -- Butterflyfishes
- Longsnout butterflyfish, *Chaetodon aculeatus*

Foureye butterflyfish, *Chaetodon capistratus*
Spotfin butterflyfish, *Chaetodon ocellatus*
Banded butterflyfish, *Chaetodon striatus*

Cirrhitidae -- Hawkfishes
Redspotted hawkfish, *Amblycirrhitus pinos*

Dactylopteridae -- Flying gurnards
Flying gurnard, *Dactylopterus volitans*

Ephippidae -- Spadefishes
Atlantic spadefish, *Chaetodipterus faber*

Gobiidae -- Gobies
Neon goby, *Gobiosoma oceanops*
Rusty goby, *Priolepis hipoliti*

Grammatidae -- Basslets
Royal gramma, *Gramma loreto*

Haemulidae -- Grunts
Porkfish, *Anisotremus virginicus*
Margate, *Haemulon album*
Tomtate, *Haemulon aurolineatum*
French grunt, *Haemulon flavolineatum*
White grunt, *Haemulon plumieri*
Bluestriped grunt, *Haemulon sciurus*

Holocentridae -- Squirrelfishes
Squirrelfish, *Holocentrus adscensionis*
Longspine squirrelfish, *Holocentrus rufus*
Blackbar soldierfish, *Myripristis jacobus*
Cardinal soldierfish, *Plectrypops retrospinis*

Labridae -- Wrasses
Spanish hogfish, *Bodianus rufus*
Creole wrasse, *Clepticus parrae*
Yellowcheek wrasse, *Halichoeres cyanocephalus*
Yellowhead wrasse, *Halichoeres garnoti*
Clown wrasse, *Halichoeres maculipinna*
Puddingwife, *Halichoeres radiatus*
Pearly razorfish, *Hemipteronotus novacula*
Green razorfish, *Hemipteronotus splendens*
Hogfish, *Lachnolaimus maximus*
Bluehead wrasse, *Thalassoma bifasciatum*

Lutjanidae -- Snappers
Black snapper, *Apsilus dentatus*
Queen snapper, *Etelis oculatus*
Mutton snapper, *Lutjanus analis*
Schoolmaster, *Lutjanus apodus*

Blackfin snapper, *Lutjanus buccanella*
Gray snapper, *Lutjanus griseus*
Dog snapper, *Lutjanus jocu*
Mahogany snapper, *Lutjanus mahogani*
Lane snapper, *Lutjanus synagris*
Silk snapper, *Lutjanus vivanus*
Yellowtail snapper, *Ocyurus chrysurus*
Wenchman, *Pristipomoides aquilonaris*
Vermilion snapper, *Rhomboplites aurorubens*

Malacanthidae -- Tilefishes
Blackline tilefish, *Caulolatilus cyanops*
Sand tilefish, *Malacanthus plumieri*

Mullidae -- Goatfishes
Yellow goatfish, *Mulloidichthys martinicus*
Spotted goatfish, *Pseudupeneus maculatus*

Muraenidae -- Morays
Chain moray, *Echidna catenata*
Green moray, *Gymnothorax funebris*
Goldentail moray, *Gymnothorax miliaris*

Ogcocephalidae -- Batfishes
Batfish, *Ogcocepahalus* spp.

Ophichthidae -- Snake eels
Goldspotted eel, *Myrichthys ocellatus*

Opistognathidae -- Jawfishes
Yellowhead jawfish, *Opistognathus aurifrons*
Dusky jawfish, *Opistognathus whitehursti*

Ostraciidae -- Boxfishes
Spotted trunkfish, *Lactophrys bicaudalis*
Honeycomb cowfish, *Lactophrys polygonia*
Scrawled cowfish, *Lactophrys quadricornis*
Trunkfish, *Lactophrys trigonus*
Smooth trunkfish, *Lactophrys triqueter*

Pomacanthidae -- Angelfishes
Cherubfish, *Centropyge argi*
Queen angelfish, *Holacanthus ciliaris*
Rock beauty, *Holacanthus tricolor*
Gray angelfish, *Pomacanthus arcuatus*
French angelfish, *Pomacanthus paru*

Pomacentridae -- Damselfishes
Sergeant major, *Abudefduf saxatilis*
Blue chromis, *Chromis cyanea*
Sunshinefish, *Chromis insolata*

Yellowtail damselfish, *Microspathodon chrysurus*
Dusky damselfish, *Pomacentrus fuscus*
Beaugregory, *Pomacentrus leucostictus*
Bicolor damselfish, *Pomacentrus partitus*
Threespot damselfish, *Pomacentrus planifrons*

Priacanthidae -- Bigeyes
Bigeye, *Priacanthus arenatus*
Glasseye snapper, *Priacanthus cruentatus*

Scaridae -- Parrotfishes
Midnight parrotfish, *Scarus coelestinus*
Blue parrotfish, *Scarus coeruleus*
Striped parrotfish, *Scarus croicensis*
Rainbow parrotfish, *Scarus guacamaia*
Princess parrotfish, *Scarus taeniopterus*
Queen parrotfish, *Scarus vetula*
Redband parrotfish, *Sparisoma aurofrenatum*
Redtail parrotfish, *Sparisoma chrysopterum*
Redfin parrotfish, *Sparisoma rubripinne*
Stoplight parrotfish, *Sparisoma viride*

Sciaenidae -- Drums
High-hat, *Equetus acuminatus*
Jackknife-fish, *Equetus lanceolatus*
Spotted drum, *Equetus punctatus*

Scorpaenidae -- Scorpionfishes

Serranidae -- Sea basses
Rock hind, *Epinephelus adscensionis*
Graysby, *Epinephelus cruentatus*
Yellowedge grouper, *Epinephelus flavolimbatus*
Coney, *Epinephelus fulvus*
Red hind, *Epinephelus guttatus*
Goliath grouper, *Epinephelus itajara*
Red grouper, *Epinephelus morio*
Misty grouper, *Epinephelus mystacinus*
Nassau Grouper, *Epinephelus striatus*
Butter hamlet, *Hypoplectrus unicolor*
Swissguard basslet, *Liopropoma rubre*
Yellowfin grouper, *Mycteroperca venenosa*
Tiger grouper, *Mycteroperca tigris*
Creole-fish, *Paranthias furcifer*
Greater soapfish, *Rypticus saponaceus*
Orangeback bass, *Serranus annularis*
Lantern bass, *Serranus baldwini*
Tobaccofish, *Serranus tabacarius*
Harlequin bass, *Serranus tigrinus*
Chalk bass, *Serranus tortugarum*

Soleidae -- Soles
- Caribbean tonguefish, *Symphurus arawak*

Sparidae -- Porgies
- Sea bream, *Archosargus rhomboidalis*
- Jolthead porgy, *Calamus bajonado*
- Sheepshead porgy, *Calamus penna*
- Pluma, *Calamus pennatula*

Syngnathidae -- Pipefishes
- Seahorses, *Hippocampus* spp.
- Pipefishes, *Syngnathus* spp.

Synodontidae -- Lizardfishes
- Sand diver, *Synodus intermedius*

Tetraodontidae -- Puffers
- Sharpnose puffer, *Canthigaster rostrata*
- Porcupinefish, *Diodon hystrix*

Appendix L – Additional Environmental Factors Effecting Marine Corridor Deterioration

Although most of the problems associated with the deterioration of marine corridors are clearly anthropogenic, many natural phenomena and indirect human activity also negatively affect the environment.

Global warming

Some of the greatest destruction to coral reef ecosystems has been caused as a major byproduct of human consumption, global warming, which is caused by increased atmospheric levels of carbon dioxide from automobiles and factories. The buildup of this gas, along with other greenhouse gasses in the atmosphere, holds heat, which causes the overall temperature of the Earth to increase. The impacts of this climate change are evident in many facets of the environment, but their effect has been most dire on coral reefs around the earth.

Rising sea temperatures cause stress on coral that live in symbiosis with a species of brown dinoflagellate algae. The stress causes the algae to leave the coral, causing the coral to turn white. If the stress is great enough, the coral will die. In recent years, there has been an increase in episodes of bleaching due to increased sea temperatures, and "in 1998, 16% of the world's coral died. In some regions such as the Western Indian Ocean, more than 48% of living coral was eliminated" (Hoegh-Guldberg, O., & Hoegh-Guldberg, H., 2004, p.208). Episodes of bleaching have increased dramatically in the past 20 years, as the temperature of the sea has risen due to global warming. Because of degradation of coral due to global warming, it is all the more vital to eliminate the

negative impact on coral reefs caused by pollution, development, tourism, and overfishing.

Algae Blooms

When nutrients caused by human waste are introduced into a marine ecosystem in extreme quantities, the levels of dissolved oxygen in the water skyrocket, causing algae to overgrow, which, in extreme cases, leads to altered and nutrient starved alternate ecosystems. These algae blooms can destroy entire marine ecosystems, as evident in the creation of "vast dead zones, the ultimate choking of life, are growing steadily larger in areas such as the Gulf of Mexico" (Agardy, 1999, p.422).

Levels of algae can be controlled by limiting the amount of nutrients imparted into the ecosystem. In addition to controlling nutrients, algae can be controlled by limiting the amount of fishing in the area. The abundance of grazing fish will reduce the chance of algae dominating an area. Marine areas, especially coral reefs are fragile and must be properly balanced to survive. The limiting of overfishing and nutrient introduction in coral reefs is vital as "coral reefs are one of the few marine habitats that undergo disturbance-induced phase shifts: an almost irreversible phenomenon in which diverse reef ecosystems dominated by stony corals dramatically turn into biologically impoverished wastelands overgrown with algae" (Agardy 2004, p.2).

Aquatic Invasive Species

Marine corridor ecosystems must maintain a balance in order to survive. While the effects of pollution, humans, and global warming have been accounted for, there exists another threat to coastal ecosystems. While invasive species may be viewed as a

secondary concern, they are one of the largest threats and can rapidly cause species extinction and loss of biodiversity in marine life. Defined as "an alien species whose introduction does or is likely to cause economic or environmental harm or harm to human health," these species endanger the life in an area by affecting the ecosystem directly or by affecting the land in ways that can harm the ecosystem (U.S. Environmental Protection Agency, 2006). Economically, invasive species result in great losses due to control costs as well as commercial and recreational disruptions. Aquatic invasive species are commonly introduced to an environment through ballast water, aquaculture, and accidental introductions (U.S. Environmental Protection Agency, 2006, Invasive Species).

Appendix M – Other Conservation Organizations in Puerto Rico

The Conservation Trust of Puerto Rico was established in 1970 to preserve the island's natural resources and heritage by establishing landmarks (Conservation Trust of Puerto Rico, 2005). In addition to the protection supplied, the landmarks also provide a way for tourists and locals to learn about the areas and their importance. This organization also works to integrate environmental awareness into the elementary school education programs. The idea is that if children are exposed to it at a young age, they will have a life long respect for the environment and hopefully pass it along to others. Additionally, the Conservation Trust holds public events such as tree plantings to increase community involvement and awareness.

Surfrider is a different type of organization. It is a non-profit environmental organization dependent on contributions from donators (Surfrider, 2005). It was founded by a group of surfers from California who wanted to protect their surfing environments. Over the years, the foundation has grown to over 40,000 members and now works to protect all near shore marine environments. Their main goal is to encourage economic growth while still restraining coastal development. They achieve this goal by speaking with knowledgeable locals and spreading information to the rest of the area regarding the prospect of creating new marine reserves.

Like Surfrider, CORALations is a non-profit ocean conservation and protection organization (CORALations, 2005). It is local to Puerto Rico and brings together locals, scientists, and the government to work together for marine preservation. They carry out long, laborious work such as coral reef reconstruction, continuous monitoring, and

development of educational programs. These actions both physically improve the habitats as well as provide education for reef protection.

Appendix N – Glossary

Artificial Reefs (Arrecife artificial)– artificial structures of diverse materials fabricated with the purpose of increase and provide habitat for marine organisms.

Aquaculture ()– cultivation of aquatic organisms in a controlled or semi-controlled environment, whether in freshwater, salt water, or brine, using technical or scientific methods for commercial purposes.

Bait (Cebo)– those species used for fishing.

Boxfish – mean the following reef fish species: honeycomb cowfish, *Lactophrys polygonius*; scrawled cowfish, *Lactophrys quadriconis*; smooth trunkfish, *Lactophrys triqueter*; spotted trunkfish, *Lactophrys bicaudalis*; trunkfish, *Lactophrys trigonus*.

Capture (Capturar)– the number or total weight of live organisms removed permanently or seasonally in an area and during specific time periods.

Channel (Canal)– narrow channel, although navigable, from a port or bay.

Closed Season (Temporada/Estación cerrada)– prohibition decreed by the Secretary when, in his opinion, confirmed scientific information corroborates the necessity of protection of public health or the restoration of a fishery through the total or partial limitation of the following activities:

a. Fishing in specified sites.
b. The use of gear or methods of fishing.
c. The partial or total fishing of identified species:
    (1) by species,
    (2) by life stage,
    (3) by size
    (4) by quantity
    (5) by sex
    (6) by time or season

All seasonal closures will always prohibit fishing, transporting, having on board (whether live, dead, or refrigerated) aquatic or semi-aquatic organisms that are to be protected unless it can be demonstrated through the possession of a purchase receipt, that the organisms have been imported.

Coral Reefs (Arrecife coral)– tropical calcareous structures in shallow waters that contain a diverse association of marine plans and animals.

Crab (Cangrejo)– a species of crustacean.

Fish (Pez)– product of fishing activity; aquatic or semi-aquatic organism during any stage of its life cycle.

Fisheries ()– one of more aggregations (usually bases on genetic relationships, geographic distribution or movement patterns) of aquatic or semi-aquatic organisms; or the fishing operations related to these aggregations of organisms that can be identified based on geographic, scientific, technologic, commercial, recreational, and economic characteristics.

Fishing Gear (Equipo para pescar)– any device or apparatus that is utilized to fish.

Full-time Commercial Fisher (Pescador comercial por/a tiempo completo)– natural person dedicated to fishing for profit, obtaining (50) percent or more of his total annual income from fishing and possessing a license to that effect given by the Secretary.

Harvest (Cosecha?)– aquatic organisms removed permanently from the population.

Interior Waters (Aguas interiors)– all water bodies of public dominion from the interior coastline, except bays.

Juvenile (Menor)– organism that has not reached sexual maturity

Landing ()– fish brought to land by commercial or recreational fishermen.

License (Licencia)– written authorization given by the Secretary to fish for aquatic or semi-aquatic organisms within jurisdictional waters of Puerto Rico.

Part-time Commercial Fisher (Pescador comercial por/a tiempo medio?)- natural person dedicated to fishing for profit, obtaining between twenty (20) and forty-nine (49) percent of his total annual income from fishing and possessing a license to that effect given by the Secretary.
Recreational Fisher - natural person who does not fish for profit, but for recreation such as a sport, or for the purpose of competition or for personal consumption and possesses a license to that effect given by the Secretary.

Reef fish (Pez de arrecife)– and aquatic or semi-aquatic organism dependent on the coral reef or other equivalent ecosystem (as, for example, rock reefs) in some stage of its life cycle.

Secretary (Ministro)– the Secretary of the Department of Natural and Environmental Resources of the Commonwealth of Puerto Rico or his representative.

Snapper ()– mean the following deep-water snapper species: silk snapper, *Lutjanus vivanus*; blackfin snapper, *Lutjanus buccanella*; vermillion snapper, *Rhomboplites aurorubens*.

Fish verb (Pescar)– to capture, take, possess, harvest, kill, destroy, injure or extract aquatic or semi-aquatic organisms from their environment through any method, use, or placement of equipment or apparatus for these purposes.

*All definitions taken from:

Commonwealth of Puerto Rico, Department of Natural and Environmental Resources. (2004). *Puerto Rican Fishing Regulations*.

Appendix O – Guide Sample Pages

Source: DNER Fish Guide

Name: Red Mangrove
Location: Near-Shore Coastal Areas
Size: Varies

Mangroves offer shelter to many juvenile fish that later move on to live in reef and open-water environments. They are an ecosystem vital to sustaining fish populations.

Mangrove Seed Pod
Location: Floating in Water
Size: 4-6 Inches

Seed pods are released from adult mangroves. They float in ocean currents until they become lodged in sand.

Baby Mangrove
Location: Near-Shore Marine Areas
Size: 6 Inches - Full Mangrove

Seed pods that are lodged in the sand begin to grow into baby mangroves. If left unharmed, they can grow to create entire mangrove forests.

Created by James Doucet
All Pictures taken by James Doucet

Appendix P – Sponsor Description

University of Puerto Rico at Rio Piedras

As an institution of higher education, the University of Puerto Rico at Rio Piedras has a responsibility to transmit learning in science and the arts while maintaining democratic ideals and a cultural integrity unique to the people of Puerto Rico. In teaching its students these ideals, the University aims to educate not only the students that traverse its halls, but also provide services to the community and to "collaborate with other organizations, within its appropriate sphere, in the study of the problems of Puerto Rico" (Puerto Rico Code, 2002).

The campus at Rio Piedras, opened March 12, 1903, was the first public university on the island of Puerto Rico. The 274 acre campus is located in Rio Piedras where 1060 faculty members provide education to approximately 15,000 undergraduate students, 4000 graduate students. (University of Puerto Rico at Rio Piedras, 2005). Students and faculty members elect representatives to the board of trustees, the main governing body of the university. Other representatives who sit on the 13 member board include 10 citizens of Puerto Rico who are appointed by the governor under recommendations from the senate. It is these board members who formulate the directives which shall govern the direction and development of the university**"** (Puerto Rico Code, 2002).

The entire university system is broken up into smaller campuses; the University of Puerto Rico is one of these campuses. While the campuses are individual and offer differing programs of study, they are all presided over by the president of the university system,. Antonio García Padilla. The president represents the higher educations council

in Puerto Rico and is responsible for enforcing the objectives, standards, and budgetary demands of the university and officially represents it. In addition to the president of the entire system, each individual campus is represented by a chancellor who is nominated by the president and is in charge of the administration his or her respective campus. The chancellors are also responsible for appointing deans of the university to help with administration (Puerto Rico Code, 2002). The chancellor at the Rio Piedras campus is Gladys Escalona de Motta (University of Puerto Rico at Rio Piedras, 2005).

Being a public university, the cost of going to school at the University of Puerto Rico is subsidized by the government. Education per semester at Rio Piedras costs approximately 1344 dollars for in-state students and 3336 dollars for out-of-state students (University of Puerto Rico: Rio Piedras, 2006). The appropriations to the university by the government each year total approximately 221 million dollars and are administrated by the people in the preceding two paragraphs.

Our liaison, Dr. Maritza Barreto, is a professor in the Geography department of the Social Sciences faculty at the University of Puerto Rico – Rio Piedras. She holds a bachelor's degree in Geography from UPR – Rio Piedras and a master's degree and Ph.D in Marine Geology from UPR – Mayaguez. Her areas of specialization and research encompass areas of marine geology and environmental sciences including remote sensing, geology, physical geography, and coastal geomorphology. In addition to these specific interests, Dr. Barreto adheres to the objectives of the University in studying the problems of the coastlines and overall ecological health of Puerto Rico. Working with Dr. Barreto, we will be able to further the University's cause by examining the causes of

marine corridor degradation and providing recommendations to government officials, tourism companies, and fishermen to alleviate this degradation.