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Dear Mr. González,

Enclosed is our report entitled "Establishing the Management Region for the Guánica Public Forest." It was written at the Department of Natural and Environmental Resources during the period of March 15 through May 6, 2004 after completing preliminary work in Worcester, Massachusetts. Copies of this report are simultaneously being submitted to Professors Addison and El-Korchi for evaluation. Upon faculty review, the original copy of this report will be catalogued in the Gordon Library at Worcester Polytechnic Institute. We appreciate the time that you and Mr. Canals have devoted to us.

Sincerely,

Jeremy Lerch
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Establishing the Management Region for the Guánica Public Forest

Proposal Submitted to:

Professor Bland Addison _____

Professor Tahar El-Korchi _____

WPI Puerto Rico Project Center
By

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May 4, 2004

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 Department of Natural and Environmental Resources or Worcester Polytechnic Institute.

This report is the product of an educational program, and is intended to serve as partial documentation for the evaluation of academic achievement.

Abstract

This document, prepared for the Department of Natural and Environmental Resources (DNER), describes the pressures of urbanization and development currently threatening the Guánica Public Forest. The most comprehensive way to address these pressures is to design a management region regulating human and societal interactions within the biosphere. The current DNER management procedure is analyzed based on factors needed for an efficient ecosystem management region, including biodiversity, urbanization, pollution and tourism. We located such pressure points in the Guánica region, including the surrounding municipalities of Yauco, Guayanilla, Sabana Grande, and Lajas. The Commonwealth is pushing for these municipalities for an increase in urbanization and tourism, which will require careful management. The forest is placed under immense pressure from the Yauco Municipal and Industrial Landfill is located on the outskirts of the Guánica Forest. We have made recommendations to the DNER that will hopefully aid in the preservation of the Guánica Biosphere Reserve and prevent future destruction arising from unmanaged urban and industrial development.

Executive Summary

The Guánica Biosphere Reserve is the largest tropical dry forest in the world located on the southwestern coast of Puerto Rico. This forest is home to over 700 uncommon types of plants and animals, 48 of which are endangered and 17 of which are endemic to the Guánica Forest. For this reason the Guánica Forest is an rich in biodiversity that needs to be protected before the wildlife becomes endangered or extinct. Through working with the Department of Natural and Environmental Resources (DNER), our goal was to identify specific areas that create stress on the Guánica forest and make recommendations on how to protect the forest from future destruction.

We carried out archival research, interviews and field research to identify the specific areas that place stress on the forest. We began identifying areas by studying the municipalities surrounding the Guánica forest: Yauco, Guayanilla, Guánica, Lajas and Sabana Grande. We performed archival research with the materials provided from the DNER, Planning Board and Census Office. We interviewed numerous authorities in the Guánica region, including Miguel Canals, the current manager of the Guánica forest, and Edgardo González, the director of the DNER-NSF (Forest Service Negocios). Through field research, we visited the Guánica forest and the surrounding municipalities, which provided us with first-hand knowledge of the forest

Currently, the Guánica Public Forest is suffering from numerous pressures resulting from human encroachment. These pressures include coastal and inland urbanization, overuse of recreational areas, commercial and road developments, and expansion of the Yauco Municipal and Industrial Landfill. We anticipate that through locating these areas of expansion, it will help warn the DNER address potentially damaging developments that might negatively affect the protected areas.

One underlying concern is that official efforts to boost the economy of the municipalities surrounding Guánica by increasing the development of hotels and resorts will exhaust the carrying capacity of the region. Expansion of hotels would require a larger infrastructure in the municipalities to support an increased number of tourists with roads, restaurants, hospitals and shopping centers. Currently, the Commonwealth government is pushing to demolish an abandoned sugar cane factory in Guánica and to convert that land into hotels.

The main pressure point affecting the Guánica Public Forest is the Yauco Municipal and Industrial Landfill, which is sending rats and other rodents into the forest. These rats and rodents are killing some species of endangered birds, particularly the Puerto Rican Nightjar, which nests on the ground. In addition, the landfill was constructed above a watershed without a proper liner to prevent toxic materials from seeping into the water system and dispersing them throughout the Guánica Forest.

Guánica consists of many environmentally sensitive areas such as the island of Cayo Aurora and the beaches where endangered sea turtles nest. Cayo Aurora is an island off the shore of Guánica that is subjected to overuse by recreational visitors during the summer months. The island is primarily made up of mangroves, which unfortunately people destroy by either performing poor boating practices or creating new trails through the island. The beaches of Guánica are the nesting grounds for the endangered sea turtles. Overuse of these beaches during the nesting period for the turtles has resulted in a detrimental effect on the sea turtle population around Guánica.

Upon locating these pressure points and environmentally sensitive areas we were able to develop recommendations for the DNER. The DNER could control the number of tourists visiting the island and the destruction of the mangroves by increasing the staff of DNER employees needed to protect Cayo Aurora. Further, the DNER could control

regional pollution and waste management problems by preventing the government from expanding the Yauco landfill. Lastly, the DNER should establish educational programs for the Guánica Public Forest to help increase awareness about the forest throughout the island of Puerto Rico.

We hope that our findings and recommendations will provide a starting point for the DNER to develop an effective conservation plan for the Guánica Biosphere Reserve. By locating these pressure points, the DNER can geographically specify the areas where they need to focus their efforts of conservation. It is important for the DNER to incorporate the perspectives of surrounding communities when developing a conservation plan. Once the surrounding municipalities recognize the aesthetic and environmental value of Guánica Forest, then the government and community can work more cooperatively to help preserve the forest from future destruction.

Authorship Page

The final product of our Interactive Qualifying Project (IQP) was an equal contribution by all project members. As a group, we equally participated in the preliminary research, documentation, editing and formatting of the project. Working collectively as a team, we feel was the most efficient way in developing of our final IQP. All group members played a significant role throughout the course of the development of our project in Puerto Rico.

Acknowledgements

Our team would like to take the opportunity to acknowledge the following people for their assistance throughout our project in Puerto Rico. First and foremost, we would like to thank our advisors, Professors Addison and El-Korchi, for their assistance and guidance throughout the past semester.

At the Department of Natural and Environmental Resources, we would like to acknowledge all the personnel for their cooperation and dedication to our project team. We would like to give a special thanks to our liaison Edgardo González, the Director of DNER-NSF. Mr. González has devoted his time and efforts in assisting us in the completion of our IQP. We would also like to give a special thanks to Miguel Canals, the Manager of the Guánica Public Forest. Mr. Canals provided us with guidance throughout the Guánica Forest and the surrounding municipalities. Without the assistance of Mr. González and Mr. Canals, this project could not be possible.

We would like to thank Rubén Padrón Veléz, Chief of the Management Office of DNER-NSF for his assistance throughout the Guánica Public Forest. We would like to thank the following people for their helpfulness and valuable information through interviews they provided for our project team. We would to thank the following people that we interviewed: Ernesto Velazquez, the Director of the Coastal Zone Management Plan, Jaime Pabon, Environmental manager at the San Juan Bay Estuary Program, Vincente Quevedo, Head of data analysis at the Natural Heritage Foundation, and Dr. Frank Wadsworth, Retired Manager of Guánica Public Forest. We would also like to thank the following personnel from the DNER for their presentations they provided for our project team: Mia Sued, Environmental Planning DNER-NSF, and Carmen Hernandez, Land Acquisition of DNER-NSF. Finally, we would like to thank Gabriel Orta Marqués from the DNER-NSF.

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1.0 Introduction

Ecosystems around the world are facing many pressures from tourism, pollution, urban expansion, and deforestation (Barrow, 1999). Implementing a management plan can help preserve the ecological and biological diversity in these ecosystems that are currently being threatened by these pressures. An effective management plan needs to guarantee that plant and animal species can survive and continue their normal biological processes (Noss, 1993). However, the objectives of conservation policies have shifted over the years from the emphasis put on the protection of biodiversity and species habitats, towards concentration on the protection of ecological processes that take into account the human activities within the management area (Noss, 1993). Organizations, such as the Environmental Protection Agency and the United States Forestry Service, have been created to enforce ecosystem management plans for the conservation of biosphere reserves and ecological processes.

One particular ecosystem facing these pressures is the Guánica Public Forest, located on the southwestern coast of Puerto Rico. Guánica contains protected areas of both an inland tropical dry forest and a coastal region. The Guánica Public Forest is being threatened by the pressures of human interaction with nature such as the development of residential and tourist housing projects, expansion of landfills into the reserve, and the loss of biological corridors (NOAA, 2004b).

The government organization responsible for the conservation of such biosphere reserves and ecosystems in Puerto Rico is the Department of Natural and Environmental Resources (DNER). The DNER currently implements a regional management approach for the preservation of Puerto Rico's public forests that is when the forests are divided by

land use purposes such as research, visitors/recreational, administration, special uses, and plantations. Each of the distinct purposes listed above will have different conservation needs, requiring varying management approaches. The DNER has asked us to design an appropriate management region for the protected biosphere reserve in Guánica.

We have developed an analysis which will help locate pressure points that have resulted in the deterioration of the coastal and inland regions of the Guánica Forest. Pressure points are areas negatively affected by human impact or areas that have the potential to be a problem in the future. They are also environmentally sensitive areas that should be protected before irreversible damage is caused by human interaction with nature. Pressure points are recognized by changes in land use, which can be produced by an increase in population, road development, urban areas, schools, recreational areas and commercial developments. In the next chapter we analyzed current human interactions in the surrounding municipalities that have the potential to harm Guánica's ecosystems in the future.

The DNER asked us to design a management region based on pressure points and biological corridors. The DNER requested us to assist in the preservation of the Biosphere Reserve from future threats of urban expansion and tourism. We have developed a regional map to identify the different conservation needs for each of the management areas in Guánica. Our main goal is to aid the DNER in producing a map indicating the pressure points that directly and indirectly affect Guánica.

2.0 Background

The purpose of our project was to design the management region of the Guánica Public Forest and Biosphere Reserve for the Department of Natural and Environmental Resources. The forest is divided into distinct regions including inland regions, which contains the biosphere reserve and coastal regions consisting of coral reefs and aquatic wildlife. The Guánica Public Forest is being threatened by the pressures of developing residential and tourist housing projects, expanding landfills into the reserve, and urbanizing into the biological corridors. This chapter defines the different management tools and frameworks that will take into account the ecological and social factors in each of these regions.

2.1 The Guánica Public Forest

The Guánica Public Forest is located at the southwestern coast of Puerto Rico, in the small town of Guánica. It is the largest subtropical dry forest in the world, spanning around 4000 hectares (UNESCO, 2004b). Guánica's beaches and exotic forests attract tourism to this region. Figure 1 and figure 2 illustrate the location of Guánica in Puerto Rico and the Guánica region, respectively.

Figure 1: Map of Guánica in Puerto Rico

Figure 2: Guánica Regional Map

2.1.1 The Guánica Biosphere Reserve

A biosphere reserve is an ecosystem that is considered to be an exceptional example of biodiversity (UNESCO, 2004c). In order for an ecosystem to become a biosphere reserve, it must be nominated by a national government. After it is nominated, the decision to give it this designation is made by the United Nations Educational, Scientific and Cultural Organization (UNESCO).

Biosphere reserves have three main functions: conservation, development, and logistic (UNESCO, 2004c). The *conservation function* is that anything named a biosphere reserve is supposed to be ecologically preserved. The *development function* is that biosphere reserves are supposed to associate the environment with economic and human development. The *logistic function* of biosphere reserves is that they are supposed to be a testing ground for new management and conservation approaches.

There is no central government for all of the biosphere reserves; instead they are managed by the local government (UNESCO, 2004c). Despite this, there are still certain global conventions for how a biosphere reserve must be managed. Each biosphere reserve is comprised of three main regions: the core area, the buffer zone, and the transition area. The core area is the main area, which is the only legally protected region of a biosphere reserve. The buffer area is an area in between the core area and the non-protected regions. The buffer area is also the area where the local government of the biosphere tests any new management or conservation policies before implementation in the core area of the biosphere. The outer transition area usually consists of either agricultural regions or urban developments. In this area the community works together to sustain the resources of the biosphere reserve.

The Guánica Public Forest was declared an international biosphere reserve by

UNESCO in 1981. It was declared a biosphere reserve because the Guánica Public Forest is considered one of the best examples of a tropical dry forest in the world (UNESCO, 2004c). The Guánica Public Forest exhibits a high level of plant and animal diversity for a tropical dry forest. The Guánica Public Forest was named a biosphere reserve before future destruction of the forest from human interaction with nature. Being named a biosphere reserve has brought more public attention to the forest, which has in turn helped in the conservation of this region. Due to this increased attention, local community has begun to realize the importance of the preservation of the Guánica Public Forest.

2.1.2 Endangered Species in the Guánica Public Forest

The Guánica Public Forest is home to more than 700 uncommon types of plants and animals. Of these species there are 48 endangered species, out of which 16 species are unique to Guánica (Rivera, 2004).

One endangered species that lives in the Guánica Public Forest is the Puerto Rican crested toad (*Peltophryne lemur*) (U.S. Fish and Wildlife Service, 2004a). This is a small toad, about 2.5-4.5 inches in length. The population of these toads in Guánica is estimated to be in the range of 1,500 to 2,000 toads, which is the largest known population of the Puerto Rican crested toad. The toad is endangered because of the destruction of its breeding grounds. There are currently construction projects in the Guánica region that would have a detrimental effect upon the Puerto Rican crested toad population. However, there are attempts to revise the projects so that they will not destroy the breeding grounds of this toad. There are many other endangered and threatened animals in the Guánica region ranging from parrots to sea turtles (U.S. Fish and Wildlife Service, 2004a).

The Guánica Public Forest is also home to many different species of birds, 12 of which are endemic. The species that need protection include the Puerto Rico Whip-poor-will, the Puerto Rican Nightjar, and the Puerto Rican Vireo. The Puerto Rico Whip-poor-will and the Puerto Rican Nightjar are both endangered birds that only breed in the Guánica Forest. The Puerto Rican Whip-poor-will and the Nightjar nest on the ground of the forest. Mongooses, which were introduced to the island by the Spaniards in the 1870's, prey on these ground-nesting birds (Vilella and Zwank, 1993). The Puerto Rican Vireo population in Guánica has been declining, mainly as a result of a lack of reproductive success caused by parasitism, predation, and environmental factors (Faaborg et al., 1997). Understanding the basic patterns, such as nesting and reproduction, of these endemic birds to the Guánica Forest is vital in developing protection procedures.

In addition to endangered animals, there are many species of endangered plants in the Guánica region. There is currently a recovery plan that has been established in the Guánica Public Forest that will attempt to conserve three specific endangered plants *Mitracarpus maxwelliae*, the *Mitracarpus polycladus*, and the *Eugenia woodburyana* (U.S. Fish and Wildlife Service, 2004b). The problem with this recovery plan is that it is being implemented in the year 2025.

The *Mitracarpus maxwelliae* and the *Mitracarpus polycladus* are both small shrubs that are native to the Guánica Public Forest. The *Eugenia woodburyana* is a small evergreen tree that also grows in the Guánica Public Forest. There are currently believed to be around 1,500 hundred *Mitracarpus maxwelliae* in the forest. This is the only area where these plants are known to grow. There is not a known number of *Mitracarpus polycladus,* but they are only known to grow in the Guánica Public Forest. The *Eugenia woodburyana* is known to grow in the municipalities of Cabo Rojo and Lajas in addition

to the Guánica Public Forest. However there are only believed to be 150 of these plants in all three of these regions (U.S. Fish and Wildlife Service, 2004b).

2.1.3 The Guánica Lagoon

The Guánica Lagoon was the largest natural freshwater body of water in Puerto Rico, located in Barrio Arena in the Guánica municipality (Morris, 1999). It was drained in 1955 for the purpose of agricultural development and irrigation. It was thought that by draining the lagoon the land could be used for agricultural applications such as grazing land and farm land. In addition, the irrigation channels created by draining the lagoon would serve as a water source for agricultural regions of the surround municipalities. Recently, the DNER has been developing proposals to refill the lagoon to its original state.

There are several reasons why the DNER is considering refilling the lagoon. The main reason is that the current land of the lagoon is suffering from poor land quality and low agricultural productivity (Morris, 1999). The land is comprised mainly of limestone covered with soil lacking proper nutrients. The land also cannot retain water for agricultural productivity. Another reason that the DNER is considering refilling the lagoon is to create a freshwater wildlife habitat which will expand and maintain biological diversity. Migratory birds and other animals will migrate to this lagoon and establish a new habitat. Lastly, the restoration of the lagoon has the possibility of socioeconomic benefits such as tourism, fishing, bird watching and nature observation.

2.1.4 Tourism and its Effects on the Guánica Region

After being named a biosphere reserve in 1981, Guánica has seen a 200% increase in tourism (MABNet, 1998). This increase in tourism has both positive and negative

effects on the Guánica Public Forest. The increased tourism brought Guánica to the public's attention by making people aware of Guánica's rich biodiversity and the need to help conserve this forest. The tourism also had many negative effects on the Guánica Region. Increased deterioration of the natural resources in the Guánica region has been a result of an increase in tourism since being named a Biosphere Reserve. More stress and damage has occurred to the forest with the increase in visitors traveling through the Guánica Public Forest. This deterioration can be seen in Cayo Aurora (Gilligan's Island), an island located off of the southwestern coast. The management restricted the number of visitors per day to 325 people in order to protect the island from further destruction.

Tourism could have many beneficial effects for the Guánica Region by increasing the public's awareness in the need of conservation of the Guánica Forest. The DNER has been using a management system known as the Education and Outreach Program to generate interest in the protected forests of Puerto Rico (Ledesma, 2000). This program is designed to promote environmental awareness for the visitors through educational activities.

Educating the younger generations through participation in these activities helps stimulate the children's interests in these protected forests. The power of decision making usually resides in adults, but children often have input into the final decisions that adults make on environmental protection issues. An example of an activity for children would be a themed poster contest in which the children make posters that contain information about the Guánica region and its importance. The winning poster could then be placed in the information booth at the forest. In addition to activities for children, the Education and Outreach Program also hosts activities for adults, such as educational workshops and public forums. It also hosts fishing clinics and catch-and-release fishing contests.

One area where tourism is negatively affecting the Guánica Public Forest is on the coastal region (NOAA, 2004b). An increase in boating and other water sports has put the coral reefs under a great amount of stress. Anchorage, land erosion, and sediment are causing accelerated damage to the reefs in the Guánica region. Until a management plan fully protects the Guánica Public Forest region, residential and tourist housing projects will put stress onto the Guánica Public Forest. The expansion of a municipal landfill into a regional one that shares a border with the biosphere reserve puts more stress on the conservation attempts in the Guánica Public Forest. These are a few problems that have led to the destruction of the biological corridors and the destruction of many privately owned natural areas in Guánica.

2.2 Ecological Regions and Factors

The Guánica Public Forest is separated into ecological regions including a tropical dry forest, an inland region, and a coastal region. All three of these regions contribute to the unique ecosystem of the Guánica Public Forest. There are important pressures such as deforestation and pollution that affect each of these regions. The following sections provide an understanding of the importance of tropical dry forests, inland regions, coastal regions and the factors of an ecosystem such as deforestation and pollution.

2.2.1 Tropical Dry Forests

Guánica Public Forest is an excellent example of a tropical dry forest with a biological diverse ecosystem. Tropical dry forests occur in climates that are warm year-round and have two distinct seasons, rainy and dry (WWF, 2001a). In these forests the dry seasons are known to last several months depending on how close the forests are to the equator. During the rainy season they may receive several hundred centimeters of rain

per year. The Guánica Public Forest receives an average of 30 inches of rain annually (Ledesma, 2000).

Most of the trees and shrubs found in tropical dry forests are deciduous that is, they lose their leaves due to the extended dry season (Mastrantonio, 2000). The tropical dry forests of Puerto Rico are filled with unique plants that show special adaptations to the long dry season and low annual rainfall. For example, many plants have developed water storage structures to help retain moisture during the dry seasons (National Geographic Society, 2001a). Thus, the plants and trees have developed waxy coatings on their leaves, trunks, and branches. Many of the species living in tropical dry forests have to display extraordinary adaptations due to the harsh climate. Due to these adaptations, the Guánica Public Forest has become the home of 16 unique species (WWF, 2001a & Rivera, 2004).

The importance of tropical dry forests can be categorized into two main areas: environmental importance and socioeconomic importance (CFAN, 2003). It is significant to understand the importance of tropical dry forests to help develop plans to aid in the preservation of existing forests. The environmental importance of tropical dry forests is the role they perform in the conservation of the plants and animals in the ecosystem. Tropical dry forests are the home of 70 percent of the world's plants and animals. These forests contain more than 13 million distinct species and more than 200 tree species per hectare exist in tropical dry forests (CFAN, 2003).

In addition, tropical forests are important in the conservation of watersheds, which supply water for irrigation and sanitation (CFAN, 2003). The importance of watersheds lies in the fact that they help absorb the excessive rainfall that will gradually be released back into the forests. The tropical forests regulate stream flows by these

watersheds absorbing the rainfall and water into the soil. Then the watersheds will gradually be releasing it into the streams and rivers, which minimize both downstream flooding and drought conditions (CFAN, 2003).

The socioeconomic aspect of tropical dry forests is that more than 500 million people live in or at the edge of the tropical forests (CFAN, 2003). These people are dependent on the forests because of the important products and environmental services they provide for food and shelter. Tropical forests provide the world with many valuable resources, such as rubber, fruits and nuts, meat, medicinal herbs, lumber, firewood, and charcoal (Mastrantonio, 2000). The surrounding communities also depend on these tropical dry forests as the center of their culture and spiritual traditions (CFAN, 2003).

2.2.2 Inland Region

Guánica Public Forest is surrounded by the expanding town of Guánica. The inland region of the Guánica Public Forest is facing pressure from urbanization from the surrounding area. In 1800 only five percent of the US population lived in urban areas. In 1999, it was estimated that within a year, 80 to 90 percent would live and work in urban environments (Barrow, 1999).

For many centuries the Puerto Rican economy was dependent on agriculture. However, towards the early 20th century, the Puerto Rican economy shifted from agriculture to an industrial economy (Mar Lopez, 2001). This shift in the economy along with an increase in population has resulted in an increase in urban areas. Due to this shift in the economy, 11.3% of Puerto Rico was classified as urban in 1977 and seventeen years later, these urban areas had increased by 27.4% (Mar Lopez, 2001). The US Census Bureau calculated that in the year 2000 Puerto Rico was 94% urban (McNally, 2003).

The Guánica Public Forest has been subjected to urbanization from the surrounding communities and from the effects of the increase in tourism. This rapid growth in urbanization and tourism has led to a number of environmental problems, such as air and water pollution, unwanted disposal and demand for fuel wood. Urban environmental management is going to become a major issue for the future of tropical dry forest in the twenty-first century (Barrow, 1999).

2.2.3 Coastal Regions

The nation's coastal and ocean resources are under increasing pressure from population growth and development. An estimated 40% of the world's population lives within two kilometers of the coast in the Caribbean (UNEP, 2002a). They are threatened by the pressures of industrial development, and urban and tourism expansion. Coastal zones are interconnected by land and sea through rivers and streams. Thus, the coasts are affected by both local and distant conditions (UNEP, 2002a). The relationship between the coastal and land areas results in air pollution, loss of marine and land resources, soil damage, and the increased level of noise and congestion.

The Caribbean coastal zone contains many important biological ecosystems (UNEP, 2002a). The difficulty with managing coastal zones is that they are highly sensitive areas. There are many aspects of coastal regions such as coral reefs and mangroves that have to be accounted for when developing a management plan for coastal zones. An effective coastal zone management strategy will incorporate the aspects of coastal regions and the direct and indirect effects developed from the inland regions.

Coral Reefs

Coral reefs are the world's most complex, biological diverse ecosystems (NOAA, 2004a). Coral is important because it provides food and shelter for the surrounding

organisms and reefs protect the coastal shoreline from floods, storms and erosion by acting like barriers (UNEP, 2002a). Coral reefs are the most important and productive coastal resources in the Caribbean. Coral reefs provide valuable assets, such as food, jobs, protection from storms and erosions. Tourism to coral reefs provides billions of dollars in revenues each year to the Puerto Rican economy (CRTF, 2004). According to the study of Caribbean reefs by British researchers,

> Coral Reefs have declined by about 80 percent in some areas, a loss that may take many decades to recover. From this study, the researchers say that there is no evidence that can convincingly attribute the coral loss to climate change from global warming or atmospheric carbon dioxide. Instead, they suggest coral is being killed by disease, storms, overfishing, pollution and habitat destruction (Garner, http://www.enn.com/news/2003-07-18/s_6705.asp, 2003).

Guánica's coastal region has a rich diversity of coral reefs. The coral reefs are located off the coast of Los Congres and along the coast of Cayo Aurora. The reefs in Guanica are mostly comprised of two different coral species, *Gorgonia spp.* and *Cerviconia spp* (Ledesma, 2000). The reefs serve as a home for a variety of different fishes, sponges, algae and other marine life. In recent years, coral reefs in the Guánica coastal region have been degrading due to numerous factors such as tourism, recreation, and natural disturbances (San Juan Bay Estuary Program, 2000). Hurricanes that have struck areas such as Cayo Aurora have caused severe damage to coastal coral reefs. In addition, the recovery rate of these reefs has been slow. The combination of degrading coral reefs and slow recovery rate has detrimental effect on the marine ecosystem (Ledesma, 2000).

Mangroves

Mangrove forests are found along the coasts of tropical and subtropical regions (UNEP, 2002b). Mangroves play an important role in ecosystems for threatened and

endangered species, shoreline protection, and nurseries. Mangrove trees help organisms by propped roots that grow out from the lower part of their trunks. These roots provide a surface of attachment for marine organisms, as well as nursery grounds of food and shelter for the organisms (Afrol News, 2004).

Mangroves also protect shorelines from damaging storm and hurricane winds, waves, and floods (South Florida, 2004). The roots act as a filter to maintain water quality and clarity, filtering pollutants and trapping sediments originating from land (South Florida, 2004). These roots help protect coasts against erosion by stabilizing sediments. Mangroves also protect reefs from land runoff sedimentation by trapping the sediments in their roots.

In the past governments and industries have classified mangrove forests as "wastelands" or useless swamps (Afrol News, 2004). However, currently government agencies have become more aware of the tremendous contributions of mangroves and coral reefs in the ecosystems. Conservation and management efforts are being aimed to help restore the damaged mangroves and coral reefs. UNESCO is currently implementing the Integrated Coastal Zone Management Plan, which effectively integrates the conservation of the coastal regions of coral reefs and mangroves (UNESCO, 2004b).

The Guánica coastal region is home to numerous species of mangrove. Species such as *Rhizophora mangle (red)*, *Avicennia nitida (black)*, *Laguncularia racemosa (white)* and *Conocarpus erectus (buttonwood)* are located in the Guánica coastal region. These mangroves are important to the coastal region of Guánica since they provide protection against erosion from hurricanes and act as a water filtering system (Ledesma, 2000)

2.2.4 Deforestation: Effects of Deforestation

The rate of deforestation has been climbing at an alarming rate and will continue uncontrollably until strict policies and laws are enforced (CFAN, 2003). The main reason behind deforestation is that humans are using natural resources faster than they can regenerate. Tropical forests cover approximately six percent of the earth's land area, but in this small percentage are the majority of plant and animal species. Acts of deforestation can entirely destroy wildlife habitats and in some cases entire ecosystems. Deforestation leads to many cases of a species endangerment or even extinction. It is important to realize that once a species becomes extinct there is nothing that can be done to reverse its extinction (CFAN, 2003). If the rate of deforestation isn't controlled, then any attempt to save tropical forests may not be possible.

The importance of tropical forests goes far beyond the scope of using them as natural resources for human needs and benefits (Gomez-Pompa, 1991). In addition to the economic variables the forests may serve, humans need to acknowledge their significant importance in sustaining life. There are economic benefits from deforestation; however deforestation results in many negative aspects that counteract these benefits. On a larger scale, tropical forests influence local and global climates; they maintain atmospheric humidity and air temperature levels and most importantly these forests absorb atmospheric carbon dioxide and break it down into breathable oxygen (CFAN, 2003). Before tropical forests can be protected people need to be educated about the reasons for deforestation and the outcomes, both positive and negative. According to the organization CIDA Forestry Advisers Network (CFAN),

> The Food and Agriculture Organization of the United Nations (FAO 1997) has estimated the annual rates of deforestation in developing countries at 15.5 million hectares for the period 1980-1990 and 13.7 million hectares for 1990-1995. The total forest area lost during the 15

year period was approximately 200 million hectares. To put this figure in perspective, 200 million hectares is more than the total land area of Mexico or Indonesia. (CFAN, 2003, http://www.rcfa-cfan.org/english/issues.12-3.html)

Figure 3 shows the Latin America and Caribbean section of the pie chart. This is the largest of the three with 85 million hectares that were subjected to deforestation from 1980-1995. Figure 4 is a line graph that shows the sharp decline of tropical forests in the world.

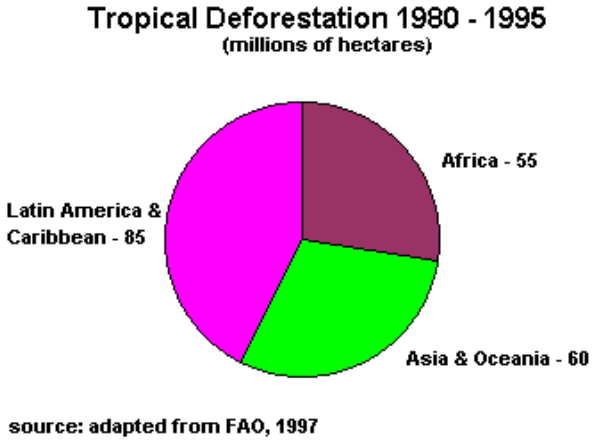

Figure 3: Tropical Deforestation in the World

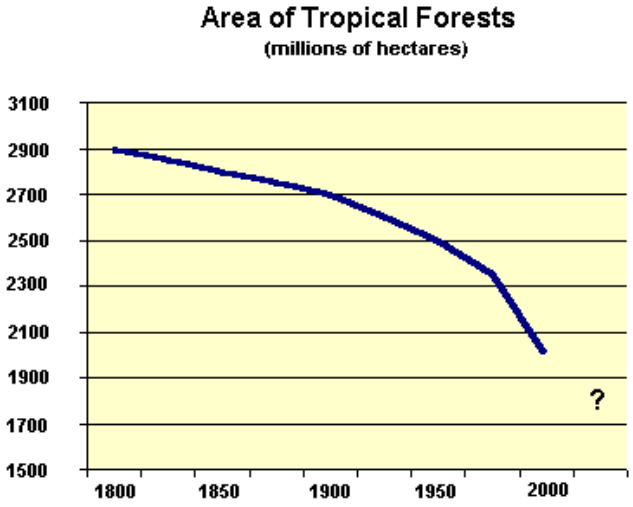

Figure 4: The Depletion of the Area of Tropical Forest in the World

2.2.5 Pollution and its effects on the Tropical Dry Forest

Pollution and waste created in the tropical dry forest is a result of the urbanization of surrounding cities. Many cities, even in developed nations, have dangerous levels of atmospheric pollution, in addition to sewage and waste problems. The expanding cities destroy the biodiversity of the tropical dry forests (Barrow, 1999).

Many of the problems generated by urban development are ones associated with domestic wastes (Edington, 1977). A majority of the wastes caused by the cities are a threat to the tropical dry forest and biosphere reserve. One cause of air pollution is smoke created by industries. Water pollution occurs because the cities and tropical dry forests are connected by rivers and streams (Nalven, 1997). These rivers and streams carry toxic wastes and excess sediments to and from the tropical dry forests

2.3 Ecosystem Management

Ecosystem management needs to incorporate the goals and principles of an effective management plan. An ecosystem management system has a number of different management tools and polices that need to be taken into account for a systematic approach. An ecosystem can be defined as a dynamic complex of plant, animal, and micro-organism communities and their non-living environment interacting as a functional unit (Park, 1980). An ecosystem management approach is a strategy that encompasses different types of management for land, water, and living resources in a way that promotes conservation (Convention on Biological Diversity, 2002). The application of an ecosystem management approach should properly balance these three elements. In addition, an ecosystem approach should consider human interaction as an integral component of an ecosystem. Due to the uncertain and dynamic nature of ecosystems, an ecosystem approach requires adaptive management techniques to deal with this instability

(Shillito, 1994).

In order to preserve coastal tropical forests, proper care and management must be implemented and strictly regulated. Without management and regulation, these areas will have no protection against disturbances such as urbanization, deforestation, tourism, and poor land use planning (Shillito, 1994). Areas such as the Guánica Public Forest are under the pressures of tourism, pollution, urban expansion, and deforestation. Coastal regions in general are being subjected to an increase in population. In Puerto Rico, 50% of the islands' population is along the coast, this number is expected to double by 2015 (NOAA, 2004a).

Table 1 below outlines advantages and disadvantages of establishing an ecosystem approach for a region such as Guánica. As seen from this table, the advantages include topics such as recognizing the mutual dependence on all parts of an ecosystem, encouraging preventive thinking and understanding the structure of an ecosystem as a whole (Slocombe, 1994). Problems of an ecosystem include the fact that there is not a standard ecosystem definition for an environmentalist to follow. Also, the narrow mindedness of the government officials for not acknowledging the importance of ecosystems is often overlooked. These advantages and disadvantages are important concepts to consider when developing an ecosystem management plan to be effectively implemented in areas such as Guánica's Biosphere Reserve.

Table 1: Ecosystem Management Approaches

Advantages	**Disadvantages**
Comprehensive, holistic approach for understanding whole systems	May neglect sociocultural issues such as politics, power and equity.
Different view of science that recognizes diversity of cause and effect, uncertainty, and probabilistic nature of ecosystems	Ecological determinism: danger of generalizing from biophysical to socioeconomic systems

Draws on theory and methods from different fields to generate models and hypotheses	Nebulous: a vague, superorganismic theory of poor empirical foundation that relies on analogy and comparison
Contributes to understanding limits, complexity, stresses and dynamics	Non-standard definition of 'ecosystem'
Encourages preventive thinking by placing people within nature	Reification of analytical systems; in some approaches linked to reductionist and equilibrium views
Facilitates locally appropriate, self-reliant, sustainable action	Narrow spatial focus on local ecosystem structures and processes
Facilitates co-operation, conflict reduction, institutional integration	Functionalist and/or energy analysis are overemphasized
Requires recognition of mutual dependence on all parts of a system	Duplicates and/or overlaps other disciplines without a special contribution of its own
Results in criteria for management actions	If ecosystem approaches can apply to everything they may be meaningless
Facilitates studies that integrate a range of disciplines (holistic)	

Adapted by Slocombe, 1994

2.3.1 Goals and Principles of an Ecosystem Approach

Every ecosystem management approach has different goals depending on the ecosystem, environment, location, etc. The Convention on Biological Diversity, a subsection of the United Nations Environment Program, defines a list of goals and principles in the implementation of an ecosystem management approach (Convention on Biological Diversity, 2002). In addition, the Department of Natural Resources in Michigan defines a similar set of goals and principles (DNER- Michigan, 2004). In reviewing both management approaches, our own goals and principles can be developed.

The points listed below serve as a guide for goals and principles of an effective management approach:

1: In defining the objectives of management for land, water and living resources, the rights and interests of society should be recognized (Convention on Biological Diversity, 2002)**.**

The management plan should consider society in the implementation of a management approach. Local communities and people living in areas where the plan will be implemented should have a voice in the objectives of a management plan.

2: Components of the coastal ecosystem are all interconnected: what happens in the watersheds, in the estuaries, and in the near shore ocean, and far at sea affects the overall (DNER- Michigan, 2004).

Proper planning and recognition of these factors must be considered since coastal and inland ecosystems are interconnected by water flow. Events that occur in watersheds, estuaries and water and inland areas are all directly and indirectly interconnected due to the close relationship between the inland and coastal ecosystems.

3: Managers of an ecosystem should consider the effects of their activities on adjacent and other ecosystems (Convention on Biological Diversity, 2002)**.**

It is important to acknowledge other ecosystems in the surrounding area since there are direct impacts from one ecosystem to the other. Careful study and analysis needs to be done.

4: Ecosystem management should consider economic effects in the implementation of an approach (Convention Biological Diversity, 2002). **Three main points are:**

a) Reduce those market distortions that adversely affect biological diversity;
b) Align incentives to promote biodiversity conservation and sustainable use;
c) Internalize costs and benefits in the given ecosystem to the extent feasible

When defining an ecosystem approach, economic issues need to be considered. Often, people who benefit from ecosystem conservation and management do not pay for it. Similarly, groups and organizations that create the need for ecosystem management, escape liability. For example, an industry that pollutes the region, results in the need for controlled pollution and waste management plan.

5: Management must recognize that change is inevitable (Convention Biological Diversity, 2002)**.**

Ecosystems are constantly changing due to the variations of weather patterns, population abundance, or species development. In order to account for these changes, adaptive management strategies must be considered, which will be discussed in later sections.

6: Balance of biological diversity should be maintained (DNER- Michigan, 2004)**.**

Biological diversity plays a very important role in the ecosystem, not only for its essential value, but also for its numerous contributions. In the past, management procedures have approached biological diversity by simply dividing regions according to "protected" and "non-protected" species. Efficient management procedures should be flexible by adapting management techniques to the undergoing change in biodiversity and ecosystem. There is great deal of literature dealing with ecosystem management.

The goals and principles listed above are derived from two sources that are useful and pertinent in our situation. The goals recognize certain factors that are affecting Guánica including how different regions are interconnected, economic impact and biological diversity. These goals and principles present the most important outcomes and objectives for ecosystem management and also provide reasoning as to why an area is managed the way it is.

2.3.2 Characteristics of an ecosystem approach

Criteria and Indicators (C&I) is a systematic approach for measuring, monitoring and reporting information on the ecosystems of sustainable forest management, or SFM (WNMF, 1999). "Sustainable forest management plans are forests that need to be managed as ecosystems, in order to maintain their natural processes and to ensure that they continue to provide a variety of benefits to society" (WNMF, 1999, http://www.wnmf.com/PDF%20Reports/C%20&%20I%20Guide.pdf). The United States has adopted the SFM criteria and indicators because principles discovered in tropical ecosystems have similar patterns to temperate forests (USDA, 2002 & ITTO, 2004). The C&I combine the environmental, social and economic aspects of forests to develop effective management practices for SFM.

The US Department of Agriculture Forest Service has adopted the criteria and indicators that were established originally by the Canadian Council of Forest Ministers, or CCFM (WNMF, 1999). A benefit of adopting the CCFM framework is the ability to make comparisons with forest management in other parts of the country. In 1992, the International Tropical Timber Organization (ITTO) adopted the criteria and indicators (Johnson, 2001). ITTO established workshops in Malaysia, Indonesia, Ecuador and

Cameroon to train management on the application of criteria and indicators. A total of 110 forest managers from 32 countries were trained during the years of 2000 and 2001. Since the CCFM framework is used internationally, environmentalists have developed a global understanding of Sustainable Forest Management.

Criteria are broad categories that answer the question "What is important?" Criteria are the range of forest values that need to be addressed and the essential elements or principles of forest management (USDA, 2002). The indicators tell us "How will we know if we are going in the right direction?" Indicators are parameters that measure specific quantitative and qualitative characteristics to help monitor the trends in the sustainability of forest management (USDA, 2002). Table 2 shows each of the criteria defined by a group of indicators that should be met to have an effective management plan.

Table 2: Criteria & Indicators of a Sustainable Forest Management

Criteria	Indicators
1. Increase in the extent of forest and tree cover	• Area of Forests • Area under open and dense forests • Trees outside forests • Per capita forest area and trees outside forests • Plantations
2. Maintenance, conservation and enhancement of biodiversity	• Varity of plant species • Variety of animal and bird species • Pure patches of certain species (specific habitats) • Waterbodies/waterholes
3. Maintenance and enhancement of ecosystem function and vitality	• Malformed, dried and deformed trees • Incidents of fire • Regeneration status • Incidence of pests, weeds and dieases • All age class trees
4. Conservation and maintenance of soil and water resources	• Number of gullies • Duration of streamflow in and around forest area • Decaying leaf litter • Water level in wells • Exposed roots and uprooted trees • Soil and water conservation measured • Perception about water availability

5. Maintenance and enhancement of forest resource productivity	• Production of fuelwood • Production of timber and poles • Number of Non Wood Forest Produce yielding trees per hectare • Number of other species per hectare • Total Non Wood Forest Produce production • Use of quality seeds in plantations
6. Optimization of forest resource utilization	• Per household consumption of timber, poles • Per household consumption of fuelwood • Availability and utilization of grass and fuelwood • Efforts to increase efficiency of fuelwood • Level of sustainable harvest of Non Wood Forest Produce • Value addition
7. Maintenance and enhancement of social, cultural and spiritual benefits	• Year of formation • Number of meetings per year • Average attendance in meetings • Average women attendance in meetings • Agenda and minutes • Fund available with Joint Forest Management Committee • Proportion of household income from forests • Trees, plants and patches protected for cultural reasons • Application of indigenous knowledge in management and use
8. Adequacy of Policy, legal and institutional framework	• Financial transparency • Capacity building • Conflict resolution mechanism • Adequacy of rules and regulations • Efforts to reduce pressure on forests • Mechanism for protection, management and benefit sharing

Adapted by ITTO, 2004

Table 2 suggests the use of criteria and indicators to determine the effectiveness of the current management plan for the Guánica Public Forest. In Guánica Public Forest, it is essential for the management plan to preserve the main ecological functions (ITTO, 2004). For example, the management plan must encompass the maintenance and enhancement of ecosystem, biodiversity, soil and water resources and forest resource productivity. Guánica's management plan needs to incorporate adequate policies and regulations that will be enforced in the ecosystem and urban areas. The way to determine the effectiveness of any management plan is by monitoring the criteria and indicators.

2.3.3 Management Tools and Frameworks

In developing a management approach it is important to review what tools and frameworks are available and evaluate how they can be used in the management of the Guánica Public Forest. A management framework outlines a general description of the main goals of a management plan. These include frameworks such as land use planning, ecological rhythms, reforestation, biological corridors, watershed management, adaptive management, collaborative resource management and habitat conservation planning. Having a detailed understanding of the different management tools and frameworks and how they have been used in environmental management has helped establish our plan.

Land Use Planning

Land use planning is an important factor that needs to be considered when evaluating a management procedure. After all, our goal was to protect and preserve the inland and coastal regions. If proper land use is not practiced, it will have detrimental effects. Land use planning redirects future development, preserves and maintains sensitive areas, and efficiently uses land in protected areas (Beale, 1980).

The most common practice of managing land use is through a type of land planning called zoning. Zoning is legislative regulations by which a municipal government seeks to control the use of buildings and land within the municipality (Hengst, 1987). *Overlay zoning* and *urban growth boundaries* are the two most applicable type of zoning for environmental management. *Overlay zoning* is a type of zoning where regulations can be put on certain plots of land without changing the base zoning. This is particularly helpful in a protected forestry region where certain areas can have different zoning regulations than the surrounding area. *Urban and growth*

boundaries are a technique of dividing urban areas from agricultural areas in order to preserve these areas (Beale, 1980). For example, growing urban areas in the Guánica Public Forest region could be separated from preserved forestry regions.

Ecological Rhythms

When designing a management plan an important factor that must be considered is ecological rhythms. Ecological rhythms are defined as biological and environmental processes that repeat at definite intervals. The most common of these repeatable patterns are issues such as precipitation and weather patterns (Scatena, 2001). Ecological rhythms can also be applied in a social sense. By analyzing repeatable patterns such as tourism and visitation periods, conclusions can be made regarding at what times certain events increase or decrease.

Two examples of biological rhythms, precipitation and tourism, are illustrated in Figure 5 and Figure 6. Figure 5 shows the average monthly rainfall ranging over a period of one year. Based on this information, a pattern can help determine how to create a management plan will take into account the ecological rhythms. Figure 6 illustrates the annual fluctuation in tourists visiting to the Puerto Rican beaches. The graph shows the peak of tourism is greatest during the summer months. Using this information displayed in these figures, repeatable patterns show trends that can help in adaptive management.

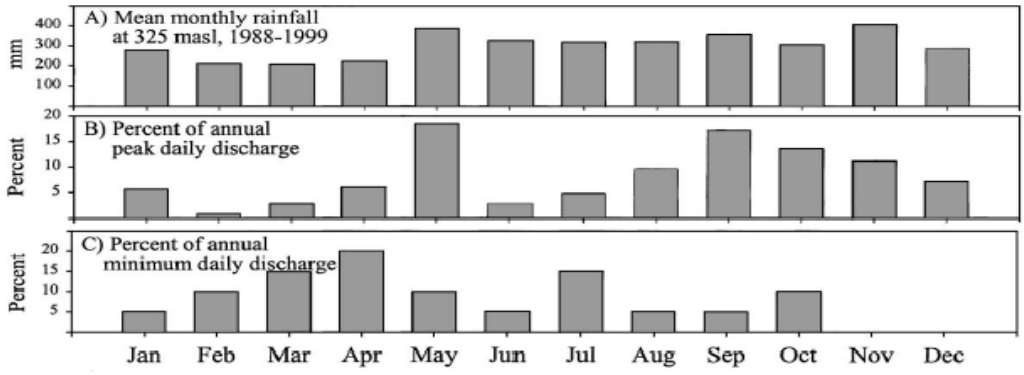

Figure 5: Annual Precipitation Amounts in Puerto Rico

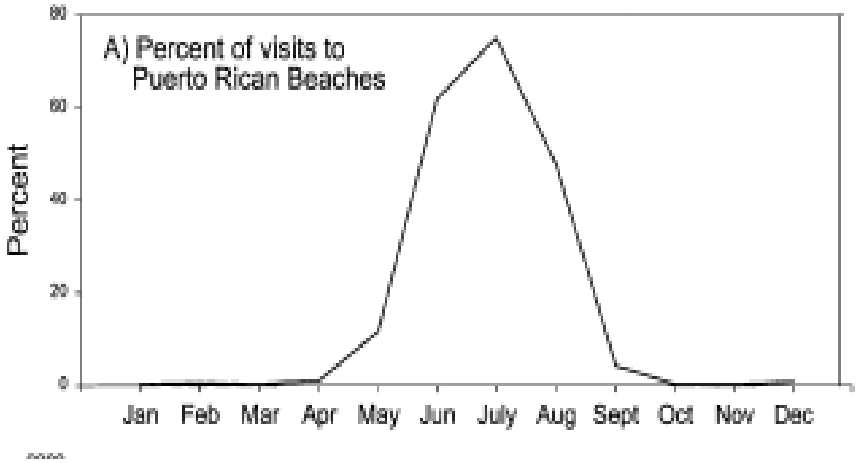

Figure 6: Annual Tourism in Puerto Rico

Reforestation

There are many reasons for reforestation other than to replace areas destroyed by loggers, farmers, transportation routes, and other means of deforestation (Chanlett, 1973). It is important to realize the effects tropical forests have on the land. The roots of the trees help prevent landslides and flooding, which can have devastating effects. Trees regulate wind speeds, which in turn protect crops, water currents, and protection of buildings and bridges (CFAN, 2003). Reforestation is also needed to ensure sustainable habitats for the species that live in the forests.

Techniques of reforestation, which can be seen in Appendix B, include planting and seeding in areas where forests were cut down or destroyed by natural disasters, such as hurricanes, floods, or droughts (Gomez-Pompa, 1991). Plants and seeds cannot be simply planted wherever the planter feels is suitable. It is important to realize that a forest can be destroyed at an incredibly faster rate than one can be regenerated. Knowledge of previous species present before deforestation is essential in reforestation techniques (Park, 1980). This is an important because to ensure proper reforestation proper knowledge of species needs to be known. Some characteristics include lifespan of species, growth per year, height variables, other species that rely on them, and estimated amount of time before reforestation areas have returned to its previous environmental status before deforestation (Park, 1980). It is necessary for organizations to work with the landowners of areas to ensure proper methods of reforestation and once these methods have been used it is essential for them to work together so the techniques are successful.

Biological Corridors

The purpose of a biological corridor is to preserve the connections between protected areas with rich biodiversity (Tierramerica, 2000). The main goal of biological corridors is to connect separate ecosystems of natural habitats. Currently, these corridors are being encouraged as an approach to promote sustainable development as well as protecting wildlife. Guánica is connected to the rest of the island by two main biological corridors. The northern biological corridor connects the Guánica Forest and the Maricao Forest. The land between the two forests is primarily used for agriculture and residential housing. The southwestern biological corridor connects the Guánica Forest to the Cabo

Rojo Forest starting at the Guánica Lagoon. These corridors help protect the rich biodiversity of the Guánica region by allowing species to migrate to and from the forest to other forests on the island. These two corridors must be analyzed, maintained and protected in order to produce an effective management plan for the Guánica Biosphere Reserve.

Watershed Management

A watershed is defined as an area of land in which precipitation, sediment runoff and water flow collect and are drained by rivers or streams (IITF, 1985). Watersheds are important factors in the conservation of forest regions since they play a crucial role in ecosystem health and human interaction. Soils within the watershed acts as a filter to purify water and dispose of waste products. Watersheds, both manmade and natural, serve as habitats for wildlife as well as reservoirs (Morris, 1997). Watersheds can also create biological corridor boundaries for adjacent regions.

Mining, grazing, timber harvesting, and constructing of roads in the watershed are some factors that can lead to the deterioration of watersheds and the increase in erosion (Morris, 1997). "Watershed management is critical for the maintenance of resources such as land, forest, soil, water, wildlife, and coastal ecosystems" (IITF, 1985).
Watershed management tools include dredging, erosion and sediment control and land use planning.

Erosion and sediment control is necessary for effective implementation of watershed management. Reservoir dredging and sediment removal is a type of tool used to manage and control watersheds. Dredging has certain side effects which include the removal and disposal of the sediment and a possibility of further erosion. These side

effects cause aquatic and land disturbances which can lead to the change or destruction of ecosystems (Morris, 1997). Land use planning is an important management tool when developing and securing watersheds. Techniques such as redirection of urban development and protection of sensitive areas are also useful for maintaining watersheds.

Adaptive Management

A key element of forest management is the adaptive management framework (Ministry of Forest, 2000). Adaptive management is the process of adjusting management in response to the fluctuations of information, knowledge or technology in ecosystems. Adaptive management recognizes the complexity and interconnectedness of ecological systems since the ecosystems are constantly changing. This framework provides a complete understanding of all the components and links that exist between the ecosystems (Gunderson et al. 1995).

Adaptive management is a continuous process for improving management policies and practices by learning from the analysis and outcomes of programs (Ministry of Forests, 2000). These programs are designed to apply selected policies and practices to determine the most effective implementation for the management issues. The outcomes of the programs will provide information on the current trends of the ecosystem and the effectiveness of management activities (USDA, 2002). Figure 7 shows adaptive management process as a six-step cycle (Ministry of Forests, 2000):

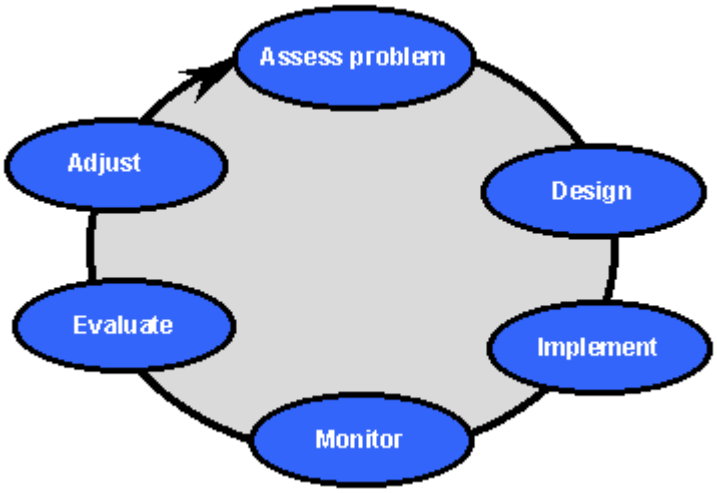

Figure 7: Six step Cycle of Adaptive Management

Adaptive management begins with determining the problems that need to be addressed in forests. For example, the Guánica Public Forest needs policies and practices to help lessen the pressures from urbanization and deforestation. Programs are designed to implement selected policies and practices on the forests. These polices are then monitored and evaluated to determine if the outcomes of these programs have been met by the original objectives. If the objectives are not satisfied, then adjustments will be necessary for the implementation of the next cycle.

Collaborative resource management

Collaborative resource management is a process in which a diverse group of people work together in the management of natural resources (Ecosystem Management Initiative, 2001). Collaborative resource management, also known as collaborative partnerships, has increased in popularity in the past decade. These groups include sustainable community initiatives, watershed councils and Coordinated Resource Management Process's (CRM's). When applied to ecosystems, collaboration

partnerships often mean collaboration between agencies as opposed to collaboration between communities. Numerous management programs based on agreed-upon principles have succeeded in protecting resources, promoting trade and guaranteeing quality (Civic Exchange, 2002). As a result, environmentalists and industry have recognized that mutual cooperation is a beneficial approach for resource management.

Collaborative Resource Management is applicable to Guánica in several ways. For one, Collaborative Resource Management is necessary for the coral reef ecosystems that exist along the coastline of Guánica. As discussed earlier, coral reefs are endangered by numerous factors (UNEP, 2002). Collaboration between agencies such as the DNER, the Center for Sponsored Coastal Ocean Research (CSCOR) and Coastal Ocean Program (COP) in addition with local fisheries will be necessary in order for proper resource management (NOAA, 2002). In addition, the numerous agencies that exist within the Guánica region itself would benefit from a collaborative approach. Since the goal of this project is to unify different management regions into one management approach, collaborative resource management will aid in this effort.

Habitat Conservation Planning

One ecosystem management framework is habitat conservation planning or HCP, which is an agreement that private landowners develop in regards to endangered species on their property (U.S Fish & Wildlife Services, 2003). This framework was established by the Defenders of Wildlife and is one of its primary conservation priorities. They are actively engaged in conducting research in an attempt to strengthen the planning process, content, and implementation. HCP has sparked local citizens involved with the environment, but most importantly these programs have linked local landowners, citizens

and the government together. This relationship is important and it can be a difficult task to overcome.

The demand for HCP has increased greatly in the past decade. By 1992 there were only 14 HCP approved, by the end of 1999 the Fish and Wildlife Services had registered more than 290, cover approximately 20 million acres (Nelson, 1999). These statistics show that landowners and citizens are actively preserving the environment and are still capable of future development in plans.

In 1973 Congress passed The Endangered Species Act that mandates the protection of threatened and endangered species and their habitat on federal and private land. This prohibits direct harm or destruction of endangered species and their habitats. Congress amended Section 10 (a)(1)(B) of the Endangered Species Act in 1982 in an attempt to balance species protection with private landowner development interests. This amendment allows private landowners to destroy some endangered species habitat through a permitting system (Nelson 1999). Under this amendment, private landowners developing, logging, or negatively affecting land known to be home to endangered species, are required to design and implement a plan that will minimize harm to the impacted species during the proposed project. Citizen involvement and cooperation with the local government is essential for HCPs to be effective.

2.4 Conclusions

Our literature review analyzes how human interaction can directly and indirectly affect the ecosystem of Guánica Public Forest. The next chapter establishes the research methods we used to develop a systematic approach to identify the problematic areas. From our methodology we were able to develop an analytical tool to help locate pressure points and environmentally sensitive areas for the Guánica Forest and surrounding

municipalities.

3.0 Methodology

The main goal of our project was to define an appropriate management region by analyzing the pressure points that directly and indirectly affect the Guánica Forest. A pressure point is a specific area that places stress on an ecosystem. We had to locate and show the pressure points that place stress on the conservation of the Guánica Public Forest. We constructed a regional map that identified the areas of conservation priority for the forest. This chapter outlines the methods we used to identify the conservation areas according to the amount of stress each of the pressure points placed on the Guánica Forest.

3.1 Study the Guánica Forest Region

To effectively define the management region for the Guánica Forest we first studied the Guánica region and the factors causing stress around the protected areas. We were able to identify the pressure points that needed to be protected through archival research and interviews.

Archival research accounted for a large amount of the information we gathered for our literature review. Our sponsor at the DNER, Edgardo González, provided us with literature on the past management plans for the Guánica Public Forest and other existing coastal management plans such as the Cabo Rojo Forest and Rio Abajo Forest. He also provided us with the master plan from the 1950's, which contained a comprehensive management plan for all of the public forests managed by the DNER.

We also gathered information from the Census Office, Planning Board, and the International Institute of Tropical Forestry Library (IITF). The 2000 Census of Population and Housing was obtained from the Census Office located in San Juan. From

this report we extracted information about the total population and the number of housing units in each of the municipalities surrounding Guánica for the year 2000. The Planning Board provided us with the global information systems (GIS) maps containing demographic and topological information, satellite imagery and political maps including municipalities, cities and roads for the entire island of Puerto Rico. The IITF Library has a collection of books, journals and articles primarily focusing on the environment and forestry. Our group was supplied with literature regarding bird and plant species in Guánica, watershed management and biological corridors.

In addition to archival research, we also conducted interviews to gather additional information to aid us in our project. These interviews were often accompanied by a presentation to give us an overview of the organization. We interviewed the following people: Miguel Canals, Ernesto Velazquez, Mia Sued, Jaime Pabon, Vincente Quevedo, Carmen Hernandez and Dr. Frank Wadsworth.

Miguel Canals is the current manager of the Guánica Forest. Mr. Canals has been associated with the Guánica Forest for over thirty years. Mr. Canals is highly respected at the DNER and is regarded as the best source for the Guánica Region. Our first interview (March 18, 2004) with Mr. Canals was in the Guánica Forest, in which he gave us a brief overview of his opinion on the management of Guánica and current threats to the forest. He feels that the entire region from Ponce to Cabo Rojo should be a protected area. Our second interview (March 25, 2004) with Mr. Canals was at the DNER office. Mr. Canals also provided us with the initial assessment of the Guánica Coastal Reserve written by Tiffany Ledesma**,** a University of Pennsylvania student. This document provided us with specific information about the Guánica region.

Ernesto Velázquez is the director of the Coastal Zone Management Plan. We

interviewed (March 17, 2004) Mr. Velázquez to gain a better understanding of how the coastal zones of Puerto Rico are maintained and the rules and regulations currently implemented. Mr. Velázquez provided us with a presentation of the overall purpose of the Coastal Zone Management Program which is to manage the coast of Puerto Rico and two kilometers inland from the high tide line. Mr. Velázquez provided us with a CD containing detailed satellite imagery of the coasts of Puerto Rico.

We interviewed Jaime Pabón (March 22, 2004) and Mia Sued (March 16, 2004) to understand the different management approaches for coastal and inland regions. Mr. Pabón is the environmental manager at the San Juan Bay Estuary Program. The estuary program consists of four members who are in charge of managing the estuary of San Juan. Mr. Pabón provided us with the Comprehensive Conservation and Management Plan for the San Juan Bay Estuary. This document outlines the entire estuary management program. Ms. Sued is an employee at the DNER whose concentration is GIS. She was at the time developing the management plan for the Rio Abajo forest based on its watersheds. She gave us a presentation about her work in Rio Abajo entailing both watershed management and how she uses GIS in defining the management regions. These presentations provided us with examples of an inland and coastal management plans.

We interviewed Carmen Hernandez (March 26, 2004) and Vincente Quevedo (March 25, 2004) to gain a better understanding of the DNER's approach for land acquisitions. Ms. Hernandez works with land acquisition for the DNER. Ms. Hernandez presented us with the Autonomous Municipalities Act which gives municipalities the power to create their own land use plans and submit them to the commonwealth. In addition to the Autonomous Municipalities Act, Ms. Hernandez discussed the plan to

reconstruct the Guánica lagoon by means of flooding. Mr. Quevedo is the head of data analysis at the Natural Heritage Foundation. He provided us with a map that indicates both the current protected areas and future government land acquisitions for protected forest reserves.

Dr. Frank Wadsworth (March 15, 2004) is the retired manager of the Guánica Forest who we met at the IITF Library. He spent a majority of his life living in Guánica. He provided us with information about the Guánica forest and he focused on birds in the region. He also described to us his ideas for encouraging the younger generations to get involved in conserving the natural resources of the island. He feels very strongly that creating educational activities that will encourage children's interest in the environment is the key to protecting the environment and continuing to conserve it in the future.

3.2 Designing the Management Region

We have designed a management region for Guánica by locating and analyzing the importance of pressure points. We have focused on the location of pressure points resulting from urban expansion, road development, pollution, waste disposal and overuse of recreational areas. We took into account the two biological corridors in Guánica to determine the extent of our management region. Using the pressure points and biological corridors we developed a regional map illustrating the areas of Guánica that need protection. This section outlines the methods we used to locate and distinguish the pressure points.

We located the pressure points that are affecting Guánica through visitations to the forest, interviews and archival research. Visits to Guánica provided us with an overview of the potential pressure points. Our first extensive visit to Guánica was April

1st, which provided us with an overview of the inland and coastal regions of Guánica. This trip furthered our knowledge of the area and its surrounding municipalities.

We used archival research and interviews to assess the two main biological corridors in the Guánica forest regions. The DNER and the IITF Library provided us literature on biological corridors. The DNER supplied us with the previous IQP focusing on biological corridors in Puerto Rico. Mr. Canals and Mr. González discussed the importance of these biological corridors for the Guánica. We used these two corridors to help define the boundaries of the protected area of our regional map.

The final product of these methods is the regional map illustrating the protected area and the pressure points placing stress on this area. Our map indicates all the pressure points and environmentally sensitive areas that we have identified in the surrounding municipalities. We established a management region for the Guánica Forest by locating the pressure points and the two biological corridors. This map was initially designing in Adobe Photoshop and if the DNER wishes they can convert it to a GIS format.

4.0 Results and Analysis

The following chapter illustrates how human interactions in each of the surrounding municipalities have affected the Guánica Forest. Human interactions such as urbanization, overuse of recreational areas, road development and tourism have resulted in varying pressure points and may also be recognized as environmentally sensitive areas. We have identified the different pressure points and environmentally sensitive areas that are placing stress on the Guánica Forest within each of the surrounding municipalities.

Pressure points are areas negatively affected by human impact or areas that have the potential to be a problem in the future. They are also environmentally sensitive areas that should be protected before irreversible damage is caused by human interaction with nature. Pressure points are recognized by changes in land use, which can be produced by an increase in population, road development, urban areas, schools, recreational areas and commercial developments. A change in land use occurs when land is converted for an alternative purpose. An example of a change in land use would be a resort being constructed in an area that was previously a forest.

Our team has designated levels of negative human interaction with nature into minor and major pressure points and environmentally sensitive areas. For example, an unpaved road is a minor road development pressure point, but a paved road is the first stage that can lead to larger pressure points. On the other hand, a paved road allows access to undeveloped areas, which can lead to the development of houses, hotels, resorts and restaurants in the future. A minor urbanization pressure point can occur when one or two houses are built with permits approved through the Planning Board in San Juan. On the other hand, a major urbanization pressure point can occur when housing units continuously spread and eventually expand into the biological corridors of the forest.

Lastly, environmentally sensitive areas are regions that must be protected and managed to ensure preservation. We used these various pressure points as our analytical tool to identify the areas that are being placed under increased stress on the Guánica Forest.

4.1 Population Expansion in Surrounding Municipalities

The municipalities surrounding the Guánica Public Forest are Guánica, Sabana Grande, Yauco, Lajas, and Guayanilla. The expansion of these municipalities is a threat to the conservation of the Guánica Public Forest and Biosphere Reserve. Figure 8 shows the population expansion for the surrounding municipalities the Guánica Forest according to the Planning Board in 1990 and 2000. The graph indicates an average increase of 2000 people in each of the five municipalities listed over a 10 year period. If you breakdown the number quantitatively, an average increase of 2000 people annually results in 200 people a year. An average increase of 200 people may not seem like a large increase in people each year. However, if you breakdown this number further, an average increase of 200 people results in the construction of about 75 houses yearly.

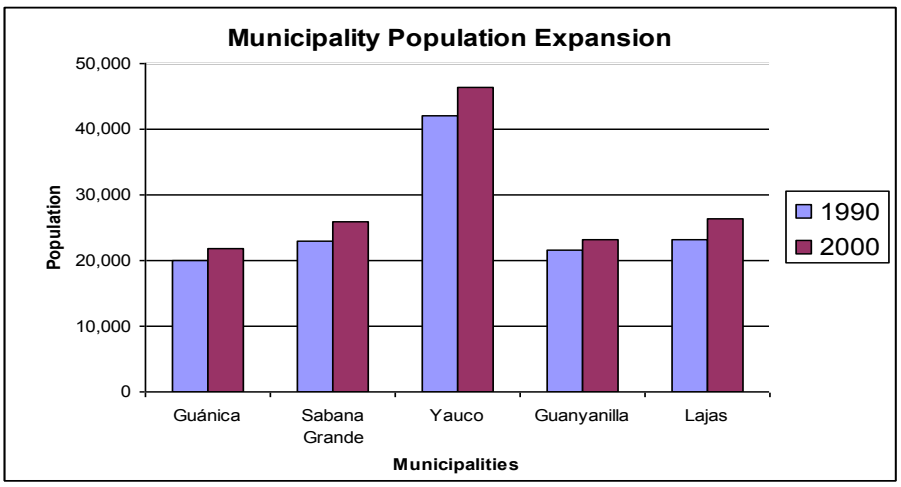

Figure 8: Municipality Population Expansion

These five surrounding municipalities may not have the infrastructure to support this continuous population and housing expansion. The increase in population results in the development of roads, housing, restaurants and other commercial developments. The increase in population also results in the depletion of resources that are limited not only in these municipalities, but also in Puerto Rico. The increase in construction of buildings requires proper water supply, electrical power and septic systems. Appendix E indicates the construction projects for housing, commercial and industrial units from 2001 to 2003 from the Planning Board. This appendix shows that there have been a small number of commercial projects and zero industrial projects constructed in the surrounding municipalities. Figure 9 indicates the steady increase in housing units for each of the surrounding municipalities in the years from 1960 to 2000. This information indicates that it is important to regulate this continuous growth before the problem can create permanent damage.

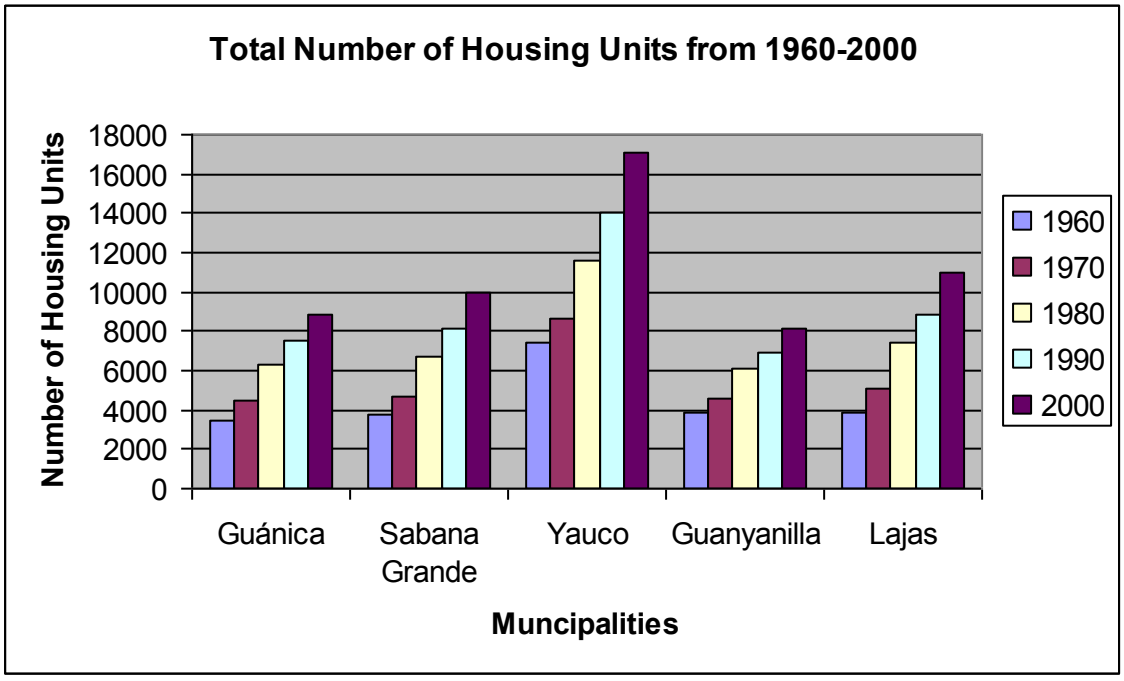

Figure 9: Total Number of Housing Units from 1960 to 2000

Each of these housing units requires a building permit from the Commonwealth

government before construction begins. However, there are many houses that are illegally built without permits within each of the municipalities. Many people avoid obtaining these building permits from the government and build houses located within the Guánica Forest. These illegal houses do not have proper running water, plumbing and septic systems, which results in an excess amount of sewage directly deposited into the forest.

The Commonwealth government is pushing for the development of Guánica into a major tourist attraction. It wants to expand Guánica by building resorts, hotels and shopping centers in efforts to boost Guánica's economy. Figure 10 shows an example of the recent effort to expand resorts in Guánica. This specific resort contains approximately 90 rooms that can occupy as many as 200 people at maximum capacity. For an underdeveloped region of Guánica, it is difficult to contain the appropriate infrastructure to support this increased population with food, transportation and other facilities.

Figure 10: Inland Urbanization in the municipality of Guánica

In the Guánica municipality, urban development and expansion has been threatening the coastal areas as well as the inland areas. Since coastal property is more desirable than inland

property, there are more building projects along the coast. Residential homes and hotels are examples of urbanization that is constantly threatening the coast. Due to the low cost of land in some of these areas, private land owners are able to acquire land at low costs and develop property. For example, a private owner from New Jersey owns 300 acres of coastal property in Guánica that the DNER wishes to purchase for $1.7 million. Figure 11 shows an example of urban development along the coast of Guánica.

Urbanization has had a harmful effect on the coastal waters by disturbing marine life through increased sedimentation and erosion. Urbanization causes sedimentation and pollution from human interaction that is being washed down into the coastal waters. Figure 12 shows how coastal urbanization disturbs the marine life by covering the organisms in the sediment and pollution. An increase in the amount of sediment can result in future dredging, which further disrupts marine life and can lead to improper dumping of the material that is dredged.

Figure 11: Coastal Urbanization along the coast of Guánica

Figure 12: Results of Coastal Urbanization on Marine Life

4.2 Municipalities Surrounding the Guánica Forest

As stated in our background, the municipalities surrounding the Guánica Forest are Guánica, Yauco, Lajas, Guayanilla and Sabana Grande. Human interactions and development in these municipalities have resulted in pressure points and environmentally sensitive areas that are placing stress on the Guánica Forest. It is necessary take into account the human interactions in the surrounding municipalities to prevent further deterioration of the Guánica Forest. In this section, we have identified the human interactions that are creating pressure points within each of the surrounding municipalities. After conducting field research in the southwestern coast of Puerto Rico, we identified specific areas within each of the municipalities that are placing stress on the forest.

A major pressure point that we have identified is the Yauco Municipal and Industrial Landfill located on the southern border of Yauco and Guayanilla. This landfill borders both the Guánica forest and the Yauco forest. The landfill is placing an enormous amount of stress on the

surrounding environment due to animal problems, toxic waste pollution and future plans of expansion.

The landfill has attracted rats and rodents to the bordering forest due to the trash that is being disposed of in the landfill. The increasing amount of rodents has disrupted animal and plant habitats. The *Puerto Rican Night Jar*, a bird indigenous to the Guánica forest which lays its eggs in the ground, is on the verge of extinction. The rodents and toxic materials from the landfill have destroyed this bird's nesting areas. Toxic materials are also polluting the *Barinas Aquifer*, an underground water system. Since the landfill is located directly on top of this aquifer, toxic materials easily leaks into this water system and disperse throughout the region.

The Yauco Landfill was improperly designed and built according to outdated environmental standards. The landfill was designed without a protective liner, which resulted in incontrollable pollution. Figure 13 shows the open cover of the landfill and the visible trash around it. Lastly, the government has recently purchased 500 acres of land around the landfill for expansion. Since Puerto Rico has twice as many municipalities as landfills and no organized recycling program, landfills are rapidly expanding. If environmental standards continue to be ignored the expansion of the Yauco landfill will only accelerate the environmental problems of the Guánica Public Forest.

Figure 13: The Yauco Municipal and Industrial Landfill

The Mayor of Yauco proposed to construct a road that directly leads to the beach from Yauco. We have identified this proposed construction as a minor road development pressure point. A privately unpaved road exists to the beach through a banana and mango orchard. However, the Mayor wants to construct a direct route open to the public in order to increase the amount of visitors to this beach. In the future this proposed road could become a major pressure point by allowing developments along the newly constructed road. Figure 14 shows a map of the proposed road on the left, the agricultural area in the center and the desired destination on the right.

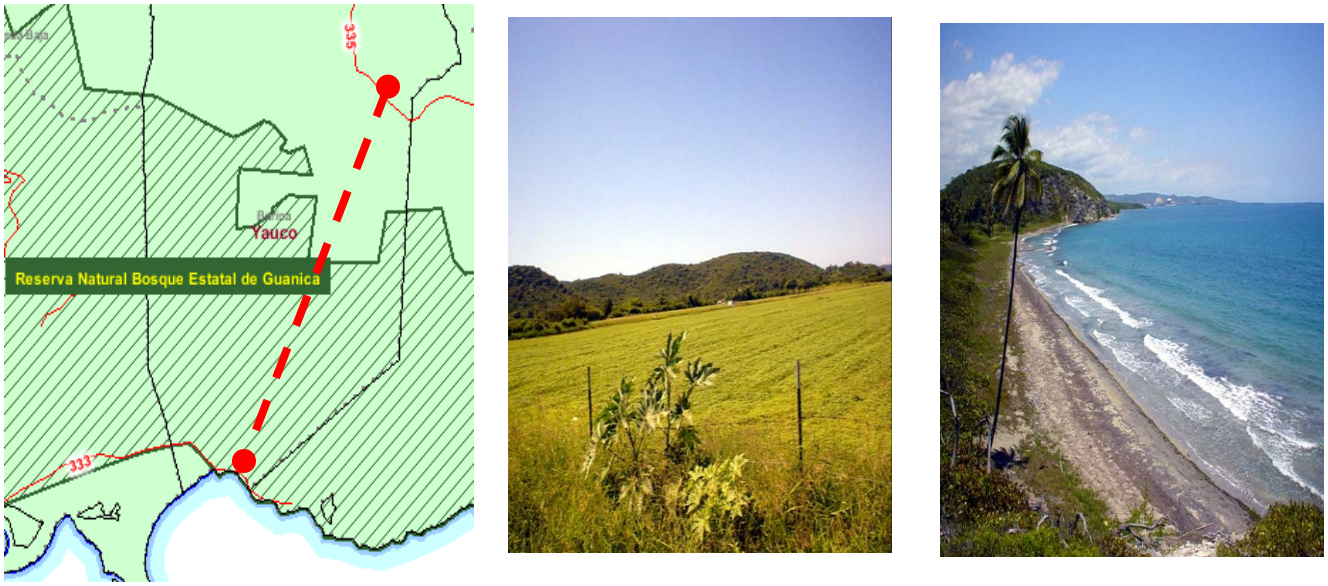

Figure 14: Proposed Road Location in Yauco to the Coast

4.3 Environmentally Sensitive Areas

The coastal region and the islands of Guánica are environmentally sensitive areas that are being threatened by tourism and overuse of recreational areas. During the summer months Guánica's coast receives half a million tourists, which places a great amount of stress on the coastal region. Figure 15 shows Cayo Aurora, also known as Gilligan's Island, an island off the coast of Guánica threatened by tourism and overuse of recreational areas.

Figure 15: Aerial View of Tourism on Cayo Aurora

The DNER had to enforce restrictions to preserve the island from future overuse and destruction caused by human interaction with nature. The DNER regulated the number of visitors to 325 people per day to Cayo Aurora. Other restrictions include prohibiting the destruction of mangroves and illegal anchoring around the island. Since the only entrance is one dock the DNER has placed buoys so boats can be tied to them. This prevented boaters from creating their own entrances to the island by destroying the mangroves along the coast. These buoys also restrict coastal anchoring, which destroys mangroves, sea grass and coral, as seen in Figure 16. Even with these restrictions, Cayo Aurora is still facing these pressures because the DNER does not have a large enough workforce to enforce these restrictions.

Figure 16: Destruction of Marine Life by Boats Anchoring

In addition to placing these restrictions on the island, the DNER has placed many facilities throughout the island for visitors to use. These facilities include paths through the island, bathroom facilities, grilling areas, and trash cans. These facilities reduce the amount of trash on the island. Even with these paths and recreational areas on the island, some visitors will still create their own paths and other clearings by destroying the mangroves. The visitors often do this by breaking branches off of mangroves or completely cutting down the mangroves, which is extremely detrimental to the island. The continuous destruction of these mangroves will increase the rate of erosion of the island. Currently, the DNER is in the process of planting mangrove seedlings to protect the island from erosion.

The coastal regions of Guánica include many beaches which are extremely popular tourist destinations. One main problem caused by these visitors is the amount of

trash that accumulated at these areas. The DNER has placed trash cans at these beaches in effort to control the trash disposal. However, if the trash cans are full, people tend to leave their garbage on the ground. Also, some people will steal the trash cans from the beaches for their own personal use.

Visitors to the coastal regions affect the wildlife of these environmentally sensitive areas. An example is the endangered sea turtles that leave the water to lay their eggs on the beaches of Guánica. Figure 16 shows an environmentally sensitive beach where the sea turtles lay their eggs at the same locations and time of the year. Visitors will destroy these eggs whether it is purposefully or not by moving the sand around on the beach and digging holes in the sand. Once the turtles hatch, they need to make their journey back to the ocean. The visitors will sometimes assist the turtles into the ocean by picking them up and placing them into the water. This is detrimental to the turtle's life cycle because they need to make it back to the ocean on their own. Some visitors will also take the turtles and keep them as pets.

Figure 17: Environmentally Sensitive Beach where Sea Turtles Lay their Eggs

There are many recreational activities that have a damaging effect on the coastal regions of Guánica. Many visitors will use the beaches to jet-ski, boat, and fish which can destroy the environment and harm the wildlife on the coast. Boaters dropping anchor has a very harmful effect on coral reefs by breaking the coral and destroying marine habitats. Many of the islands around Guánica have very shallow waters surrounding them which contain sea grass. Boats and jet-skis not only affect the environment through disrupting the waters, but they also leak gasoline and oil into the water. These substances in the water are extremely harmful to the wildlife in the region by affecting the growth of any marine plants.

Guánica has designated fishing areas located along the coast. People will use these designated fishing areas, however, if these areas are over fished, they will create there own fishing locations. They will destroy any mangroves and other trees to create fishing location that they feel would be a more desirable fishing spot. The mangroves serve as nurseries for fish and habitats for other marine wildlife. People who are creating their own fishing locations are unknowingly reducing the fish populations.

Our team has developed a map to identify all of the pressure points and environmentally sensitive areas for the Guánica forest and the surrounding municipalities in Appendix D. All of these pressure points and environmentally sensitive areas are interconnected with one another. It is important to identify each of these pressure points in a systematic approach to help protect the Guánica forest from future destruction. After analysis of our finding and results, we were able to develop recommendations for the DNER.

5.0 Conclusions and Recommendations

Development and growth in the Guánica municipality and surrounding municipalities is inevitable. The most effective way to preserve the rich biodiversity of the Guánica Public Forest would be of course to completely prevent the development of the commercial and residential areas; however this would not be a practical solution. The prosperity of these municipalities is dependent upon a balance between continued urbanization and the preservation of the forest and its resources. We have developed recommendations on how to balance this continued development in the surrounding municipalities. This chapter provides recommendations for each of the pressure points and environmentally sensitive areas that we have identified.

5.1 Control Urban Development

Over-development of the Guánica Region is one main threat to the conservation of the Guánica Public Forest. Residential, commercial, and industrial development must be controlled to properly preserve the forest. There are many negative human interactions with nature that must be taken into account to properly control this growth and development.

5.1.1 Regulate the Building of Houses without Permits

There are houses being built in and around the Guánica forest without proper permits obtained from the Planning Board. This practice needs to be controlled and eventually brought to a stop. These houses are being built without permits and are often constructed with improper running water, plumbing and septic systems. This has

detrimental effects on the environment surrounding these illegally built houses. There are many ways to regulate the construction of these houses without permits in the Guánica Forest.

These houses are simply constructed of cinder blocks, concrete and steel reinforcing rods. The most effective way to prohibit illegal houses is by regulating the supplies necessary for construction. Requiring proof of a permit upon purchase of these materials in large quantities would help limit these housing developments. Another way of controlling this type of construction would be to require a permit to be visible during the construction of a house. A sign could be present to allow authorities in the region to easily recognize that the construction in progress is legal. These two methods would control the number of houses being built without permits and hopefully eliminate this type of construction.

5.1.2 Regulate Road Development in Biologically Sensitive Areas

Roads are the first stage in urban development, once a road is built it allows for the future construction of houses or commercial developments. The regulation of road development is vital to the protection of the Guánica Forest. One road development project that needs to be addressed is the proposed road in Yauco that would directly connect Route 335 to the beach.

The Mayor of Yauco has proposed to build a road from Route 335 to the beach on the coast of Yauco to promote tourism in this region. The problem with the construction of this road is that it would be developed directly through the Guánica Forest. A road going through the forest would separate sections of the forest, which would form a barrier to the animals that migrate throughout the forest. We recommend that this proposed

development be terminated. One way to avoid the construction of this road would be to utilize the private unpaved road that already exists through the banana and mango orchards. Allowing public use of this road would prevent the destruction of the Guánica Forest. The DNER should also consider purchasing this privately owned road before allowing the development of a new road through the forest to the beach. Purchasing this land would have minimal effects on the forest because there is already an unpaved road present.

5.2 Regulation on Tourism

Tourism can have either a positive or negative effect on the Guánica Public Forest. The Commonwealth government is pushing to increase tourism in this region in efforts to boost the economy. Their proposed increase in tourism could have a detrimental effect on this region but proper regulation of tourism would help to ensure that it will have a positive effect. Some areas of the forest require stricter regulations while other areas would benefit from an increase in tourism. Also, the regulation of hotel and resort development is critical to the protection of the forest.

5.2.1 Update Regulations for Cayo Aurora

Cayo Aurora has a problem with overuse by recreational boaters, which needs to be addressed. Considering the small size of this island, it receives a large number of visitors during the peak summer months. There are regulations that control the use of this small island, but they are not strictly enforced.

The DNER has established many rules for Cayo Aurora, but in order for them to

be effective they need to be enforced properly. The workforce for the DNER is limited resulting in minimal enforcement of their established regulations. The island has a posted limit of 325 visitors per day. For this to be effective an employee or volunteer needs to be on the island counting the number of visitors to verify that the limit isn't exceeded. Employees should patrol the island to regulate that no one grounds their boats or drops anchor in ecologically sensitive areas. These recommendations would help protect the mangroves and other wildlife in and around the island.

Activities on the island also need to be monitored by the DNER to reduce the amount of people harming the mangroves when creating new pathways or entrances. This would also reduce the continuous replanting of mangroves that is necessary for protection of the island from further erosion. One possible way to employ additional personnel would be to charge a small admission fee for visitors the island. A fee of five dollars would help to fund the additional work force required to protect the island.

5.2.2 Protecting Sea Turtle Nesting Grounds

The coastal areas of Guánica contain many beaches where endangered sea turtle nest their eggs. The use of these beaches for recreational purposes can be very detrimental to the sea turtle populations. Controlling the beach use during the nesting period would ensure these endangered sea turtle are protected.

There are many ways that the sea turtle's nests can be protected. One way to protect the turtle eggs would be to mark the areas where the eggs are laid on the beaches. Then people would not unwittingly crush the eggs by digging in the sand or by just stepping on the nests by accident. In addition, these areas could be roped off and be placed off limits to visitors until the eggs hatched. These ideas would allow for better

protection of the seat turtles without having to completely close the beaches down during the nesting periods.

5.2.3 Controlling the Development of New Hotels and Resorts

Hotels and resorts can bring more attention to the Guánica Public Forest, but it is not necessarily the type of recognition that the Guánica region wants to receive. The hotels mainly constructed to increase tourism to the beach and coastal regions of Guánica, which already receive approximately 95% of the visitors. These hotels should emphasize more eco-tourist activities for visitors inside the forest. This would spark an interest on the biodiversity of the forest instead of just the coastal areas.

The development of new hotels in this region needs to be controlled since the addition of one hotel to a region requires the development of more roads, restaurants, and other commercial developments. The need for a larger infrastructure should be considered every time there is a proposed hotel development. The infrastructure necessary to support a single hotel might be acceptable to the preservation of the forest, but adding additional hotels and resorts would require a much larger infrastructure that would damage the forest.

The placement hotels and resorts is a very important factor in the preservation of the forest. These hotels should not be placed in or next to the forest because the construction of them could have irreversible damaging effects. Also, the hotels should not be placed anywhere where they can affect the biological corridors connecting the Guánica forest. The government currently has plans to demolish and remove the abandoned sugar cane factory in Guánica to build a hotel replacing this factory this. One recommendation would be to turn this factory into a museum about Guánica's history.

This would be useful for creating historical interests about the Guánica region other than the recreational interest in beaches and off shore islands.

5.3 Educational Programs for the Guánica Forest

As a positive way to encourage tourism to the Guánica Public Forest we recommend developing educational incentive program. The DNER currently has educational programs through local schools and communities but does not have widespread programs throughout the island of Puerto Rico.

Figure 18 below shows the DNER educating the youth about the Guánica Forest. A variety of educational tactics could be used to spark interests depending on the age of children visiting the forest. For example, kids could play games in the forest where they have to identify certain plant and animal species. Another example would be creating a scavenger hunt where youths are exposed to the forest in efforts to finding hidden treasures.

Figure 18: Educational Programs for the Guánica Forest

We recommend educational incentive program to encourage school communities of Puerto Rico to consider field trips or even weekend trips to the forest. This will increase awareness of the forest to young children by teaching them the importance of tropical dry forests. Many problems that the Guánica forest is currently facing are due to environmental ignorance. By teaching the younger generations why it is important to preserve this forest, future problems can be prevented.

5.4 Regulations for the Yauco Municipal and Industrial Landfill

The Yauco Municipal and Industrial Landfill is a major problematic area concerning the Guánica Public Forest. Currently, the landfill consists of 300 acres of land bordering the forest; however the Puerto Rican Commonwealth has purchased 500 acres of land around the landfill for expansion. We have recommended several alternatives for this landfill expansion in attempts to protect the Guánica forest from future destruction.

The harmful pressures that the landfill is currently placing on the forest were explained previously in the results chapter. If the landfill expands into the region that was recently acquired by the Commonwealth the harmful effects will only be accelerated. The DNER should consider purchasing this land around the landfill to eliminate the possibility of expansion, since the landfill is an extreme threat to the biological diversity of the forest.

If a new landfill is necessary, one should consider constructing a new landfill that is distant from the Guánica biosphere reserve. This would eliminate the problem of foreign species migrating from the landfill to the forest and destroying the nest of the

Puerto Rican Nightjar. Current expansion of this landfill would only further the problem of toxic material leaking into both the aquifer and the bordering forest. A new landfill should be constructed with a protective liner to reduce the amount of toxic waste exposure to the environment.

5.5 Conclusions

The Commonwealth government will certainly continue to encourage the development of housing, hotels and resorts on the southwestern coast of Puerto Rico. We developed a systematic approach to identify future problematic areas to protect the Guánica Forest to regulate development in order to minimize damage. Our regional map illustrates the pressures points and environmentally sensitive areas that we have identified in the surrounding municipalities. As a result of our map, we were able to develop recommendations for the DNER. We were able to distinguish areas of Guánica that require immediate attention before the problematic areas suffer irreversible damage. We hope our recommendations will help protect the Guánica Forest from future destruction from unmanaged urbanization and development.

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Appendices

Appendix A: Mission and Organization of the DNER-NSF

Department of Natural and Environmental Resources

P.O. Box 9066600, PTA. De Tierra Station

San Juan, PR 00906-6600

The Department of Natural and Environmental Resources (DNER) was established on June 20, 1972. The DNER consists of a number of subdivisions, including the Corporate Development of Mineral Resources, Administration of Matters and the Division of Forestry, Environmental Planning, Scientific Research, Environmental Management, and Natural Resources Protection. The Department relies primarily on funding from the Commonwealth Government. The DNER is responsible for the protection and preservation of Puerto Rico's most valuable natural resources. The DNER regulates forests, wildlife, coastal regions, solid waste, and hazardous waste policies throughout the island of Puerto Rico.

Edgardo González, the Director DNER-NSF (Forest Service Negocios) is our liaison for our IQP. Our liaison requested that we assist the DNER to identify the threats that the Guánica Public Forest is currently experiencing from human interaction with nature. Mr. González asked for our team to locate the pressure points and environmentally sensitive areas in and around the Guánica Public Forest. The DNER

also requested that we produce a map that clearly indicates the pressure points and environmentally sensitive areas in the Guánica region to help the Department develop a conservation plan. Our project will aid the DNER's in conserving and protecting the largest subtropical dry forest in the world.

Appendix B: Reforestation Management Systems

Knowledge of the causes, mechanisms and factors that drive the processes of species change, population change, and replacement throughout time, are necessary components when choosing a method for a forest management plan or for regenerating a forest (Gomez-Pompa, 1991). Understanding these components will ensure more efficient management schemes. Management options are limited and most likely ineffective without an understanding of ecological background information and previously implemented ecosystem management philosophies. The following four classifications of systems serve as a guideline in forest management: natural regeneration systems, clearing systems, replacement systems, and restoration systems.

The Natural Regeneration Systems

This is the simplest and least complex of the of the reforestation systems. During this process a few trees are cut down or removed and then natural regeneration is allowed to occur in its place. The local people of the area, who live near the forest, most commonly use this system. Commercial foresters and forestry departments also use this system (Gomez-Pompa, 1991). Once removing or killing a large tree in the forest at least five different groups of species begin to take over the newly opened area (Gomez-Pompa, 1991). This includes the species that were already there that were able to survive the environmental changes, the seeds of species which are triggered by the light and temperature, dormant species usually found on the forest floor in the seedling or juvenile stages with little or no growth towards adult size, species coming from the rootstocks

from the surrounding forest, and lastly the new species that arrive during the time that the light gap remains open. These different groups of species interact and compete for available resources; this will then form the new natural regeneration forest.

Natural Regeneration also occurs after environmental destruction factors, such as hurricanes and lightning (Park, 1980). Without any human involvement, the area of the forest is able to redevelop. The time that it takes for this redevelopment depends on the damage caused by the natural disaster.

The Clearing system

This system involves the removal of some or all commercially valuable trees and also the elimination of unwanted species by cutting, girdling, or poisoning techniques (Gomez-Pompa, 1991). After completing this process, natural or artificial regeneration is allowed to occur. The most important feature of this system is the seedlings or juveniles left behind from the commercial species. The goal of this system is to protect the valuable species while eliminating the unwanted ones. The importance of this system is to decrease the number of new seedlings of undesirable species.

This is similar to the natural regeneration system, but on a larger scale involving a much larger area. Drawbacks of this system are the amount of time required for the regeneration process and the destruction of all the unwanted species, which may be located in the topsoil as seeds. This system is also used for urban expansion, or areas cleared for industry developments (Park, 1980). For these cases forest regeneration is not capable.

The Replacement Systems

This system involves the cutting down of an entire forest and replacing with tree plantations either immediately or within a few years. Regeneration depends on the seed bank, the remaining standing trees, the species remaining as stumps, and the seeds from nearby forest areas or planted by people (Gomez-Pompa, 1991). An advantage of this system is planting desirable trees in the newly cut area; these trees can be non-native. Planting non-native trees can also be a disadvantage because the ecosystem can permanently tainted. A major disadvantage of this system is the possible loss of animal and plant species from the forest ecosystem. This system is often discouraged or disparaged by governments and financial institutions because of the possible side effects (Dickert, 1974). There is a need for polices and laws, which must be enforced, to protect the environment and educate the people that may be involved.

The Restoration Systems

This system is the least known, but the most needed. The system is used to manage the heavily disturbed and abandoned forested areas as well as areas that have been cleared for a long time (Gomez-Pompa, 1991). Areas like this are usually created by farmers who clear forest areas in order to plant crops, which then remove much of the nutrients from the soil. Using the restoration systems include techniques for planting desirable species in cleared forest areas. This process can take decades, but if done correctly and efficiently can serve very beneficial.

Knowledge of these systems and research provided by others has proved helpful for developing management techniques in Guánica. Understanding different causes and their effects on the environment will need to be assessed. Most importantly, the cooperation from the local government and private landowners will be essential.

Appendix C: Gantt Chart

Project Assignment Key

= Jeremy Lerch
= Prity Patel
= Todd Pearson
= Nate Salemme
= ALL

Start date: 3 / 15 / 2004

Project: Identifying the Pressure Points and Ecologicaly Sensitive Areas in the Guanica Forest

Current Week								↓
Weeks **Tasks**	03/15 to 03/22	03/22 to 03/29	03/29 to 04/05	04/05 to 04/12	04/12 to 04/19	04/19 to 04/26	04/26 to 05/03	05/03 to 05/10
Meet Sponsor	■							
Review Proposal	■							
Interview Department of Natural and Environmental Resources		■						
Interview Coastal Zone Management Program		■						
Interview Guanica Forest Manager			■					
Interview San Juan Bay Estuary Program			■					
Interview National Heritage			■					
Field Research in Guanica Forest				■				
Field Research in Lajas				■				
Field Research in Yauco					■			
Field Research in Guayanilla					■			
Field Research in Sabana Grande						■		
Compile Data				■	■	■		
Analyze Data						■		
Work on Final Report			■	■	■	■	■	
Final Presentation						■	■	
Submit Final Paper							■	
Leave Puerto Rico								■
Tasks Weeks	03/15 to 03/22	03/22 to 03/29	03/29 to 04/05	04/05 to 04/12	04/12 to 04/19	04/19 to 04/26	04/26 to 05/03	05/03 to 05/10
Current Week								↑

Appendix D: Building Construction Permits in the Surrounding Municipalities

NUEVOS PERMISOS DE CONSTRUCCION EXPEDIDOS PARA MUNICIPIOS SELECCIONADOS POR AÑO NATURAL 2001 (en miles de $).

Año Nat.	Houses	Unid. de Viv.*	Value	Commercial	Value	Industrial	Value	Municipality
2001	10	10	378	1	48	0	0	GUANICA
	24	43	1,296	0	0	0	0	GUAYANILLA
	46	72	5,114	4	322	0	0	LAJAS
	36	140	4,430	4	566	0	0	SABANA GRANDE
	26	99	4,755	2	255	0	0	YAUCO
2002	22	65	5,415	0	0	0	0	GUANICA
	13	29	1,337	2	138	0	0	GUAYANILLA
	57	96	5,804	4	377	0	0	LAJAS
	46	77	3,184	5	510	0	0	SABANA GRANDE
	41	113	5,326	2	512	0	0	YAUCO
2003	11	16	748	0	0	0	0	GUANICA
	22	102	3,587	0	0	0	0	GUAYANILLA
	63	67	3,305	2	2,968	0	0	LAJAS
	52	88	6,009	0	0	0	0	SABANA GRANDE
	32	99	4,999	6	551	0	0	YAUCO

Fuente: Junta de Planificación, Programa de Planificación Económica y Social, Subprograma de Análisis Económico. Unidad de Estadísticas sobre Construcción.

* Unid. De Viv. : New Units of Private and Public Housing for Municipality

Appendix E: A Regional Map identifying the Pressure Points