Interdisciplinary and Global Studies Division
100 Institute Road · Worcester, MA 01609-2280
Phone 508 831-5547 · Fax 508 831-5485 · http://www.wpi.edu

May 1, 2002

Sr. Daniel Galán, Director
Forest Management Division
Department of Natural and Environmental Resources
Box 9066600
Pta. De Tierra Station
San Juan, PR 00906-6600

Dear Sr. Galán:

Enclosed you will find our report entitled Recommendations for Management Alternatives in La Parguera Natural Reserve. It was written at the Department of Natural and Environmental Resources during the period of March 18th through April 30, 2002. Preliminary work was completed in Worcester, Massachusetts prior to our arrival in San Juan, Puerto Rico. Copies of this report are also being submitted to Professors Chrysanthe Demetry, and Richard Vaz for evaluation. Upon faculty review, the original copy of this report will be catalogued in the George C. Gordon Library at Worcester Polytechnic Institute. We would like to extend our deepest thanks to you and your colleagues for all your time and resolute assistance.

Sincerely,

Patrick Cody

Robert Cordell

Katherine O'Neill

Recommendations for Management Alternatives in La Parguera Natural Reserve

Report Submitted to:

Professor Chrysanthe Demetry
Professor Richard Vaz

WPI Puerto Rico Project Center

By:

Patrick Cody _____

Robert Cordell _____

Katherine O'Neill _____

In Cooperation with
Daniel Galán, Director
Wendy Boneta, Biologist

Departmento de Recursos Naturales y Ambientales (DRNA)

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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. The report should not be construed as a working document by the reader.

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Abstract

La Parguera Natural Reserve, which is managed by the Puerto Rico Department of Natural and Environmental Resources (DNER), is an ecologically vital area that has been deteriorating in recent decades due partially to development and growth in tourism. The goal of this project was to develop management alternatives for recreational activities in La Parguera using the Limits of Acceptable Change planning system, a methodology for sustainable development. This report provided DNER with our findings and recommendations for the continuation of the LAC process.

Authorship

This Interactive Qualifying Project report is the product of an equal effort by the entire project team. All members took an active role in its development throughout the course of the project. Primary authorship of certain sections of the report, however, should be noted in order to give proper credit to those involved.

The Introduction was completed primarily by Katherine O'Neill. The Literature Review was an equal contribution by all team members. Patrick Cody was primarily responsible for researching laws and regulations, Katherine O'Neill responsible for the research for the La Parguera section, and Robert Cordell was responsible for the section on the Limits of Acceptable Change process. Key contacts were made throughout the term in Puerto Rico by Patrick Cody. The Executive Summary was completed by Robert Cordell. Portions of the project containing GIS ArcView™ material were completed by Patrick Cody.

The entire group made contributions to the rest of the project including the Methodology and the Conclusions and Recommendations chapters. The Results section was completed jointly by Katherine O'Neill and Robert Cordell. The entire group participated in the editing and formatting of the final report.

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Finally we would like to thank all the professors form Worcester Polytechnic Institute that helped make our project a success, in particularly to our advisors, Professor Chrysanthe Demetery and Richard Vaz.

Executive Summary

The Puerto Rico Department of Natural and Environmental Resources (DNER) is concerned with the declining condition of La Parguera Natural Reserve in Lajas, Puerto Rico. At the forefront of the DNER's concern is the deterioration of La Parguera's bioluminescent bay, *Bahia Fosforescente*. As one of the few places in the Caribbean that produces year-round bioluminescence, the bay is a major tourist destination. The reserve also contains extensive coral reefs, seagrass beds, and mangrove systems, all of which are vital to the survival of many wildlife species.

The main symptom of decline in the overall condition of the reserve is the fading level of luminescence in the bioluminescent bay over recent years. This deterioration may be a direct effect of abuse and overuse of the bay. There are currently four tour boat operators that rent boats and provide trips to the bioluminescent bay. It is believed by experts that these tour boats may be a leading cause for the deterioration of the bay by creating excess water turbulence beneath the surface, thus disturbing the delicate balance of the shallow bay and killing dinoflagellates, the microorganisms which cause the luminescence.

The problem of the tour boats in the bay is only one of the challenges that the reserve is facing. In the past forty years, La Parguera has undergone a transformation from a quiet fishing town to a center of tourism, bringing in over 100,000 visitors a year (DNER, 1984). While tourism has economic benefits, it also uses resources, generates waste, and creates environmental costs (United Nations – Sustainable Development). Along with loss of luminescence in the bay, sea-grass beds and coral reef are being destroyed, and social concern for the health of the reserve is growing. In addition, current laws and regulations designed to maintain the health of La Parguera are not uniformly enforced.

In order to decrease the impact of recreational activities, DNER is looking to apply the Limits of Acceptable Change planning process to La Parguera. The LAC process was developed by the United States Department of Agriculture in 1985 and involves nine steps that provide a framework for determining acceptable and appropriate resource and social conditions in recreational areas facing increasing demands. The goal of this project was to use the LAC process as a guideline to develop management

alternatives for La Parguera. We focused specifically on the following recreational activities: trips to Bahía Fosforescente, boat rentals, maritime transportation to Mata La Gata and the Caracoles Keys, and tours of the reserve's mangrove channels.

To apply the LAC planning system to La Parguera, we began by investigating ecological values and public and managerial concerns shared by experts, residents, visitors to the reserve, and DNER officials. We determined that the coral reefs, mangroves, and seagrass beds, which exist interdependently, serve as a nursery for a variety of animals are of high ecological importance to the reserve. Public areas of concern were mainly related to specific geographical areas of the reserve including the biobay, Mata la Gata, Caracoles Keys, coral reef areas, and highly used boat routes to and from these areas. Other public concerns were the large number of people who participate in recreational activities and the manner in which the boat operators run their businesses. Resource managers were most concerned about the lack of education of both the public and boat operators, lack of appropriate laws and regulations, and lack of enforcement of current policies.

The next step of the LAC process involved defining and describing "opportunity classes", which are used to reflect a range of conditions managers wish to provide in an area. Taking into consideration the public and managerial concerns just discussed, we judged that it was appropriate to establish three opportunity classes: low, moderate, and high impact areas. We also developed qualitative descriptions of ecological, social, and managerial conditions which would be appropriate and acceptable in each type of area. The three opportunity classes are as follows:

Low Impact Zone
Resource Conditions - Human impacts are seldom evident - Includes mostly undisturbed, unmodified area of the reserve - Natural and ecological processes are not measurably affected by the actions of users - Loss of resources is both temporary and minor Social Conditions - Low chance of encountering other parties Managerial Conditions - Management encourages sustaining natural ecological processes - Little or no evidence of site management - If user-induced damage occurs, management should begin resource protection measures

Moderate Impact Zone
Resource Conditions - There may be moderate changes in the environment due to visitors - Essentially an unmodified natural or natural-appearing environment - Visible impacts or natural and ecological impacts exist but are not significant enough to cause long term negative consequences Social Conditions - Inter-party contacts may range from seldom to frequent Managerial Conditions - Occasional patrols of areas of concern - This area contains subtle controls or restrictions such as travel lanes for boats and/or restrictive signs - Management emphasizes sustainable use of areas by providing visitors with informational and educational materials

High Impact Zone
Resource Conditions: - High level of impact due to humans - Resource impacts found in many locations (some very substantial) - Impacts may persist from year to year - Potential for substantial loss of resources or a drop in water quality - Impacts are apparent to most visitors Social Conditions: - Fairly high level of human contact Management Conditions: - Frequent patrols of the area of concern - Management enforces rules and regulations concerning use of these areas - Information and education provided to visitors through direct interaction

We then evaluated possible indicators that could be used to measure and monitor the condition of areas within the reserve. Resource indicators were established by talking with numerous experts, while social indicators were established using suggestions from the LAC packet and the results of our evaluation of public, social, and managerial concerns. For resource indicators we selected aerial photography, live coral reef coverage, and dinoflagellate population count. For social indicators we chose to use evaluate the number of other groups encountered within the duration of the individual recreational activity and number of people in each group.

Due to time constraints, we used previously gathered data to inventory existing resource conditions for the indicators. We obtained a historical account of dinoflagellate population, current live coral coverage data, and aerial photography to establish growth

or destruction of vegetation and coral. To inventory social indicators we used our interviews with the tour boat operators.

Using this inventory of conditions and the qualitative descriptions of opportunity classes developed previously, we then established quantitative standards to define acceptable and appropriate conditions for each indicator in each opportunity class. For several of these opportunity classes we adapted the policy of non-degradation, which requires that conditions in an area not get any worse. If they do, management actions need to be implemented to bring the condition back to their normal level. A list of these standards are as follows:

Opportunity Class	Factor	Indicator	Standard
Low Impact	Solitude during visit	Number of other groups encountered during activity	2
Moderate Impact			4
High Impact			> 4
Low Impact	Solitude during visit	Number of people in own group	6
Moderate Impact			50
High Impact			150
Low Impact	Bioluminescent Bay	Species and number of dinoflagellates	Pyrodinium Bahemense = 7,600/L
Moderate Impact			Increasing number of Pyrodinium Bahemense
High Impact			Pyrodinium Bahemense = 2475/L
Low Impact	Coral reef, sea grass bed, and mangrove conditions	Live coral reef coverage at monitoring stations	Live coral coverage = 20%
Moderate Impact			Increasing in areas where live coral coverage is below 20%
High Impact			Non-degradation
Low Impact	Coral reef, sea grass bed, and mangrove conditions	Aerial photography of overall coral reef coverage	Increasing coral coverage
Moderate Impact			Increasing in areas where coral coverage is low
High Impact			Non-degradation

We then developed two alternative opportunity class allocations for La Parguera; a recreationally oriented classification and a more ecologically oriented classification. The recreationally-oriented classification would require management actions and monitoring to prevent further degradation of the reserve, but may not require establishing visitation limits. The long-term goal of the more ecologically-oriented classification would be to improve conditions of the bioluminescent bay, which would require intensive management, more resources, and would likely require more cooperation from the local community and boat operators. The ecologically-oriented opportunity class allocation will be more extensive in content and results, and will be more expensive and time consuming to implement. We have provided DNER with a set of management recommendations for each opportunity class allocation:

Opportunity Class Allocation I (recreational-oriented)

- Work with Public Service Commission when granting permits to boat operators
- Post signs throughout the reserve informing boaters of speed limits, areas of ecological fragility, endangered species, and in what areas to tie onto buoys
- Mark travel lanes along frequently used boat routes to keep destruction limited to certain areas
- Provide educational materials to visitors including signs outside their businesses informing customers of areas of fragility within the reserve, and laws and regulations
- Provide educational materials to visitors in the form of an informative pamphlet detailing the protected areas of the reserve and maps of places to go and things to see
- Prohibit boats from using engines as a means of stimulating the bioluminescent effect of the dinoflagellates
- Discourage trips to the biobay during the full moon

Opportunity Class Allocation II (ecologically-oriented)

- Encourage boat operators to abide by standards regarding the number and size of boats allowed to enter the biobay
- Offer incentives for boat owners and operators who are willing to attend educational classes
- Work with Conservation Trust in development of floating dock and the phasing in of electric boats
- Make frequent patrols of the areas of high concern
- Pursue funding for the increase in rangers designated to patrol La Parguera

It is our hope that our adaptation of the Limits of Acceptable Change process will be eventually implemented by DNER to help improve the environmental and social health of

La Parguera Natural Reserve. It is also our hope that it may be used as a model for sustainable use of similar natural reserves in Puerto Rico.

1.0 Introduction

La Parguera Natural Reserve is located on the southwestern coast of Puerto Rico in the municipality of Lajas. La Parguera boasts a diverse and fragile ecosystem with several natural tourist attractions, including one of the most important coastal mangrove systems in Puerto Rico, an extensive coral reef system, and two bioluminescent bays. Only in a few places in the world are the conditions supporting bioluminescence constant enough throughout the year to produce a luminous bay. The luminescence of these bays, their rarity, and their importance to marine biology have made them internationally significant and the destination of many visitors. Many individuals also visit the area simply to enjoy the beauty of the reserve.

In large part because of these natural attractions, La Parguera has undergone a transformation from a quiet fishing town to a center of tourism. The number of visitors per year has increased from 35,000 in 1984 (NOAA/DNER 1984) to over 100,000 in 1998 (García, 1998). While tourism has economic benefits, it also uses resources, generates waste, and has environmental costs (United Nations – Sustainable Development). The bioluminescent bays are losing some of their luminescence, sea-grass beds and coral reefs are being destroyed, and social concern for the health of the reserve is growing. In addition, current laws and regulations designed to maintain the health of La Parguera are not uniformly enforced.

The Department of Natural and Environmental Resources (DNER), the governmental agency designated to protect Puerto Rico's natural resources, is interested in promoting long term sustainable growth for La Parguera. The DNER wants to explore

the impact tourism has had on the environment of La Parguera and the effectiveness of current law enforcement there, and perhaps consider changing its management of the reserve. A management approach that has been used around the world to address similar issues is focused around the philosophy of sustainable tourism. The intention of this concept is to achieve a sustainable balance between visitor enjoyment, the local economy, and protection/conservation of ecological resources (Ceballos-Lascuráin, 2000).

There are many approaches to developing and implementing a sustainable tourism program in an area. The planning system chosen by DNER is the Limits of Acceptable Change (LAC) planning system developed in 1985 by the United States Department of Agriculture. The LAC planning system is a widely accepted process for ecological planning and is increasingly being used in the United States, Canada, Australia, Venezuela and South Africa (Giongo, Bosco-Nizey, 1999). The method provides guidelines for how to evaluate current conditions in a reserve and produce management solutions for problems that may be present. Users of this process consider both the desired visitor experience and the ecological values of the area and develop standards for appropriate and acceptable social, resource, and management conditions within the area. The DNER is interested initiating the LAC process to promote sustainable use of La Parguera.

The goal of this project was to develop management alternatives for activities in La Parguera Natural Reserve using the Limits of Acceptable Change planning system as a guide. The activities we focused on include boat rentals, trips to the bioluminescent bay, and maritime transportation to Mata La Gata and Caracoles Keys. We provided DNER with the results of our LAC methodology, as well as recommendations for

continuation of the process. Our findings and recommendations provide DNER with a basis for implementing management actions in La Parguera that could help improve the environmental health and social conditions in the reserve. This project may also serve as a model for management of similar natural reserves throughout Puerto Rico.

2.0 Background

As described in Chapter 1, our project focuses on devising management alternatives for La Parguera Natural Reserve using the Limits of Acceptable Change (LAC) methodology. In order to better understand the state of La Parguera, in this chapter we first provide an overview of the ecological and economic importance of La Parguera, its attraction as a tourist destination, the problems it is facing, and the current status of management within the reserve. Since La Parguera is an increasingly popular nature-based tourist destination, we include information regarding the growth in tourism and nature tourism, and the effects they may have on the environment. Sustainable tourism is then introduced as a concept for maintaining and promoting sustainable use of natural areas. Finally, we discuss methodologies that incorporate resource and visitor management to promote sustainable tourism. In particular, we describe the Limits of Acceptable Change methodology in detail, as this is the methodology recommended by the Department of Natural and Environmental Resources (DNER) for use in La Parguera.

2.1 La Parguera Natural Reserve

La Parguera is a natural reserve located on the southwest coast of Puerto Rico. It is home to a complex and highly diverse ecosystem comprised of coral reefs, seagrass beds, and mangrove systems that provide the habitat for various types of aquatic life. The reserve also contains two bioluminescent bays. Such attractions and the availability of boat trips to these areas have attracted increasing numbers of tourists to this part of the island. This surge of visitors has led to an often negative human impact on the ecological

resources of the reserve. Although some laws and regulations are in place to limit this damage, enforcement is often a problem. In this section we discuss these resource and management issues in more detail.

La Parguera, located in the coastal fishing village of Lajas, is an extremely valuable and unique biological area. The coral reefs, mangroves, and seagrass beds exist interdependently and provide the ecological environment that serves as a nursery for a variety of organisms. The coral reefs of La Parguera take up approximately 20% of the insular shelf of the reserve and are home to various aquatic species (García, 1998). In addition, the rare mangrove wetlands present in the reserve function as breeding grounds for different species of indigenous and migratory birds. The extensive system of seagrass beds provides living space, foraging grounds, and protection from predators for invertebrates and fishes (García, 1998).

The natural reserve also has the rare conditions necessary for the occurrence of bioluminescent bays. The bioluminescence of these bays is caused by the abundance of luminescent dinoflagellates, called *Pyrodinium*, that populate them (U.S Department of the Interior, 1969). These organisms produce flashes of light related to the stability of their environment. *Pyrodinium* glow only when disturbed or agitated, and only at night. La Parguera also has the warm waters, a nearly closed-off bay, and wetlands that provide a favorable setting for bioluminescent bays.

The bioluminescent bays in La Parguera are Bahía Fosforescente, and Monsio José (DNER). As the brighter of the two, Bahía Fosforescente is the bay to which most tourists are taken. The Bahía Fosforescente, and the diverse ecological environment previously mentioned serve as natural attractions for Lajas. As the word of the

bioluminescent bays and the beauty of the coral reefs and mangrove systems have spread, La Parguera has become more popular as a tourist destination.

The town of Lajas is centered on the tourist industry and is growing as a tourist center. The tourist population in La Parguera has increased from approximately 35,000 visitors per year in 1984 (NOAA, DNR, 1984) to over 100,000 in 1998. While visiting La Parguera, tourists are offered trips to nearby islands, mangrove channels, and to Bahía Fosforescente. From May to August, trips to the bay can generate up to 70% of annual tourist-related income (González, 2000). Tourists can also take part in snorkeling, scuba diving, and fishing activities. In addition, tourists are able to rent boats from businesses located in La Parguera to visit the islands located throughout the waters of the reserve.

The tourist industry in La Parguera relies heavily on the health of the reserve since tourist activities are mostly environmentally based. However, the environment within the reserve has deteriorated, at least in part because of tourist activity. The waters of La Parguera were documented in 1981 as being partially contaminated by pollutants from commercial and private boats (Armstrong, 1981). Boat and foot traffic have increased the rate of coastal erosion, boat waves have disturbed the fragile coral reef, and boat anchors have left scars on the ocean floor (González, 2002). In addition, seagrass beds are being disturbed, increasing the turbidity of the water and destruction of organisms (Armstrong 2002, González 2002).

The increasing rate of the eutrophication has also been identified as a problem in La Parguera (González, 2002). Boats passing through the reserve stir up nutrient-rich sediment from the ocean floor, mixing lower layers of water with the highly oxygenated upper layers, causing overall oxygen levels to decrease. Although this process is

increasing naturally, it is accelerated by the re-suspension of sediment from boat activity. This disturbance directly affects the phytoplankton organisms by diminishing light and altering the make-up of species. Several boat operators have been observed using the boat's engines as a means of stimulating the bioluminescent effect in the bay, adding to the turbidity of the water (González, 2002).

Construction around the reserve has also been an area of concern. In some areas, mangrove trees have been cut down to make room for the construction of 200 summer homes; salt marshes were also filled in to provide access to the homes (García 1998, EPA Water Enforcement Bulletin, DNER).

Key factors involved in management of La Parguera include the role of the Department of Natural and Environmental Resources (DNER), the role of rangers, the permit process for commercial boats, regulations and their enforcement, and the role and actions of the Environmental Protection Agency. While there is some level of management designed to regulate behavior in the reserve, the regulations are limited not uniformly enforced (Ramon, Ranger in La Parguera, 2002).

The Department of Natural and Environmental Resources is charged with protecting the island's natural resources through conservation and enforcement of local laws (DNER). This organization has a Puerto Rican constitutional right to impose fines and jail sentences in order to enforce environmental laws and regulations. Any violations of environmental laws are considered misdemeanors and can be punishable by a fine no less than fifty dollars but no more than five hundred dollars, or imprisonment of no less then five days but no more than ninety days, or both penalties (Laws of Puerto Rico Annotated, The Secretary of State of Puerto Rico and Lexis-Nexis).

Currently, there are two rangers who patrol La Parguera and other nearby reserves. According to Joel Rowen Florés, one of the DNER rangers at La Parguera, it is extremely difficult to enforce the laws. He points out that there is not enough manpower to patrol the area to watch for violators; as a consequence, illegal activities may go unnoticed. If there did happen to be a witness, this individual would have to accompany the ranger to court in order to press charges. Also according to Florés, there is very little willingness on the part of individuals who live in La Parguera to go to court, and little interest from tourists who are in the area for a limited amount of time. In addition, rangers only have the ability to perform safety checks on boats and monitor speeding.

Currently the only agency that is issuing maritime transportation permits in Puerto Rico is the Public Service Commission (PSC). The permit process is focused on economic and safety issues, and the permit process only requires that the individual applying for a permit have a captain's license, proof of insurance, and a boat that passes safety inspections. The applicants must also publish a public notice of permit request in two local papers for just one day. Local individuals are allowed to submit objections for a period of 15 days after the notice is run. After this waiting period, the Public Service Commission issues a study on the economic impact and necessity for issuing a new permit (Rivera, 2002).

The Public Service Commission also has the power to impose stipulations on issued permits. However, according to Ruben Rivera, the PSC employee in charge of granting permits, the commission rarely imposes any stipulations, allowing boat operators unrestricted access to all areas in La Parguera. The permit is valid for five years, and boat operators must have their boats inspected yearly.

The entire permit process takes about three months and does not take into account the environmental impact of increasing the number of permits. Applicants need only to meet the minimal requirements and pay $65 to obtain a permit. However, in 2001 the Public Service Commission started to collaborate with the Department of Natural and Environmental Resources to take environmental impacts into consideration during the permit process. This collaboration is on a trial basis in a few selected areas.

As a commonwealth of the United States, Puerto Rico is also subject to all federal environmental regulations, including those of the Environmental Protection Agency (EPA). There have been several instances in which the EPA has taken action against violations in La Parguera. In 1997, 48 permanently moored houseboats were found to not have permits from the Environmental Protection Agency. They were investigated, and as a result, 41 of the 48 boats were denied permits on the basis that they caused a detrimental environmental impact and were forced to relocate (EPA Water Enforcement Bulletin). This case is an example of enforcement of the River and Harbors Act. The EPA also has the right to impose fines of up to $137,500 for wetland violations, and may reduce the fine if cooperation is obtained to correct the violation (EPA).

2.2 Tourism and Sustainability

Nature tourism is often promoted as a means of balancing enjoyment and conservation of natural areas such as La Parguera. Tourism is one of the largest industries in the world and is continuing to grow; the World Tourism Organization projects that international tourism will grow from 593 million tourists in 1996 to over 1 billion by 2010. In Puerto Rico, tourism currently represents 7 percent of the gross

national product (GNP); in 1999 alone, an estimated 5 million tourists visited the island (Honey, 2002). Tourism in Puerto Rico is growing rapidly (Honey, 2002), and the area of tourism that is undergoing the fastest growth is nature-based tourism (Ceballos-Lacrain, 2000). This form of tourism, however, does not come without its disadvantages. The human impact on the resources on which nature tourism is centered is often negative. If tourism is uncontrolled, irreversible damage may occur; it is important to consider the sustainability of natural areas in order to preserve resources for future enjoyment.

2.2.1 Nature Tourism

Current trends show a shift in tourist preferences; increasing numbers of tourists are moving toward tourism that is environmentally based (Cook 1992). Experts agree that increased sensitivity toward environmental issues and toward the need for protecting natural resources has contributed to the expansion of tourism that is centered on natural areas and the observation of nature (Giongo, Bosco-Nizeye, et. al., 1999). According to the World Travel and Tourism Council (WTTC), nature-based tourism has been estimated to account for between 10 and 15 percent of all international travel expenditures (WTTC, 1992).

Nature tourism has both positive and negative impacts on the environment and the areas in and around tourist destinations. Positive impacts include income, jobs, tax revenues, and cross-cultural interaction (Giongo, Bosco-Nizeye, et. al., 1999). In addition, natural reserves provide study opportunities for individuals whether they are school children or researchers. On the other hand, many problems have developed from nature tourism. The United Nations emphasizes in their publication “Planning for Development” the damage being done to coastlines, unique scenic spots, aquatic

ecosystems, islands, mountain regions, countryside, and historical sites and monuments (United Nations, 1993).

2.2.2 Sustainable Development and Sustainable Tourism

The concept of sustainable development can be used to limit the negative impacts that result from nature tourism. Its objective is to improve quality of life by managing the economic, social, and cultural aspects of society in harmony with the management of the environment and its natural resources (DNER, 1999). Sustainable development ventures away from a strictly socio-economic focus to one where development "meets the goals of the present without compromising the ability of future generations to meet their own needs" (World Commission on Environment and Development, 1987, p. 43).

While sustainable development is the concept of developing and maintaining an area so that it remains practical over an indefinite period of time, sustainable tourism can form part of the actual infrastructure that supports this idea. Tourism Concern (1992) defines sustainable tourism as tourism and associated infrastructure that, both now and in the future, operates within natural capacities for the regeneration and future productivity of natural resources. Planning systems can be used to achieve the ideals behind sustainable tourism.

2.3 Methodologies for Sustainable Development and Tourism

There are several possible methodologies that can be used to control impacts that threaten the quality of outdoor recreation areas. The three most widely applied frameworks include Visitor Impact Management (VIM), Visitor Experience and

Resource Protection, and Limits of Acceptable Change (LAC) (Manning, 1999). The basic steps of these frameworks are shown in Table 2.1.

All of the listed methodologies are accepted ways to promote sustainable development. There are however, similarities and differences among them. All three planning systems involve assessing the current resource conditions and using indicators and standards to monitor the impact on these conditions. The Visitor Experience and Resource Protection (VERP) and the Limits of Acceptable Change (LAC) systems take both resource and social conditions into account, whereas the Visitor Impact Management (VIM) system focuses primarily on resource conditions. The VERP and LAC methods also use a strategy of offering and maintaining a range of conditions and experiences through the use of zones or opportunity classes, respectively. The Visitor Experience and Resource Protection (VERP) system, unlike VIM and LAC, assembles an interdisciplinary project team (Element 1) and develops a public involvement strategy (Element 2). The last step, or element, of the three processes involves the implementation of the proposed management strategies

Table 2. 1 Sustainable Development Methodologies (Manning, 1999)

Visitor Impact Management (VM)	*Visitor Experience and Resource Protection (VERP)*	*Limits of Acceptable Change (LAC)*
Step 1. Preassessment database reviews	Element 1. Assemble and interdisciplinary project team	Step 1. Identify area concerns and issues
Step 2. Review of management objectives	Element 2. Develop a public involvement strategy	Step 2. Define and describe opportunity classes
Step 3. Selection of key impact indicators	Element 3. Develop statements of primary park purpose, significance, and primary interpretive themes	Step 3. Select indicators of resource and social conditions
Step 4. Selection of standards for key impact indicators	Element 4. Analyze park resources and existing visitor use	Step 4. Inventory resource and social conditions
Step 5. Comparison of standards and existing conditions	Element 5. Describe a potential range of visitor experiences and resource conditions	Step 5. Specify standards for resource and social indicators
Step 6. Identify probable causes of impacts	Element 6. Allocate potential zones to specific locations	Step 6. Identify alternative opportunity class allocations
Step 7. Identify management strategies	Element 7. Select indicators and specify standards for each zone; develop a monitoring plan	Step 7. Identify management actions for each alternative
Step 8. Implementation	Element 8. Monitor resource and social indicators	Step 8. Evaluation and selection of an alternative
	Element 9. Take management action	Step 9. Implement actions and monitor conditions

While VIM, VERP, and LAC are all widely used, DNER has decided to use the LAC planning process for La Parguera. The Limits of Acceptable Change System for Wilderness Planning manual was created in the mid-1980s by the United States Department of Agriculture to address visitor management issues. The LAC process was originally developed for wilderness planning, but is applicable to other protected areas (Giongo, Bosco-Nizeye, 1999). The method provides a guiding process for evaluating current conditions in a reserve and producing management solutions for problems that

may be present. The LAC planning system has been used in various countries to promote sustainable use of natural reserves. Countries where LAC has been used include The United States, Canada, Australia, Venezuela, and South Africa (Giongo, Bosco-Nizeye, 1999). The process involves a series of nine interrelated steps described in more detail in the next section.

2.4 Limits of Acceptable Change Planning System

The nine steps of the LAC process can be grouped into four major components (Mount Rogers National Recreation Area): (1) identifying issues, concerns and opportunities; (2) determining the present condition of the reserve; (3) determining a plan of action; and (4) implementing and monitoring the action plan. Experts agree that it is important for managers to try to accomplish the goal of each of these components. Lindberg and Hawkins state: "Until protected area managers can develop and describe management objectives and then show specifically how sites within a park or reserve that correspond to those objectives are being impacted, it will be hard to make a case for changes in the type or number of concessionaires, group size, mode of transport, or many other management decisions" (Lindberg and Hawkins, 1993). Below is a detailed description of each of the four components and the steps involved in each component, focusing on the purpose and product of each.

2.4.1 Identifying Issues, Concerns, and Opportunities

In the first component, concerns about resource and social conditions are investigated. By identifying areas of concern in the reserve, one can better understand

how to approach defining opportunity classes. An opportunity class can be understood as a geographical section of the reserve that is classified by desired current and potential future conditions. Opportunity classes are the primary means of offering a range of acceptable resource and social conditions to both protect the reserve and allow visitation.

LAC Step One – Determining Issues and Concerns

The first step of this process begins with the identification of issues and concerns related to the area. The terms *concerns* and *issues* both refer to specific interests one has in an area and can cover a wide range of social, managerial, and environmental factors. Issues and concerns may be related directly to the features and characteristics of the area, or indirectly to the area's relationship with the surrounding area. This step also involves identifying specific ecological values within the reserve. The result of this step is a write-up that identifies areas of value requiring special attention as well as particular issues and problems that are of concern to the public and to management.

LAC Step Two – Defining and Describing Opportunity Classes

The next step involves defining opportunity classes. According to LAC, an opportunity class is defined by descriptions of desired resource, social, and managerial conditions for that specific natural area. They reflect the range of conditions managers wish to provide in the area (Stankey, et.al., 1985).

The authors point out that for large recreational areas four to six opportunity classes may be required, while a small area may require only one or two. Examples for an area with three designated opportunity classes include low impact, moderate impact,

and high impact. In low impact areas there is little noticeable impact from humans and few encounters between groups. Management for these zones involves little site-management and promotes sustainable use. In moderate impact areas there is some impact from humans and inter-party contact is seldom to frequent. Management for these zones is subtle and emphasizes sustainable use and corrective measures. In high impact areas there is a high degree of impact from humans and encounters between groups are frequent. Management of these areas may involve frequent patrols and extensive on and off-site management.

The process of defining opportunity classes provides the basis for which the appropriateness of indicators (step 3), standards (step 5), and management actions (step 7) can be assessed (Stankey et. Al., 1985).

2.4.2 Determining the Present Condition of the Reserve

In the second component of LAC, management planners undertake the task of establishing the current conditions in the area of interest. This stage combines steps three, four, and five of the LAC process and deals mainly with selecting indicators to measure conditions in the reserve. The focus of the second component is on analyzing the relationship between existing conditions and those judged acceptable using the specified indicator (Stankey, et. al., 1985).

LAC Step Three – Selecting Indicators of Resource and Social Conditions

The third step of LAC involves selecting social and resource indicators that can be used to judge the overall condition of the defined opportunity classes, and to assess the effectiveness of management actions. To identify indicators, the social and resource

concerns developed in step 1 of the LAC process should be considered. This is an important consideration since the indicators are used to measure the status of these specific social and resource concerns.

Indicators should be able to be measured cost effectively and accurately, and the condition of the indicators should illustrate the amount and types of use taking place. In addition, social indicators should be related to user concerns, and the condition of the indicators should be responsive to management control (Stankey, et. al., 1985).

Indicators can encompass a wide range of measurements. A social indicator may be the number of other parties an individual encounters. Resource indicators may be types of damage, water quality, air quality, soil quality, or progression (or regression) of any of these indicators. The recommended outcome of the third step is a list of measurable resource and social indicators.

LAC Step Four – Performing an Inventory of Existing Resource and Social Conditions

The fourth step of the process involves the collection of up to date data for each indicator. It is often the case that managers must use previously recorded data. If current data is not available, managers may have to use data that is not complete. This is a limitation that should be noted. To be of value to managers, the inventory must be collected in an objective and systematic fashion (Stankey, et. al., 1985). The product of this phase is to produce a map of the existing conditions of each indicator throughout the wilderness area.

LAC Step Five – Specifying Standards for Resource and Social Indicators

In step five, standards for each indicator are assigned. Standards refer to specific values of the indicators that can be used to determine whether the resource and social conditions in a particular opportunity class are acceptable. They should be highly specific measures that are meaningful yet attainable. These standards are used to evaluate what level of management is needed by comparing existing conditions with those considered acceptable. In some cases, the concept of non-degradation can be used as a standard. The non-degradation seeks to prevent degradation of current naturalness and solitude and to restore substandard settings to minimum levels (Hendee and others 1987). A table or chart is created that defines and quantifies the standards for each indicator.

2.4.3 Determining a Plan of Action

The third component of the LAC process includes steps six, seven, and eight. The objective of this component is to come up with a plan of action for managing the reserve (Mount Rogers National Recreation Area). This component builds on the previous one, as it proposes management actions necessary to achieve the conditions determined in the second component.

LAC Step Six – Identifying Alternative Opportunity Class Allocations

Step six of the LAC process is the allocation of alternative opportunity classes. In this step, geographic areas of the reserve are assigned to particular opportunity classes. Since management solutions are developed for each of the opportunity classes assigned in this step, it is important to take both resources and social interests into consideration

during allocation. Fiske states that conserving resources is not only a bio-ecological process, but a socio-cultural one as well (SJ Fiske, 1992), emphasizing that researchers must receive input from all possible sources in order to gain a broad scope of interests in the area. These sources include, but are not limited to, managers of the area, residents, visitors, and environmental experts.

Step six involves an analysis of the area issues and concerns identified in step 1, the opportunity classes that are defined in step 2, and the data collected in step 4. The product of this step is to create a map and tabulate summaries of alternative opportunity class allocations that incorporate both area issues and concerns and existing resource and social conditions (Stankey, et. al., 1985).

LAC Step Seven – Identifying Management Actions

The seventh step of the LAC process includes the identification of management actions for each alternative opportunity class allocation developed in step six. As part of this management solution, costs and effectiveness for each solution should be evaluated. Managers should keep in mind the "principle of minimum regulation" (Hendee, et.al. 1978), which states that only the level of control necessary to achieve a specific goal should be used. At the end of this process, a list or a map of areas that are below standard is developed. In addition, a set of management conditions is created that can be used to facilitate positive change in the area.

LAC Step Eight – Evaluating and Selecting of Management Plan

Step eight of the LAC process involves choosing an alternative from step six and committing to one of the management plans developed in step 7. The selection of a

management plan should be guided in part by input from managers and the public. The result of this phase is a final list of what areas fit into each of the opportunity classes as well as predictions of what opportunity class that area may fall into after the management solution has been implemented.

2.4.4 Implementing and Monitoring the Action Plan

The final component consists of only the ninth step of the LAC process. In this step, a program for monitoring and evaluating management effectiveness is prepared. It intends to assure that the program is scheduled for review at regular intervals (Stankey, et. al., 1985).

LAC Step Nine – Implementing Management Solution and Monitoring Conditions

This final phase involves the implementation of the management solutions developed in step seven and the actual monitoring of the conditions of the area. Monitoring of conditions can be completed through the use of the established indicators. The authors of the LAC process recommend that a study be completed once every three to five years, depending on the status of the opportunity class. These studies are used to determine the progress and usefulness of the implemented management plans.

The product of this final step is a summary of the relationship between existing and standard conditions for all indicators typical of each opportunity class. Recommendations of needed changes in the management program may also be useful to continue to help bring conditions up to minimum standard.

3.0 Methodology

The primary goal for this project was to present the Department of Natural and Environmental Resources with management alternatives for activities in La Parguera Natural Reserve by conducting an iteration of the Limits of Acceptable Change (LAC) planning system. We also made recommendations to DNER for continuation of the process.

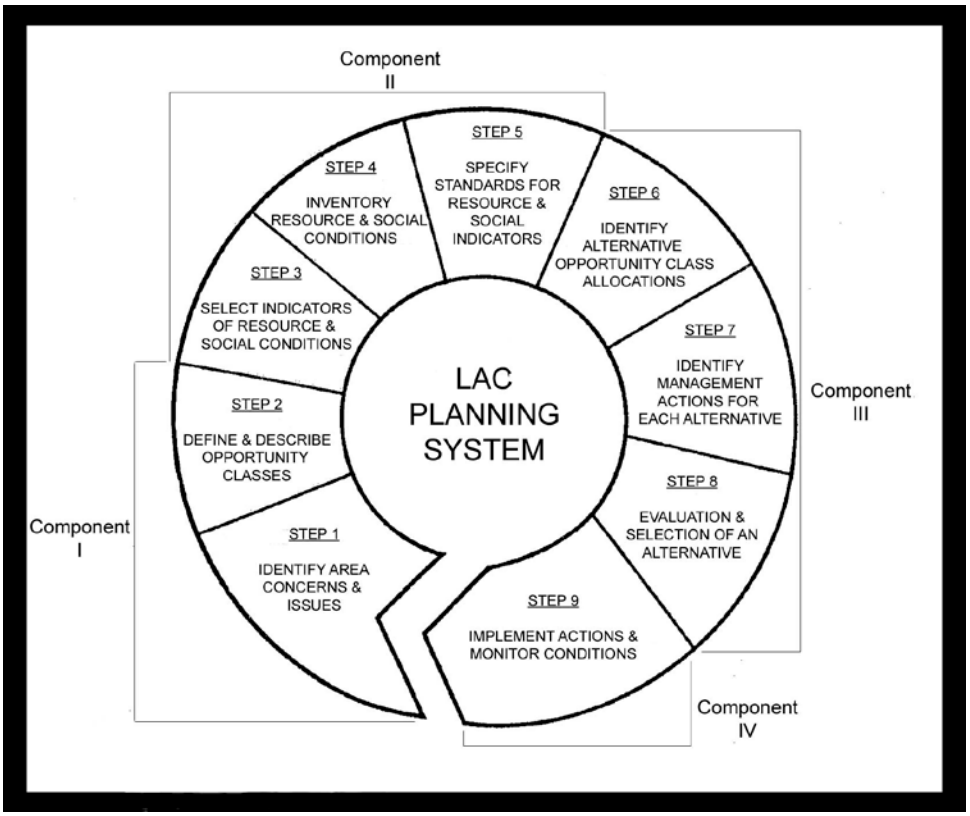

Figure 3. 1 LAC Planning System Adapted from Limits of Acceptable Change Planning System (Stankey, et. al., page 3, 1985)

Our methodology followed the process outlined by the LAC planning system, shown schematically in Figure 3.1. The application of this system to La Parguera provided us

with an appropriate framework for making management recommendations for the reserve. Due to time constraints, we modified some aspects of the process, making recommendations for completion where we were unable to adequately follow through with the entire step. Our project focused on the implementation of LAC to the following activities: maritime transportation to the Mata La Gata and Caracoles keys, boat rentals, and trips to the bioluminescent bay and channels.

3.1 Identifying Area Concerns and Issues

Our first objective was to identify public and managerial areas of concern pertaining to La Parguera Natural Reserve. The terms *concerns* and *issues* both refer to specific interests one has in an area and can cover a wide range of social, managerial, and environmental factors. By the end of step one, features or values that must be achieved or maintained and specific locations of concern should be established.

We visited La Parguera in order to observe the area and to meet with ecological experts, reserve employees, and local boat operators and visitors. The objective of this was to solicit input about public and managerial concerns and to identify specific values and overall importance of the reserve.

We were taken on a tour of La Parguera by a ranger from DNER, an employee of La Parguera, and Daniel Galán, the director of the Forest Management Division for DNER. The purpose of the tour was to give us a better understanding of the role of La Parguera and its environment. During our tour, we traveled to the island of Magueyes where we had an informal meeting with Roy A Armstrong, a professor from the University of Puerto Rico. Professor Armstrong has done extensive research into the

health of the Parguera ecosystem, focusing primarily on the deterioration of coral reefs. We met with Professor Armstrong to discuss areas of ecological importance as well as areas of value needing special attention.

To gain feedback needed to establish public concerns, we spoke with visitors, boat operators, and residents. We spent a few hours in the waterfront area of La Parguera speaking with passersby and the operators or owners of the boat companies located in the area. The area is approximately .25 square miles, making it easy for us to locate the companies and speak with visitors and residents. To gather the information we were looking for, we created two different questionnaires, one for visitors and one for boat operators.

The series of questions used in our visitor questionnaires was developed in order to obtain information about visitor patterns and concerns they had regarding the reserve. To administer the visitor questionnaires, we talked to people in the main strip of La Parguera. We explained to the individuals we approached that we were doing an educational study and that any information they could give us would be helpful. Our questionnaire focused on their reasons for coming to La Parguera, how important the environment was to their trip, the activities they had participated in, the desired number of people they would like to see while participating in these activities, how satisfied they were with their visit, and what they might change about the area. Since our time was limited, we were only able to interview fifteen people. This proved sufficient as we encountered recurring themes during the interviews.

Our questionnaire for the boat companies was designed to learn about operation frequency and possible overuse of the waters in the reserve. We also wanted to learn

about the level of education given to customers in order to establish what type of information is supplied by the operators. The four tour operators we interviewed were identified during our tour of the reserve. Our questionnaire focused on number of years of operation, days open per year, trips/rentals per year, occupants per trip, extent of education they give to their customer about the reserve, regulations they are aware of, and the importance of the environment to the reserve. Our complete questionnaires are available in Appendix C.

Throughout the trip, we took the opportunity to speak with residents whenever possible to learn how they felt about living in a tourist destination and the effect of tourism on La Parguera. We then used this information to establish public concerns.

The public and managerial concerns were used to develop the narrative write-up, the product of step 1. The purpose of this narrative write-up is to identify unique values and special opportunities to be featured in an area's management, and problems requiring special attention (Stankey, et. al., 1985). The purposes and results of this step serve as the foundation for the rest of the process.

3.2 Defining and Describing Opportunity Classes

The second step in our methodology was to define and describe opportunity classes for La Parguera. An opportunity class is a hypothetical, qualitative description of an area with regard to the resource, social, and managerial conditions deemed acceptable for that location. Opportunity classes are designed to reflect the range of conditions managers wish to provide in an area (Stankey, et. al., 1985).

To describe opportunity classes, we used suggestions from the Limits of Acceptable Change guidelines. For resource conditions, the type of impact, severity of

impact, extent of impact, and apparentness of impact were considered. For social conditions, extent and location of inter-party contact were considered. For management conditions, the presence of management personnel, onsite versus offsite management strategies, site modifications, and rules and regulations on behavior were all taken into account (Stankey, et. al., 1985).

We used the resource, social, and management conditions identified in step 1 to determine the descriptions for each opportunity classes. The process of defining opportunity classes provides the basis for which the appropriateness of indicators (step 3), standards (step 5), and management actions (step 7) can be assessed (Stankey, et. al., 1985).

3.3 Selecting Indicators for Resource and Social Conditions

Our next objective was to identify social and resource indicators that can be used to judge the overall condition of the defined opportunity classes, and to assess the effectiveness of management actions. To identify these indicators, we first considered the social and resource concerns developed in step 1 of the LAC process. This is an important consideration as the indicators are used to measure the status of these specific social and resource conditions.

To determine social indicators, we referred to the LAC guidelines for suggestions on how to determine the social interactions in the area. The two social indicators that the LAC document recommends are to determine the amount of inter-party contact, and the number of people in each party.

To determine resource indicators, we first consulted individuals having experience with ecological indicators. We visited the Biobay Conservation Group from

Vieques since they are currently collecting water quality data for the bioluminescent Mosquito Bay. The LAC guidelines recommend that, where possible, only one or two indicators be used to assess resource conditions so that implementation is more feasible. Therefore we sought an indicator that would best reflect the overall health of the reserve. To find a more encompassing indicator, we contacted Reni García, Jack Morelock, and Juan Gonzalez, professors at the University of Puerto Rico who specialize in coral reefs and bioluminescent bays.

In evaluating possible indicators, we took the following criteria recommended by LAC into account (Stankey, et. al., 1985):

1. The indicator should be capable of being measured in cost-effective ways at acceptable levels of accuracy.
2. The condition of the indicator should reflect some relationship to the amount and/or type of use occurring.
3. Social indicators should be related to user concerns.
4. The condition of the indicator should be, at least potentially, responsive to management control.

3.4 Performing an Inventory of Resource and Social Conditions

This step, as described in the LAC process, focuses on collecting up-to-date data on all indicators within the reserve. To inventory our social indicators we used information gathered from out interviews with the tour boat operators administered during our trip to La Parguera. After speaking with the tour operators, we were able to identify areas of high, medium, or low visitor use. Using this information, we were able to estimate the range of social conditions in the reserve.

Since we were limited by time, we did not attempt to begin the data collection process for resource indicators. Instead, we used data that had previously been collected on the reserve. To inventory resource conditions we contacted Professors Juan Gonzalez, Roy A. Armstrong, and Jack Morelock from the University of Puerto Rico. Professor Gonzalez has done extensive research on the bioluminescent bay in La Parguera. Professors Armstrong and Morelock have both conducted research on the coral reefs present in La Parguera. We contacted them for documents containing information on the existing conditions for our indicators. To graphically display our results of existing conditions for each available indicator throughout La Parguera, we used the Geographical Information System (GIS) mapping tool, ArcView™.

3.5 Specifying Standards for Indicators for Each Opportunity Classes

Standards refer to acceptable values that can be used to determine the status of the indicators across each opportunity class. By specifying standards for the indicators from step 3 and 4, we established the basis for determining whether or not the inventoried conditions are acceptable. These standards are later used to evaluate what level of management is needed, by comparing existing conditions with those considered acceptable.

To specify social standards, we used the feedback gathered from our visitor questionnaire regarding the number of other individuals visitors prefer to see during their stay. We weighed this number against the number of people we could realistically limit it to for each activity. These realistic limits were based on the views and needs of the boat

companies which depend on the income generated by recreational activities in the reserve. We used this current information as a basis for identifying standards.

To specify ecological standards, we contacted the professors who supplied us with the information on the current condition of our indicators. They provided us with suggestions for minimal acceptable standards for our indicators. They also provided information on location of testing, techniques, and time periods of testing for ecological indicators. The outcome of this step was a list of acceptable social and resource conditions, or standards, for each indicator in each opportunity class.

3.6 Identifying Alternative Opportunity Class Allocations

Step six involves an analysis of the area issues and concerns identified in step 1, the opportunity classes that are defined in step 2 and the inventory data collected in step 4. This step also involves developing alternative opportunity class allocations for areas in the reserve using the results and data collected in the previous steps.

To allocate these opportunity classes, we first had to decide what resource and social conditions were to be maintained or achieved. To make this decision we took into account the areas of the reserve that endure the highest impact from tourists. We also recognized that input from both managers and the public should be taken into account before making decisions. Maps of alternative opportunity classes allocations, reflecting both area issues and concerns and existing resource and social conditions, result from step 6 (Stankey, et. al., 1985).

3.7 Identifying Management Actions for Each Alternative

The objective of step 7 is to identify management actions for each alternative. The LAC guidelines recommend that managers should evaluate the costs of implementing the different management alternatives and how effective each will be to bringing existing conditions up to standard. Specifically, the LAC guidelines suggest the following process (Stankey, et. al., 1985):

- Review the managerial condition portion of the opportunity class description defining the appropriate types of actions
- Analyze the differences between existing conditions and those defined as acceptable by the standards
- Analyze the alternative management actions for bringing existing conditions up to standard

Taking into account practical interests, we, as much as possible, provided DNER with possible management actions to achieve each opportunity class allocation. These were developed after considering social, managerial, and ecological conditions within the reserve. A pressing issue when determining management solutions for each opportunity class was the difficulty of enforcing laws and regulations within the reserve due to the lack of resources with which to impose them. Taking this issue into consideration we also sought to provide management solutions for the improvement of law enforcement in the reserve.

3.8 Evaluating and Selecting a Management Plan

The objective of step 8, as described in the LAC document is to select a specific opportunity class allocation and associated management plan. According to the LAC document, the selection of a management plan should be guided in part by input from

managers and the public. Since gathering this input was beyond the scope of our project timeline, instead of providing DNER with a specific management plan, we made recommendations as to how to decide on the final management solution.

3.9 Implementing Actions and Monitoring Changes

Implementation and evaluation of these management solutions will be left up to DNER in the final step of the LAC process. However, using LAC guidelines, we developed recommendations for frequency of monitoring and monitoring priorities.

4.0 Results and Analysis

The following chapter is of the results from steps 1-7 of the LAC process. We first establish areas of value and concern in La Parguera as determined from our visit to the reserve. We then list and describe the three opportunity classes developed for La Parguera and the indictors used to monitor the conditions of each class. We provide an inventory of the indicators and establish standards for each indicator in each opportunity class. Lastly, we develop two alternative opportunity allocations and management actions for each alternative.

4.1 Area Issues and Concerns

The result of step one from the Limits of Acceptable Change process is a narrative write-up on La Parguera natural reserve. The write-up identifies ecological values and conditions, public concerns, and managerial concerns related to La Parguera. Areas of value and concern were determined after gathering and compiling information received during a two-day visit to the reserve. Background information on La Parguera is provided before issues and concerns are described in order to establish this location as an area requiring special attention.

Description of La Parguera

Ecological Values and Conditions

La Parguera is a natural reserve located on the southwest coast of Puerto Rico in the town of Lajas. It is an extremely valuable and unique biological area. The coral reefs, mangroves, and seagrass beds exist interdependently and provide the ecological environment that serves as a nursery for many terrestrial and marine animals.

The coral reefs of La Parguera are among the most developed in the island. They take up approximately 20% of the insular shelf of the reserve and are home to various aquatic species (Garcia, 1998). In addition, the rare mangrove wetlands present in the reserve function as breeding grounds for different species of indigenous and migratory birds and are critical habitats for terrestrial and marine animals (Garcia, 1998). The extensive system of seagrass beds provides living space, foraging grounds, and protection from predators for invertebrates and fishes (García 1998).

The floor of the of La Parguera waters has an extensive cover of turtlegrass which is used by the West Indian Manatee and the Hawksbill sea turtle. In addition, the largest breeding colony throughout Puerto Rico of the Brown Pelican is found in a mangrove near the eastern end of La Parguera at Bahia Montalva. The area also provides what has been determined as a critical habitat for the Yellow-shouldered Blackbird.

The natural reserve also has the rare conditions necessary for the occurrence of bioluminescent bays. There are only few biobays present throughout the world. The bioluminescence of these bays is caused by the abundance of luminescent dinoflagellates, called P*yrodinium*, that populate them. La Parguera has the warm waters, nearly closed-off bay, and wetlands that provide a favorable setting for a bioluminescent bay. In 1960, the National Park Service, working in cooperation with the Commonwealth government, completed a report for *Bahía Fosforescente*. The report concluded that the bay was an extraordinary feature that was threatened by the deterioration of its environment and in need of protection (US Department of the Interior, 1968). The bay remains threatened to the present day.

Public Issues

The town of Lajas depends a great deal on the income generated from nature-based tourist activities. While visiting La Parguera, tourists are offered trips to nearby islands, mangrove channels, and *Bahía Fosforescente*. According to people with an invested interest in La Parguera, such as residents of Lajas, visitors to the reserve, DNER employees, rangers in La Parguera, and commercial boat owners or operators, a current problem in La Parguera is that the environment within the reserve is deteriorating.

It is apparent that the environment of the reserve is of importance to many people. Residents and visitors voiced concern regarding pollution and the destruction throughout the reserve. Boat operators and owners also understand that the success of their businesses is reliant on the health of the reserve.

Within the reserve, there are four companies that provide trips to the biobay and that rent boats for recreational use. These businesses include Johnny Boat Tours, Torres Boat Service, Cancel Boat Tours, and Pepe Boat Tours. Most of these boats can fit anywhere from 6 to 10 people comfortably, but some can fit up to 12 or

14. Cancel Boat Tours has a boat that is permitted to have 149 people on board. Trips to the bioluminescent bay cost $5, while the cost for boat rentals varies. Most boats are rented by the hour.

The number of other people that visitors hope or expect to see when they participate in any of the recreational activities varied from person to person and activity to activity. However, many visitors that had taken the bioluminescent bay tour, reported feeling crowded. In the bay, it is common for boats to come into contact with other tour groups, which may result in a less than satisfactory visitor experience.

Managerial concerns

Managerial concerns of DNER employees focus on the lack of education, lack of appropriate laws and regulations, and lack of enforcement of current policies. Lack or education refers to both the confusion of boat operators regarding laws and regulations, and to the lack of information operators give to their customers.

There is some confusion on what is and is not allowed in the reserve. One operator tells customers they must tie boats to buoys, while another tells them that it is illegal to tie to the buoys. Visitors to La Parguera are sometimes observed tying their boats to the mangroves instead of to buoys, but may not be aware that they were in violation of any laws.

When customers rent boats, they usually receive a short safety lesson concerning the use of the boat and the location of the safety equipment, but almost never receive information about the ecological importance of the area or how to avoid damaging fragile areas of the reserve. Customers renting boats are simply shown an aerial photograph of Caracoles and Mata La Gata, pointed in the right direction, and told that it is the best place to go for swimming, recreation, and sightseeing.

Lack of education give to customers during biobay trips is also a concern. During these trips, little or no educational or environmental information concerning the biobay is explained. Often times, operators do not provide customers with information regarding the reason behind the luminescence, its ecological importance, or on how to protect it. Customers are taken to the bay, allowed to swim for a few minutes, and brought back to the land.

Another major managerial concern is the lack of law enforcement within the reserve. Funds and rangers are limited, making it extremely difficult to keep people from obeying laws and regulations. The “Cuerpo de Vigilantes”, DNER’s law enforcement division in La Parguera, is not adequately staffed. The vigilantes are given large areas to patrol and, as a result, cannot fully enforce the laws that govern the reserve. During high tourist season, the vigilantes are overwhelmed by the number of visitors, and many laws and regulations are not enforced.

The lack of education, laws and regulations, and enforcement has resulted in the deterioration of several areas in La Parguera. Specific geographical areas of

concern specified by DNER employees include the biobay, Mata la Gata, Caracoles Keys, coral reef areas, and highly used boat routes to and from these areas.

4.2 Opportunity Classes

Using the guidelines established in the LAC document, we defined three opportunity classes for La Parguera. Although some locations where LAC has been applied warrant as many as six classes, while others have only one, we judged that the identification of three classes was appropriate for the size and conditions of La Parguera. This determination was based on the results obtained from step 1. We discovered that some areas of the reserve experience high visitation and impact while others do not. There are also some areas where resource conditions are especially sensitive. The use of three opportunity classes offers a good balance of sensitivity and feasibility, providing room for improved conditions while still providing a realistic range of opportunities. The opportunity classes were named "Low Impact", "Moderate Impact", and "High Impact". We then developed a description of each class with regard to resource, social, and managerial conditions. The prescribed conditions for Low Impact, Moderate Impact, and High Impact Zones are displayed in Tables 4.1, 4.2 and 4.3, respectively.

Table 4. 1 Low Impact Opportunity Class Description

Low Impact Zone
Resource Conditions - Human impacts are seldom evident - Includes mostly undisturbed, unmodified area of the reserve - Natural and ecological processes are not measurably affected by the actions of

users
- Loss of resources is both temporary and minor

Social Conditions
- Low chance of encountering other parties

Managerial Conditions
- Management encourages sustaining natural ecological processes
- Little or no evidence of site management
- If user-induced damage occurs, management should begin resource protection measures

Table 4. 2 Moderate Impact Opportunity Class Description

Moderate Impact Zone
Resource Conditions - There may be moderate changes in the environment due to visitors - Essentially an unmodified natural or natural-appearing environment - Visible impacts or natural and ecological impacts exist but are not significant enough to cause long term negative consequences Social Conditions - Inter-party contacts may range from seldom to frequent Managerial Conditions - Occasional patrols of areas of concern - This area contains subtle controls or restrictions such as travel lanes for boats and/or restrictive signs - Management emphasizes sustainable use of areas by providing visitors with informational and educational materials

Table 4. 3 High Impact Opportunity Class Description

High Impact Zone
Resource Conditions: - High level of impact due to humans - Resource impacts found in many locations (some very substantial) - Impacts may persist from year to year - Potential for substantial loss of resources or a drop in water quality - Impacts are apparent to most visitors Social Conditions: - Fairly high level of human contact Management Conditions: - Frequent patrols of the area of concern - Management enforces rules and regulations concerning use of these areas - Information and education provided to visitors through direct interaction

A Low Impact Zone has resource conditions that have experienced few impacts from humans, and social conditions where there is little human contact. There should be little site management within these zones. A Moderate Impact Zone has resource conditions where there is some evidence of human impact, and social conditions where human contact ranges from seldom to frequent. Management for these areas involves subtle control and emphasizes sustaining or restoring conditions. A High Impact Zone has resource conditions that tend to be negatively impacted by humans and social conditions where there is a high chance of human contact. Management should enforce strict regulations in these zones.

4.3 Indicators of Resource and Social Conditions

After establishing the opportunity classes, we selected factors for resource and social conditions, and then indicators for each of the factors. These factors and indicators relate to the issues and concerns identified in step one and the opportunity classes identified in step two. We limited our list to one factor and two indicators for social conditions and two factors and four indicators for resource conditions, as displayed in Table 4.4.

Table 4. 4 Social and Resource Factors and Indicators

Social Factor	Social Indicators
A. Solitude during visit	1. Number of other groups encountered within the duration of the individual recreational activity 2. Number of people in own group
Resource Factors	Resource Indicators
B. Bioluminescent bay conditions	3. Species and number of dinoflagellates
C. Coral reef, sea grass bed, and mangrove conditions	4. Live coral reef coverage measured at monitoring stations 5. Arial photography of overall coral reef coverage

The social factor, solitude during visit, was based on feedback we obtained from our visit to La Parguera. Many visitors felt that having too many other groups in the area or too many people in their group lessened their experience. To measure solitude we decided that both the number of other groups encountered within the duration of the individual recreational activity, and the number of people in each group were appropriate indicators for that factor.

The resource factors were split into health of the bioluminescent bay and the combined health of the coral reefs, sea grass beds, and mangroves. These two factors

were expressed as areas needing special attention by ecological experts, DNER employees, and scientists who have completed research in La Parguera. The indicators chosen for the bioluminescent bay are species and number of dinoflagellates. The use of dinoflagellates as an indicator was determined after speaking with employees from the Biobay Conservation Group. Since specific species of dinoflagellates are responsible for the luminescence in the bay, data for both species and number of these organisms should be collected to determine the health of the biobay. For more detailed information on the collection of dinoflagellates populations, see Appendix F.

The factor we chose for the health of the rest of the reserve was coral reef health. Since seagrass beds, mangroves, and coral reefs are all interdependent, the health of one can signify the health of the others, as well as the overall health of the reserve. We determined that the use of monitoring stations to measure coral reef coverage relatively frequently at particular sites combined with the use of aerial photography to measure overall coverage in La Parguera less frequently would best meet all the criteria of an indicator as described in our methodology.

Professor Jack Morelock suggested the use of monitoring stations in order to obtain an accurate depiction of the live coral coverage. This method was used for his report detailing the current state of health of coral reefs. This method has a very low percent error. The use of monitoring stations would provide the reserve manager an accurate indication of the health of those sites. For detailed information regarding the use of monitoring station and how to perform collected of this data, please refer to Appendix F titled Methods for Live Coral Coverage Monitoring.

The use of aerial photography was recommended by Professor Roy Armstrong to monitor long-term change in coral reefs over the whole area of La Parguera. He supplied us with his publication titled "Changes in a Puerto Rican Coral Reef From 1936-1979 Using Aerial Photoanalysis", which documents the destruction of coral reefs and the use of aerial photography in recording the health of coral reefs. This publication can be found in Appendix M. This indicator was chosen in addition to monitoring stations because it gives an overall view of the coral reef health rather than the health of specific locations. While this method does have greater limitations, such as an increase in percent error and more time lapse between observations, it can show areas of deterioration that may be in need of a monitoring station. Since aerial photography data is collected every 5-8 years by the Puerto Rican Road Authority, the use of this information as an indicator will require little extra effort or funds on the part of DNER. Alexis L. Dragoni Cebollero, the Director of Scientific Inventory for the DNER, can analyze the aerial photographs. More information on methods for using aerial photography as an indicator, see Appendix F.

4.4 Inventory of Existing Resource and Social Conditions

To inventory our social indicators we used information gathered during our trip to La Parguera. Due to lack of time, we were unable to obtain exact information for our social indicators regarding number of other parties encountered and number of others in each group. To compensate, our inventory for the social indicator of visitor solitude was based on the information gathered through our interviews with the tour boat operators. During the interviews we were able to determine the relative extent to which visitors used areas throughout the reserve. We placed sections of the reserve into high, medium, or

low use categories. This information is displayed in Figure 4.1. The bioluminescent bay, Mata La Gata, Caracoles Keys, the tourist center, and the travel lanes are all of high social use. The mangrove channels are of moderate use and the rest of the reserve was of low visitor use.

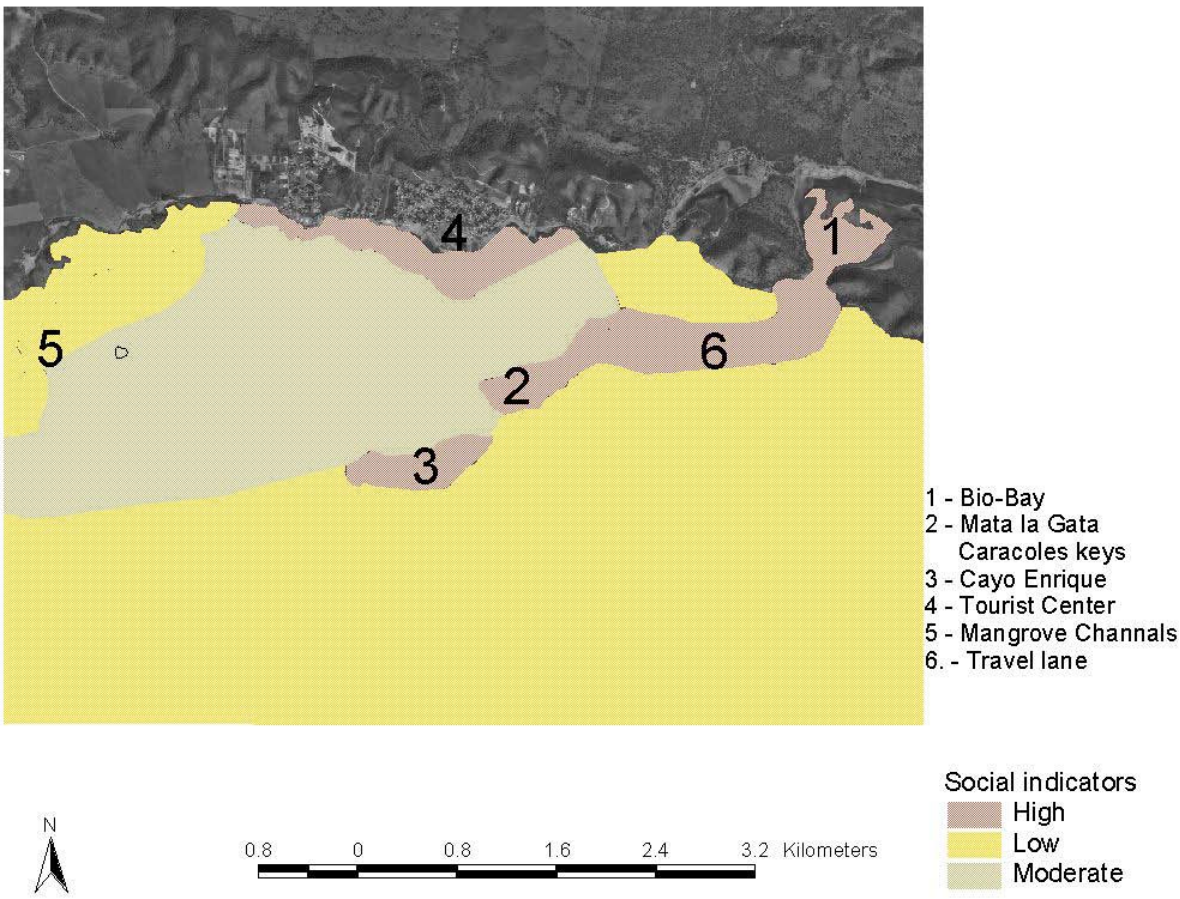

Figure 4. 1 Map of Social Indicators

To inventory resource conditions, we used previously gathered. To inventory conditions for dinoflagellate counts we used information provided to us by Professor Juan Gonzalez. The most recent available data on dinoflagellate species and numbers are from 1996 and are shown in Table 4.5.

Table 4. 5 Dinoflagellate Count for Bahía Fosforescente, February 1996

Dinoflagellates in 1 liter of surface water. Bahia Fosforescente, Puerto Rico, **February 1996**	
Pyrodinium bahamense	2475
Pyrodinium divergens	884
Ceratium Furca	10325

We decided to inventory these three species as they provide insight into the health of the bay and level of luminescence. According to Professor Gonzalez, an increasing presence of *Ceratium Furca* is indicative of the deteriorating health of the ecosystem. This is based on the fact that this species of dinoflagellates flourishes in adverse water conditions. Both *Pyrodinium bahamense* and *divergens* are luminescent species of dinoflagellates. An increase in these organisms results in an increase in luminescence. In addition, a decrease or increase in either of these species may reveal a change in water quality.

To inventory live coral data, we used information provided be Professor Morelock. This data is displayed in Figure 4.2. This inventory is of percentages of live coral throughout the waters around La Parguera. This data serves as a basis for which we can compare future inventories of live coral coverage data obtained from monitoring stations. We can use this data to determine the health of the coral. According to Professor Morelock, 20% live coral is considered healthy. Given this information, it is important to point out that the coral reefs with less than 10% living coral cover, designated in green, are located closest to La Parguera. The coral reefs around Mata la Gata and the Caracoles Keys, designated in blue, have 10-30% live coral coverage.

Areas with more than 30% live coral coverage, shown in pink, are located furthest from La Parguera.

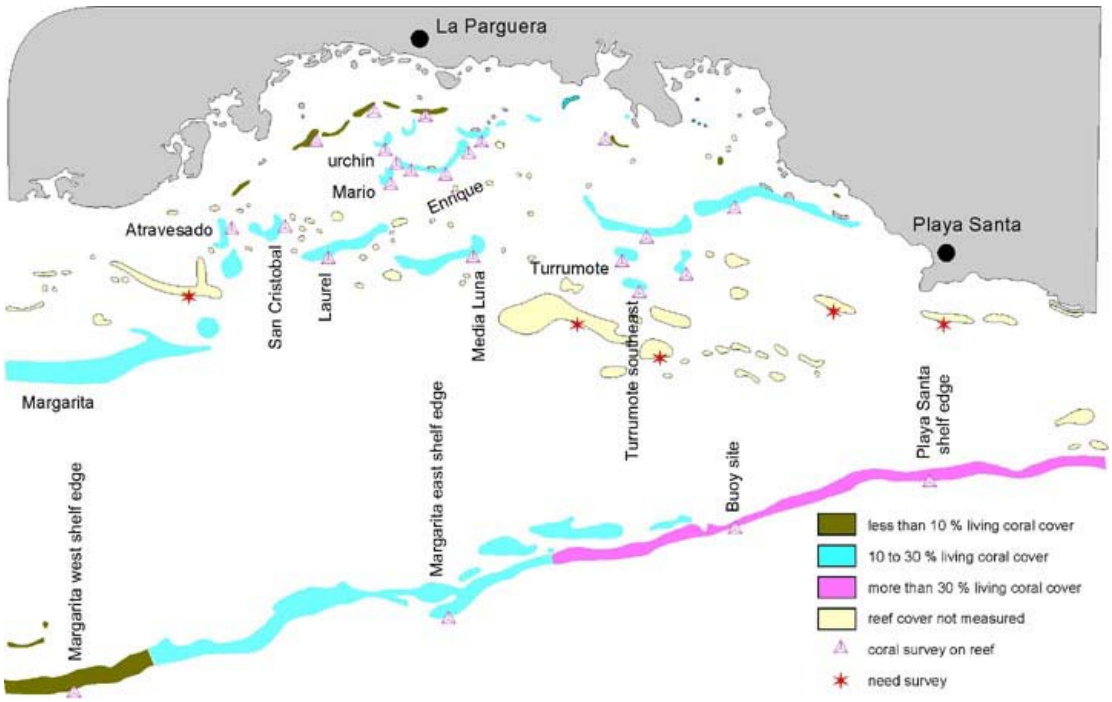

Figure 4. 2 Live Coral Coverage Percentages in La Parguera for 2001.
Adapted from "Status of coral reefs, Southwest Puerto Rico" by Jack Morelock

4.5 Standards for Resource and Social Indicators for Each Opportunity Class

After inventorying the current resource and social conditions, we defined standards for each indicator for each of the opportunity classes. These standards are listed in Table 4.6. The LAC guidelines stress that managers should not worry too much about whether or not the identified standards are "right". The process is intrinsically judgmental and should be continuously reviewed and evaluated.

Table 4. 6 Standards for Indicators in Each Opportunity Class

Opportunity Class	Factor	Indicator	Standard
Low Impact	Solitude during visit	Number of other groups encountered during activity	2
Moderate Impact			4
High Impact			> 4
Low Impact	Solitude during visit	Number of people in own group	6
Moderate Impact			50
High Impact			150
Low Impact	Bioluminescent Bay	Species and number of dinoflagellates	Pyrodinium Bahemense = 7,600/L
Moderate Impact			Increasing number of Pyrodinium Bahemense
High Impact			Pyrodinium Bahemense = 2475/L
Low Impact	Coral reef, sea grass bed, and mangrove conditions	Live coral reef coverage at monitoring stations	Live coral coverage = 20%
Moderate Impact			Increasing in areas where live coral coverage is below 20%
High Impact			Non-degradation
Low Impact	Coral reef, sea grass bed, and mangrove conditions	Aerial photography of overall coral reef coverage	Increasing coral coverage
Moderate Impact			Increasing in areas where coral coverage is low
High Impact			Non-degradation

The standards for the number of other groups encountered during activity were based on information received from our interviews with the tour operators. We were only able to obtain information for number of other groups encountered for trips to the bio bay. The boat operators informed us that when entering the biobay at night, they usually encounter five other groups of people. Based on this number, we set the standard for the low impact zone to two groups, the standard for the moderate impact zone to four group, and the standard for the high impact zone to five

To determine standards for the number of other people in own group, we obtained from the Public Service Commission a list of boats permitted for use in La Parguera. This list, which can be found in Appendix H, also included the number of people each of these boats was allowed to carry. Our standard of six for the low impact zone would allow only the use of small boats in these areas. The 30 passenger standard for the moderate impact zone was determined as an appropriate number to meet the social conditions described for the moderate impact zone. When determining the standard for the high impact zone we took into consideration that one operator had a boat permitted to carry 149 passengers. With the understanding that the businesses depend a great deal on the income generated from boat trips, we set this standard at 150.

Standards for species and type of dinoflagellates count were identified only for the *Pyrodinium Bahamense*. According to Professor Gonzalez, this species of dinoflagellates was the dominant species in Bahía Fosforescente in 1959 and gives off the most luminescence. The standard for the high impact class was established as non-degradation. In a high impact area, it is desired that the number of this species not decrease below the 1996 level of 2475/L. In a moderate impact area the desired number

should be improving, above the current count of 2475/L. In a low impact area the desired standard is 7600 *Pyrodinium Bahamense* per liter, the number located in the bay in 1959.

Standards for live coral reef coverage in high impact zones are based on the concept of non-degradation. In these zones, is it desired that the current conditions not get any worse. The current conditions are based on the map supplied by Professor Morelock representing the percent of total coral cover for La Parguera reefs as of 2001 as recorded by monitoring stations. For moderate impact, the percentage of live coral should be increasing in areas with live coral coverage percentages below 20%. For low impact zones, the percentage of live coral coverage should be above 20%. According to Professor Morelock, a percentage at or above 20% is considered healthy.

Standards for aerial photography are similar to those of live coral reef coverage. For high impact zones we used the concept of non-degradation. For moderate zones the standard is increasing coral coverage in areas of low coverage and for low impact zones the standard is that coral reef coverage be increasing.

4.6 Alternative Opportunity Class Allocations

We identified two alternative opportunity class allocations for La Parguera: a recreationally oriented classification and a more ecologically oriented classification. The recreationally-oriented classification would require management and monitoring to prevent further degradation of the reserve, but does not require establishing visitation limits. The long-term goal of the more ecologically-oriented classification would be improved conditions of the biobay, which would require intensive management, more resources, and would require more cooperation from the local community and boat operators.

The more recreationally-oriented alternative, displayed in Figure 4.3, focuses on stabilizing the current situation and preventing condition in these areas from getting any worse. To sustain conditions in the bioluminescent bay, Mata la Gata, Carocoles Keys, and through the travel lanes from the businesses to the bay, we placed them in the high impact zone. These areas were considered a high impact zone because the resources in these areas are subject to high visitor impact and are of high visitor use. Recreational activities are still allowed in these areas but management actions are required to keep within the standard of non-degradation. The rest of the areas within the reserve were designated as low impact areas. These areas have experienced few impacts from humans and within these areas there is little chance of encountering other parties.

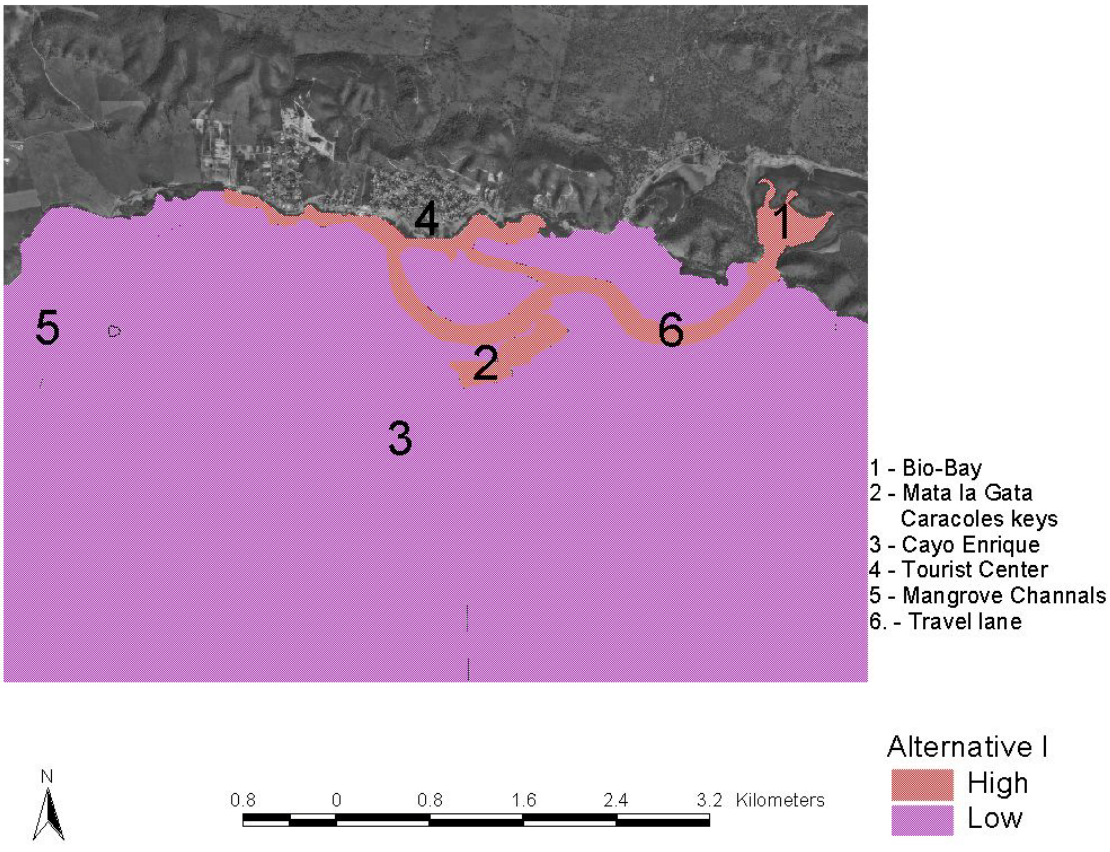

Figure 4. 3 Alternative I (Recreationally-Oriented)

In the more ecologically-oriented alternative, displayed in Figure 4.4, the bioluminescent bay, Mata la Gata, and Carocoles Keys were moved from a high impact zone to a moderate impact zone. In the moderate impact zone, human impacts will be less evident and fewer visitors will be allowed. To meet the conditions prescribed for moderate impact zones, aggressive management actions need to be taken in these areas. By moving the bioluminescent bay to a moderate zone, the 149 passenger boat will be restricted from the bay. This is appropriate for the more ecologically-oriented alternative as it aims to preserve the conditions in the bay. The travel lanes will remain as a high impact zone. By establishing these lanes as a high impact zone, it will restrict destruction to seagrass beds to the lanes. The rest of the area will be kept in the low impact zone. Management for this zone is focused on sustaining use of the area.

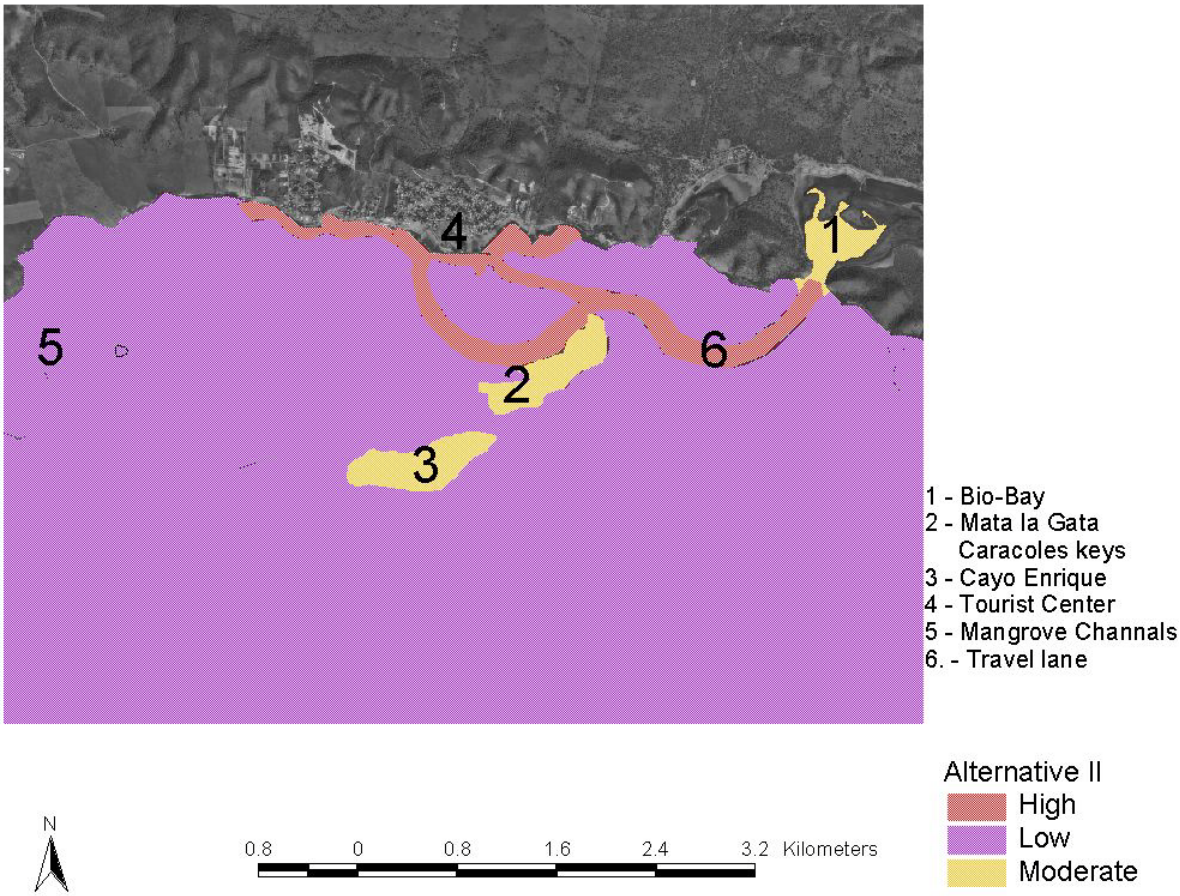

Figure 4. 4Alternative II (Ecologically-Oriented)

4.7 Management Actions for Each Alternative

Step seven involves identifying management actions for the alternatives described in step six. For guidelines, we used the qualitative descriptions of management practices for particular opportunity classes that we developed in step two, shown in Table X. Using suggestions offered by DNER employees and scientists during interviews, we have developed the following management actions that DNER could implement to achieve each alternative.

Alternative I (Recreation-Oriented): Possible Management Actions by DNER

- *Work with the Public Service Commission (PSC) when granting permits*. The DNER could work in conjunction with the Public Service Commission during the permitting process for boats in La Parguera. In addition to the economic feasibility study performed by the PSC, an environmental study should be performed before issuing new permits. These two agencies could also consider a moratorium on new permits and-or a restriction of permit renewals for big boats if the non-degradation standard is being violated.

- *Post signs throughout the reserve.* These signs should inform boaters of the speed limits and areas that they must stay within (under 5mph in the bioluminescent bay and within 150 feet from shore), signs designating areas of ecological fragility (the bioluminescent bay, damaged coral reefs, and important animal nurseries), and signs around Mata La Gata and the Caracoles Keys reminding visitors to tie only to buoys.

- *Mark travel lanes* along frequently used boat routes in order to keep destruction confined to particular areas.

- *Provide educational signs to tour operators* to be posted outside their businesses. These signs should explain to visitors the ecological importance of the biobay and other resources throughout the reserve and should inform visitors of responsible use and travel within the reserve.

- *Work with boat operators* to provide customers renting boats with maps of places to go, maps of travel lanes, a list of laws and regulations regarding tying to buoys, anchoring on reefs or seagrass beds, speed limits, and ecological importance of the reserve.

- *Discourage biobay trips on nights with a full moon.* DNER should consult with Biobay Conservation Group from Vieques regarding limits of when to tour the biobay in relation to times of a full moon.

- *Prohibit boats from using the boat's engines as a means of stimulating the bioluminescent effect in the bay.*

- *Encourage communication between local and federal law enforcement agencies.*

Alternative II (Ecologically-Oriented): Possible Management Actions by DNER

Recommendations for Alternative II would include all of the following in addition to the recommendations made for Alternative I.

- *Encourage boat operators to abide by standards* regarding the number and size of boats allowed to enter the biobay.

- *Invite tour guides in La Parguera to the Biobay Conservation Group in Vieques* so they can observe how tours of the luminescent Puerto Mosquito Bay are conducted.

- *Offer incentives for boat owners and operators who are willing to attend educational classes* on the ecological importance of the bioluminescent bay and ecosystems through La Parguera and how this affects their business. Information gathered from these informational sessions can then be conveyed to their customers.

- *Work with Conservation Trust in development of floating dock and the phasing in of electric boats.* The Conversation Trust is currently in the process of gaining support from the public and from the boat operators for the construction of a floating dock. The operators will still be able to use their boats to travel to the dock where they will then board an electric boat that will take them into the bioluminescent bay.

- *Make frequent patrols of the areas of high concern.*

- *Pursue funding for the increase in rangers designated to patrol La Parguera.* In addition to pursuing the avenue of acquiring additional funding from federal and commonwealth governments, better cooperation is needed between local and federal authorities.

While it would be greatly beneficial for DNER to implement all of these recommendations, it is understood that changes such as these take time and money. They should also get public input on these alternatives. DNER must evaluate both alternatives and select the most appropriate one.

5.0 Conclusions and Recommendations

Two separate management alternatives have been developed for La Parguera natural reserve. The first alternative is recreationally-oriented, while the other is more ecologically-oriented. The recreationally-oriented classification would require management actions and monitoring to prevent further degradation of the reserve, but does not require establishing visitation limits. This opportunity class allocation follows the strategy of non-degradation, stabilizing current conditions and not allowing current conditions to worsen. The long-term goal of the more ecologically-oriented classification would be to improve conditions of the biobay, which would require intensive management, more resources, and would require more cooperation from the local community. This alternative works toward the improvement of conditions to former levels by using a more stringent classification of regions of La Parguera.

The Department of Natural and Environmental Resources (DNER) is the agency that decides which of the two alternatives should be implemented. Before committing to either alternative, the DNER should consult the public for input. Public input is important as the livelihood of numerous businesses and people in La Parguera depend on the tourist industry. Since there are many social implications in La Parguera, the DNER should conduct a thorough evaluation of impacts of the implementation of LAC process to La Parguera.

One method of implementing our LAC process in La Parguera begins with the immediate adoption of Alternative I. Then, after gaining public support, the DNER would work towards implementing the second, more stringent allocation. It will be beneficial to eventually implement the second alternative opportunity class allocation, because this

alternative aims to improve the conditions within the reserve, rather than just sustaining conditions. Recommendations on how to select, monitor, and evaluate an alternative are as follows:

- *When analyzing multiple management decisions for selection*, managers should take into consideration what use groups are affected, what values are promoted and which are diminished, how each alternative fits into supply and demand considerations, and the feasibility of managing the area as prescribed (Stankey, et. al., 1985).

- *Frequency of monitoring* should be considered before monitoring actually takes place. It is understood, however, that budgetary constraints may be an issue. Priorities for monitoring should consider situations where: 1. Conditions were very close to standards at the time of last assessment, 2. Rates of resource or social change are judged to be the highest, 3. The quality of the data base is poorest, 4. the understanding of management action effect is poorest, 5. There have been unanticipated changes in factors such as access, adjacent lands uses, etc. (Stankey, et.

  al., 1985).

- *Evaluation of a plan should be performed often to ensure that the chosen management plan is promoting sustainable use.*

For further continuation of the process, the DNER is advised to refer to the Limits of Acceptable Change program developed by the United States Department of Agriculture. Another key recommendation that we are making is that the DNER complete another iteration of the LAC process for La Parguera. In six weeks we were able to initiate the LAC process and make some recommendations for its continuation. At this time, however that the best recommendation we can make to DNER is that they continue through the LAC process, possibly using ours as groundwork. Each step should be done to the extent set forth by the authors of the LAC packet. Recommendations for the reiteration of this process are as follows:

- *Re-evaluate public and managerial areas of concern.* While we were able to determine specific areas of concern and found recurring themes, we realize that it would be more beneficial to a successful LAC program if more people were interviewed during both the high and the low season. Focus should be on residents, business owners/operators, and visitors.

- *Collect a dinoflagellate sample in the bioluminescent bay on the same day of every month.* The standard we set for this indicator is just for February measurements. We recommend that samples be taken monthly so that in the future, DNER can compare these reading with readings taken throughout the year. A table of monthly readings from 1988 and 1996 can be found in Appendix J.

- *For the future selection of indicators for the bioluminescent bay, select the indicators used by the Biobay Conservation Group in Vieques.* The Biobay Conservation Group currently collects data on water temperature, conductivity, salinity, pH level, total dissolved solids, reduction-oxidation potential, and cell identification. These measurements will keep track of conditions within the bay and possibly identify problems within the bay. They can also be used to compare Bahía Fosforescente with Puerto Mosquito Bay in Vieques. Vieques is a good object of comparison as it is the most pristine bioluminescent bay in Puerto Rico.

The DNER is advised to also refer to the Limits of Acceptable Change program, found in Appendix G, developed by the United States Department of Agriculture for a more in-depth description of each stop.

In conclusion, there is much to be gained by the completion of the LAC system in La Parguera. The bioluminescent bays of Puerto Rico are of special value to the residents of the island, and the outstanding resources of La Parguera serve as a highlight of Puerto Rico's natural resources. As a result of the implementation of our iteration of LAC the social setting of La Parguera will change slightly but for the better; boats will be less crowded and there will be more satisfaction with tours. The ecological state of the reserve and of the bioluminescent bay may improve over time. Businesses may benefit from the improved conditions of the resources on which they are based.

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Appendix A – Department of Natural and Environmental Resources

The Department of Natural and Environmental Resources is a Puerto Rican Government Department which is responsible for the implementation of the Environmental Quality laws of the Commonwealth of Puerto Rico. The department was created in the Constitution of Puerto Rico under Section Nineteen of Article Six (Laws of Puerto Rico Annotated, The Secretary of State of Puerto Rico and Lexis-Nexis).

The DNER mission statement is to ensure that the development of Puerto Rico incorporates conservation and efficient usage of natural resources to guarantee a balance between sustainable economic development and the quality of life. The DNER sponsors educational programs that call attention to the public's responsibility to protect Puerto Rico's natural resources but also their right to use them sensibly.

The DNER has several environmental responsibilities on the island. These responsibilities include the development and recommendation of public policy that encourage environmental quality through conservation, social, and economic environmental quality. This includes the development of waterway conservation and development, permitting, environmental impact reports, and the management of estuaries. The DNER is also responsible for studying the deterioration of the environment through pollution and erosion. In addition, the department is in charge of designing methods that mitigate these detrimental environmental effects (DNER, Laws of Puerto Rico Annotated, The Secretary of State of Puerto Rico and Lexis-Nexis).

Appendix B - Interviews

Professor Roy Armstrong
University of Puerto Rico
Marine Biologist

Interview at La Parguera
March 21, 2002

On March 21, 2002 we met with Professor Roy Armstrong. Professor Armstrong has studied remote censoring with the use of past and present aerial photography. The area of study he is most interested in is coral reef and sea grass. He advised us that one could notice a drastic change in the make up of the sea grass beds and mangroves though the use of aerial photography. He pointed out that large tourist boats have caused concern because of the damage they do to seagrass beds. In addition, rental and private boats are causing damage to the coral reefs, in particularly to La Gata reef. The over-use of the Caracoles Keys and Mata La Gata are also evident from aerial photography because of the extensive sea grass damage around the islands.

To obtain more information, Professor Armstrong suggested we contact additional professors. He recommended we speak with professor Jorge Corredor of the University of Puerto Rico, who is specializes in water quality and nutrient information and Gracilla Ramirex a professor from the Inter American University, who is specializes in water and sea grass quality. He also suggested we try and contact anyone from Sea Grant to obtain tourist and environmental information. The contact name at sea grant was Anna Navario.

Professor Armstrong provided us with a copy of his a paper he published on the health of sea grass beds in La Parguera.

Professor Jorge Corredor
University of Puerto Rico
Marin Biologist

Phone interview
April 11, 2002

We first contacted Professor Jorge Corredor by phone on April 3, 2002. However our phone interview was brief because he was busy. He promised to send copies of his published works. We followed up our interview on April 11. We asked him for his professional opinion on to which indicators to us. He suggested that we use live coral reef

Ernesto Dias
DNER Costal Zone Management
Management

DNER
April 12, 2002

Ernesto Dias is a manager with the DNER Coastal Zone Management division. Ernesto is working with the UPR's Sea Grant program. He offered to try to obtain tourist information relating to La Parguera. Ernesto gave us several new contacts that he believed might be helpful. He advised us that Professor Jack Morelock of the UPR has several papers published on live coral cover that could be found on the internet. We were also given several reference material to look through to see if was any information we may find useful.

Some of the probable causes for the deterioration according to Ernesto included poor land zoning and management. The increase of run off from human development in La Parguera and encroachment on the reserve may also be a possible contributor to the deterioration of the reserve.

Ernesto supported the use of aerial photography to identify vegetation coverage and live coral reefs coverage as an over-all indicator to the health of the reserve. A suggestion for further indicators was to count the abundance of large fish around the coral reefs and to monitor bottom dwellers. He also suggested DNER establish closed fishing areas for monitoring.

Professor Garcia Ramirez
Inter American University
CECIA Director
Marin Biologist

Phone interview

Professor Garcia has been conducting extensive studies in La Parguera area for over five years. As director of the Center for Environmental Conservation Interpretation, she has helped with four Masters Degrees and one Doctorial thesis that pertain to La Parguera. Currently she is working on two projects, how policies without science can be harmful to the environment and how science can be used for policies.

The studies have collected indictor data for over five years. These thirty indicators range from biological to chemical indicators. They included water quality data. Professor Ramirez´s work was performed in conjunction with the University of North Carolina, Philadelphia University and Drekil University.

Professor Ramirez agreed to supply us with a copy of the water quality data and thesis papers. She has also invited us to attend a presentation on studies conducted in La Parguera April 19, 2002.

Professor Jack Morelock
University of Puerto Rico
Marin Biologist

Phone Interview
April 17, 2002

Professor Jack Morelock has conducted several studies on the coral reef system in La Parguera. We contacted him with a list of our tentative indicators for the health of the reserve. He agreed with our assumption for the biological interdependence of the mangrove, sea grass, and coral reefs. He suggested that we use the live coral reef percentage as an indicator of the health of the reserve, with the limit of non-degradation.

In order for us to establish this limit he suggested we obtain his published works off the Internet. The web sites where he's work can be found are the Caribbean Journal of Science and his personal web site rmgcfis.upr.clu.edu/morelock.

Professor Juan Gonzalez
University of Puerto Rico
Marin Biologist

La Parguera
March 21, 2002

On March 21, 2002 we met with Professor Juan Gonzalez. Professor Gonzalez has studied the bioluminescent bay for thirty years. He shared with us some of the concerns he has with relation to the bioluminescent bay. One concern was the proliferations of light pollution around the bioluminescent bay caused by the increase in development and use of outdoors lighting near the bioluminescent bay. It also worried him that the relative size of tour boats was drastically increasing along with the number of trips to the bioluminescent bay. Professor Gonzalez has reported that when there is a full moon, the bioluminescent effect from the bay is negligible. Eutrophication, a natural occurring event, has been accelerated by the use of tour boat motors as a means to stimulate bioluminescent organisms. Education to the local population and tourist over the importance and fragile ecosystem are lacking.

The outdoor light pollution has been caused by the popularity of a shopping area with a lighted parking area, the antiquated public lighting system, and the DEA surveillance base. The parking lots and public lighting do not have shades to prevent light from escaping into the ski. This light is then reflected into the bioluminescent bay area diminishing the experience. The extensive use of security floodlights at the DEA base contributes to the light pollution.

Tour boat size has increased, the boats are damaging the see grass beds. One may observe the lawnmower action easily. When big boats travel over a bed of grass a wake of cuttings are left behind. The use of tourist boat propellers are used as a means of stimulating the dinoflagellates so that they produce lights has accelerated the eutrophication process. The resuspension of nurturance stimulates the opportunistic organisms to flourish and depletes oxygen levels. The motors also mix the oxygen poor

water on the bottom with the oxygen rich water on top. An overall decrease in oxygen occurs in the bioluminescent bay.

Tour boats are constantly running trips to the bioluminescent bay, even on nights with a full moon. The tourists are not educated about the bioluminescent bay or on the importance and fragility of the ecosystems in La Parguera. This lack of education is even present in the local population. They are unaware of how fragile the ecosystem is. They do however understand the importance of the bioluminescent bay to their economy.

Mr. Michael Nemeth
DNER
Field Research

Phone Interview

Michael Nemeth is currently working with first round of rough information collected at three environmental monitoring stations. This monitoring stations monitor biological and physical indicators, from water oxygen levels to live coral coverage. Mr. Nemeth is in the process of tabulating the first year's data. He has promised to provide us a document with his findings and location of monitoring stations.

Miguel Canals
DNER Guanica reserve manager
Biologist

DNER
April 5, 2002

Miguel Canals is the manager of the Guanica Reserve. The Guanica reserve is smaller than La Parguera and is located adjacent to it. Even though the reserve is smaller than Parguera, it has more workers. Miguel Canals explains he is able to achieve this by aggressively applying for federal and Puerto Rican grants.

Law enforcement is greater in the Guanica reserve because of a cooperation of all the law enforcement departments. Miguel not only relies on DNER vigilantes to enforce the law but also incorporates local and federal agencies.

Ruben Rivera
Public Service Commission
Auditor IV

Public Service Commission:
March 20, 2002

We met with Mr. Ruben Rivera to obtain an understanding of what was needed to obtain a permit to operate a boat in La Parguera. Ruben informed us that in order to obtain a permit, an applicant needs to have a captain´s license, proof of insurance, and proof of inspection. They are also required to post a notice in two local news papers. After the notices have been posted, people have fifteen days to object to the permit. If there is a complaint, the Public Service Commission will investigate the complaint. After the fifteen days have past, the Public Service Commission conducts an economic study to see how the permit will affect the existing tour bout operators. After the permit is issued, a yearly inspection is required. At the end of five years the permit expires and a new permit is needed.

The service commission has the power to stipulate conditions for the permit. This power can be used in the future to enforce DNER suggested regulations. However, in the past the service commission has only revoked one permit for not observing the stipulation.

During the current application process, the environment is never considered. Not until recently has the Environment been considered in certain areas. There is an experimental cooperation between the Service Commission and DNER. With in this partnership DNER would have a voice to take into account the environment in the permit process.

“Seven”
DNER
Reserve maintenance worker

La Parguera
March 21, 2002

On March 21, 2002 we meet with one of La Parguera´s maintenance workers. He gave us a tour of the reserve aboard a DNER ranger boat. We were able to see first hand what the effects of tourism and development had done to the area. We were taken to the mangrove forest and toured the canals. Next we where taken to the island of Mata La Gata. The island is designated as a picnic area where visitors can have cookouts and stop their boats to swim, snorkel, and relax. They can also use the public restrooms. Mata la Gata was the only place in the reserve where the laws for boating were displayed. Later we were taken to the island where bathing was allowed. We noticed very few litter because the reserve workers try to keep the area clean. Seven also noted that the public is become more aware of the effects of littering on the reserve. We where also taken to the Bioluminescent bay where we observed a manatee enjoying the afternoon sun.

The following day we were taken to the Enrique coral reefs. On our way to the reefs we encountered a sea turtle. Our guide showed us the wonderful coral formations and the places where boats had damaged the coral. We also noticed that there were few floating balloons to tie on to. Seven suggested that there were more balloons near all the reefs.

Seven also suggested that there be an increase in patrols to enforce the speed limit and no littering laws. He also noted that not all individuals where observing the law that forbids boaters from tying onto mangroves. During Holy week there is an increase of rangers but they are not there enforcing all the laws. The laws they are mostly enforcing are the safety laws. He would like to see more patrols enforcing the rest of the laws. Seven also noted that there where homes on the reserve shore line that where not in complete compliance with all environmental laws.

Captain Sharon Grasso
Executive Director
Biobay Conservation Group

Vieques
April 4, 2002

Sharon Grasso agreed to meet with us and allowed us to observe her outreach program and eco-tour of Mosquito bay. Sharon Grasso has facilitated several studies conducted on bioluminescent bays, from JohnsHopkins University to German Television.

Sharon Grasso explained that there are two leading theories for the cause of the bioluminescent phenomenon. The dinoflagellates may actually be collected into the bay, or the dinoflagellates may be flourishing within the bioluminescent bay because of the ideal environment. She also explained that there are several causes for temporary loss of dinoflagellates, such as seasonal rains, increase in natural predators, and tides.

The United States Navy has awarded Sharon with a grant to conduct an environmental study on the health of the reserve and to conduct an outreach program. Sharon believes that it is important to get the community involved and educated about the importance of the reserve. Sharon has created a non-profit organization call the Bio-Bay Conservation Group.

The out reach program takes school children from Vieques and shows them the how the bioluminescent bay works and why it is important to conserve the bay. Sharon has offered to reduce the cost of the eco-tour for local residents so that everyone can enjoy and understand the bay. The eco-tour offered to tourist is both exciting and educational. After the tour the tourist walk away with a better understanding of the fragile ecosystem.

The United Nations has declared 2002 to be Eco-tourism year. Sharon has helped by developing sustainable tourism for the bio-bay. Sharon is currently starting a captains program to educate would be potential captains with the safety of operating a boat and

the importance of the environment. Sharon has offered to host the tour boat operators from La Parguera to educate them in the importance of sustainable tourism, with help from DNER.

There is still a need for further studies and cooperation between bio-bay users and DNER. The land use around the reserve is a concern because the Puerto Rican Park Service plans on constructing fifty cabañas around the bay, as well as local development encroaching on the reserve.

The current management of Vieques differs from La Parguera because there is a limit on the total number individuals allowed to visit the reserve daily.

Appendix C – Questionnaires

La Parguera Natural Reserve Oral Questionnaire
Owners and Operators

Name of company: _____

Date: _____

Time: _____

Contact name: _____

Phone: _____

Fax: _____

E-mail: _____

Mailing address: _____

Permit Number: _____

How long has your business been operating in La Parguera?

Trips/rentals per day?

Occupants per trip/rental?

Days of operation per week?

Do you educate your customers about use of the equipment or environmental issues in the reserve?

- Why or why not?
- If so how?

Are you aware of any regulations that may have to do with the way you run your business?

How important is the environmental health of La Parguera to your business?

La Parguera Reserva Natural Cuestionario Bucal
Visitantes

Día:

Tiempo:

Localización:

Como se siente con la cantidad de personas que participaron en la actividad?

Porgue vino a La Parguera?

Que importante es el ambient a tu visita?

Este es tu primero visita a La Parguera?

- Si no cuantas veces as venido?

Cuales otras actividades as disfrutado?

Cuanto estaba satisfecho con su viaje a la Parguera

1	2	3	4	5
No Satisfecho		Satisfecho		Muy Satisfecho

Que te gustó de to visita?

Que no te gustó de tu visita?

Que cambiaras se pudieras?

De donde es usted?

Appendix D – Contents of CD-ROM

Contents of accompanying CD-ROM

A CD accompanies the report which includes the IQP document, all Arc-View layers used to display information gathered for the LAC process, surveys and excel files used to summarize the surveys. Included with in the CD is a free copy of Are Explorer which may be used to view the Arc-view program file.

Table D- 1 Contents of accompanying CD-ROM

File	Description
\explorer\	Directory containing installation files for the free Arc-explorer program required to view the ArcView layer.
\gis\	Directory of all Arc View files
\survey\english\	English version of surveys
\survey\spanish\	Spanish version of surveys
\report\	MS Word Document of this report
\presentation\	PowerPoint file with final presentation of project

Appendix E – GIS Images of La Parguera

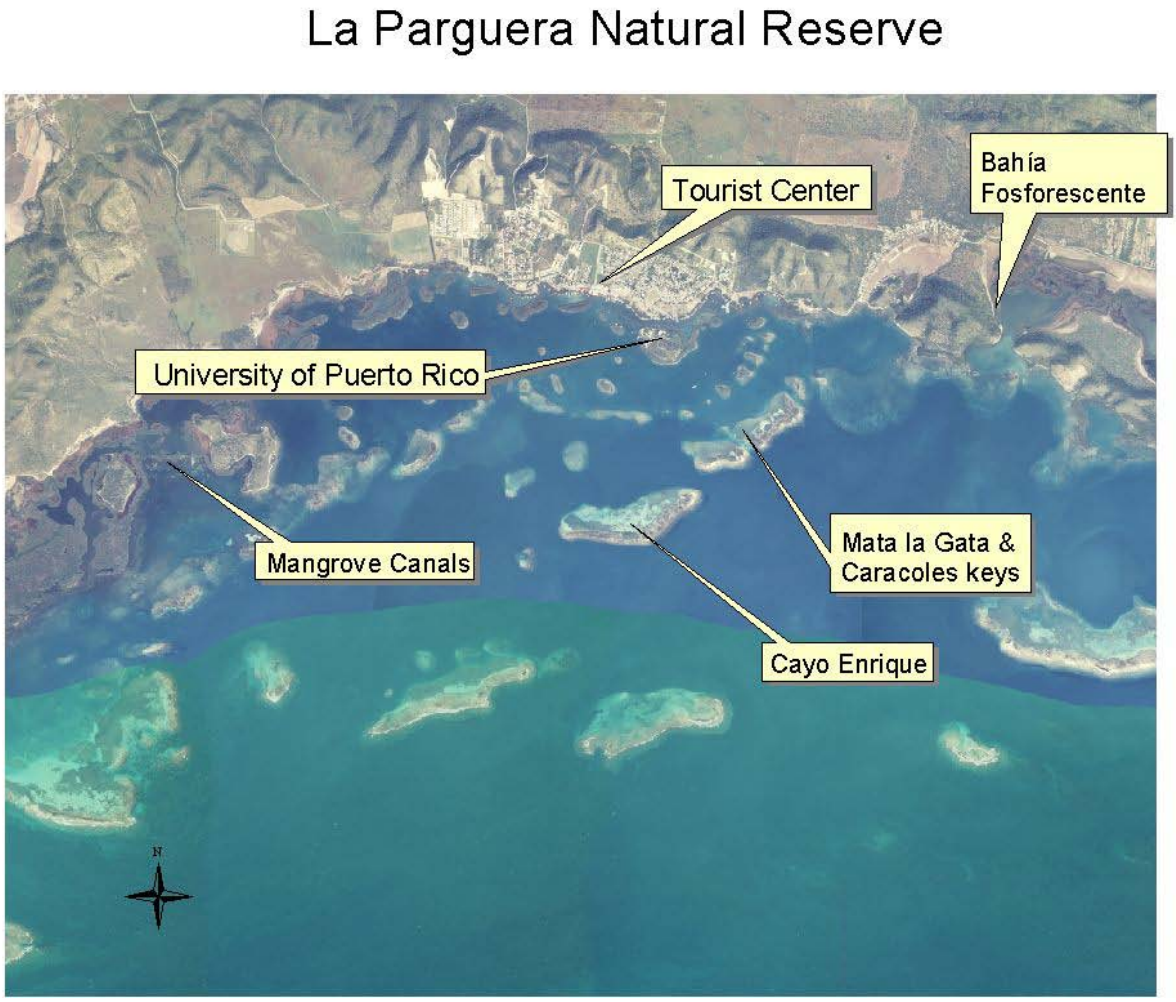


Figure E - 1 Aerial Picture of La Parguera

Figure E - 2 Benthic Habitat 1977

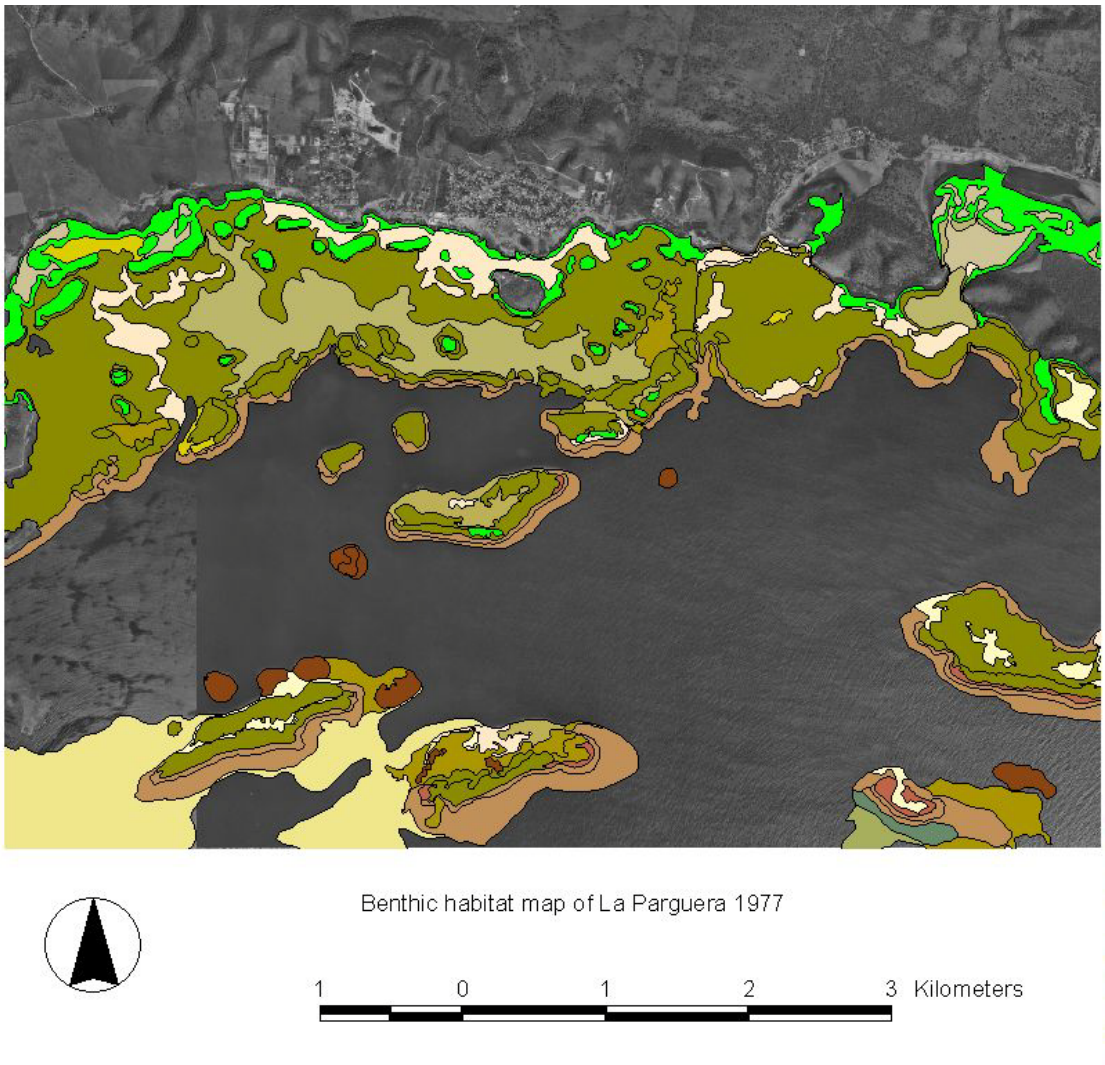
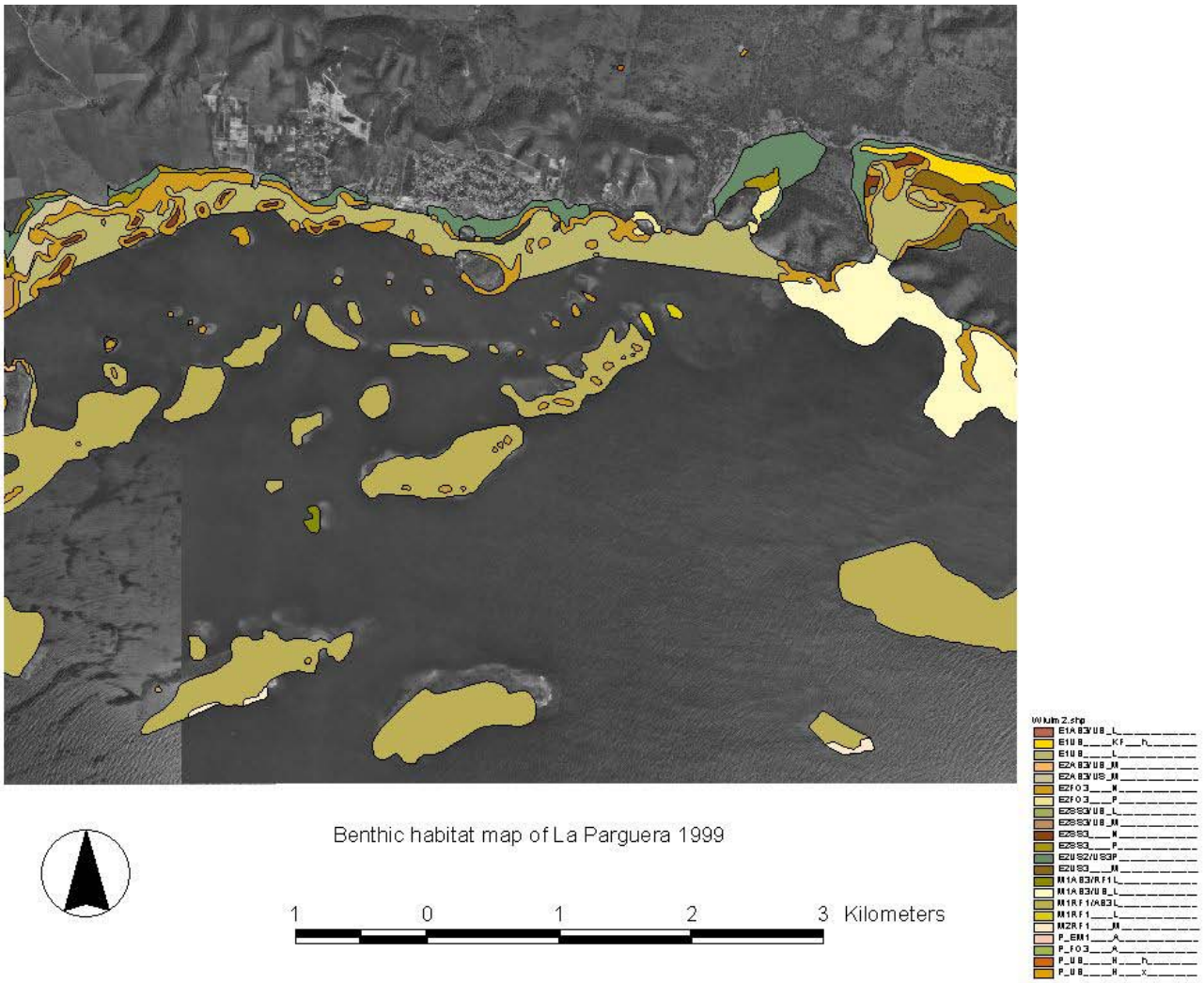


Figure E - 3 Benthic Habitat 1999



Appendix F – Methodology for Inventorying Indicators

Methods for live coral coverage monitoring

Figure F - 1 Aerial Photograph of La Parguera

In order to identify locations of monitoring stations for coral reef areas with in the reserve, photo-quadrants should be used. The aerial photographs will provide a rough estimate of the live coral coverage and areas of management concerns.

Once areas are identified, DNER should establish monitoring stations. A thirty meter border would be established parallel to depth contours along the coral formations. The monitoring station should then be spaced three meters apart and consist of quadrants that are seventy centimeters by one meter. This will give the monitoring station an area .7 meter squared. The long side of the quadrant should be parallel to the contour line.

Monitoring of these quadrants should be done once a year. The monitoring will require two divers. Numbered tag should be

Figure F - 2 Monitoring Station

assigned to each coral so to facilitate the

count and condition of coral, as illustrated in diagram labeled “Monitoring Station”. When observing the monitoring station divers should record the count and condition of the corals. Photograph should also be taken of the quadrant from an elevation of 1.2 meters above the surface of the quadrant. In order to reduce error, a measured stick that is 1.2 meters long should be used to establish elevation.

The coral coverage is then determined by developing the photographs. The photographs should be digitized and coral should then be traced. The area of the digitally traced image area should be calculated. The percent coverage area is computed as a percent coverage of the quadrant. There is an expected human error to this process; however this error is very minimal according to Professor Morelock.

Method for using aerial photography as an indicator

Aerial photography may be used as a means to measure changes in coral reef, mangrove and sea grass coverage. To accomplish this objective DNER will need to obtain vertical panchromatic aerial photographs for past and present years of the entire reserve.

In order to determine the scale of all photographs, an inventory measurement of physical structures should be taken. Actual measurements are next compared to the measurements in the photographs. All the photographs should then be enlarged to a common scale. In Professor Roy Armstrong’s paper “Changes in Puerto Rican Coral Reef From 1936-1979 Using Aerial Photo Analysis,” he used a scale of 1:4000.

Field research should be conducted to inventory damage cased by hurricanes and other natural damages. Coral reef, mangrove, and sea grass coverage is then determined using the characteristics described the following table labeled "Criteria used to define coral reef, mangrove, & sea grass beds using panchromatic photographs. Once key fixtures are identified the area covered should then be obtained. A comparison should then be carried out to determine change.

Feature		Tone
Acropora palmata zone		Medium to dark gray contrasting with light substrate
Millepora-Palythoa zone		Light grays, usually defined by white line of breaking waves
Living and dead Porites and other corals		Light gray mixed with sandy areas
Thalassia-Zoanthus zone		Medium to dark gray
Mangroves		Even medium gray tone, mottled appearance
Thalassia sea-grass beds		Light to medium gray tones
Sandy areas		White to very light gray tones that vary with depth
Small patch reefs		Dark to very dark spotted pattern over light gray lagoon sands
Boulder ramparts		Brilliant white tone with dark edges

Table F - 1 Criteria used to define coral reef, mangrove, & sea grass beds using panchromatic photographs.

National Oceanic & Atmospheric Administration (NOAA) has started to create benthic habitat maps for La Parguera. These maps may provide a more accurate measurement of the mangrove, coral & sea grass coverage in the reserve. A comparison of coverage in present and future benthic maps can easily and accurately be done using GIS software such as Arch-view.

The following is an example on how GIS can be used. The following diagram shows the benthic habitat map of Parguera from 1977. It was obtained from the land use map as supplementary information. As a result it is not as accurate as the map created by NOAA

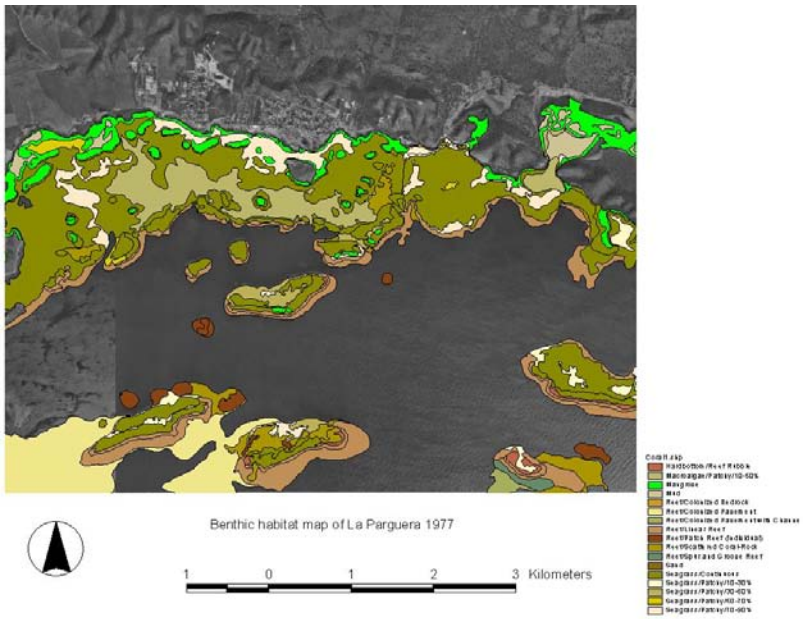


Figure F - 3 Benthic Habitat 1977

The next diagram shows the benthic map created by NOAA in 1999. Using Arch-view GIS area function it is easy to find the area covered by mangroves, coral reefs, and sea grass beds. Once the areas are obtained a comparison between the coverage can be made.

The next table displays the results of this analysis.

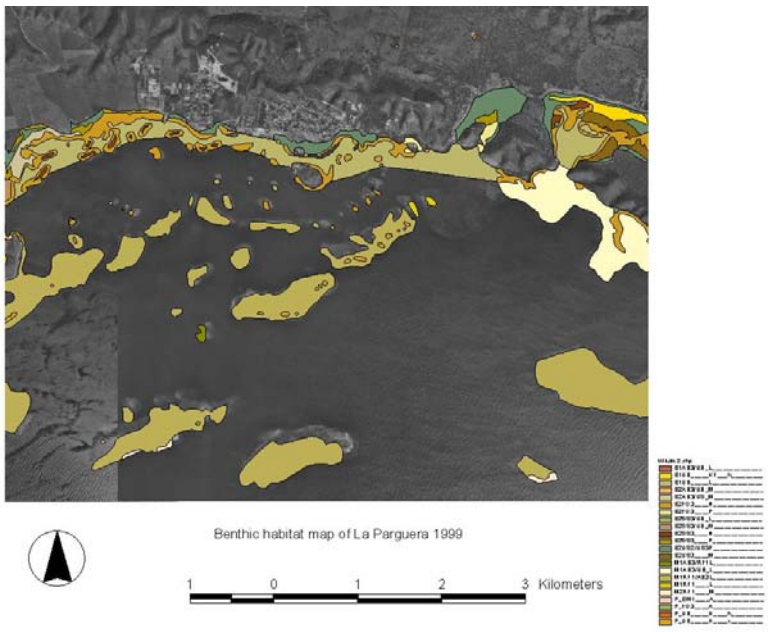


Figure F - 4 Benthic Habitat 1999

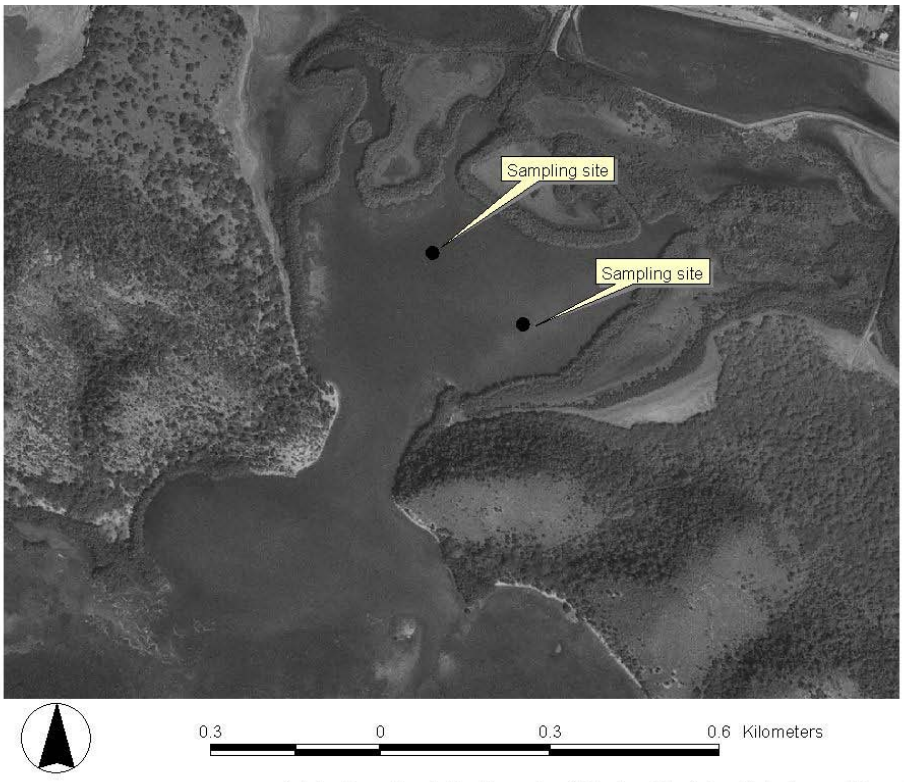
Table F - 2 Results of GIS area comparison

	Mangrove	**Coral reef**	**Sea grass beds**
1999	5752076	4197784	8886464
1977	4197784	11095273	18836325
Percent change	37%	-62%	-53%

Methods for sampling dinoflagellates

Dinoflagellates sampling of Bahía Fosforescente should be done monthly at two stations. Three samples of 6 liters should be taken at the surface and at a two meter depth. The location of the two sampling areas should be based on high bioluminescence. Professor Juan Gonzalez has identified two areas for sampling, as illustrated in the diagram labeled Dinoflagellate Sampling Sites. After appropriate locations are located, the longitude and latitude should be recorded using a global positioning system (GPS). By using GIS to identify sampling areas, DNER will be able to return to the e same area for sampling.

Figure F - 5 Dinoflagellates sampling sites



Adapted from "Population Dynamics of Dinoflagellets in two Bioluminescent Bays:"

Samples should be filtered through a 64um filter and preserved with full strength formalin to a final concentration of 4-5%. The filter size of 64um is appropriate because the dinoflagellates size in the bay is no smaller than 64um.

Appendix G – Limits Of Acceptable Change System for Wilderness Planning

Confidential materials removed from scanned project

Original may be viewed at Gordon Library

IQP/MQP SCANNING PROJECT

Appendix I – “Inventory of Boats in La Bahía Fosforescente” by Juan Gonzalez

Appendix J – “Population Dynamics of Dinoflagellates in Two Bioluminescent Bays”, by Juan Gonzalez

Appendix K – “Final Report to The National Park Service”, by Howard Seliger

Appendix M – ”Changes in a Puerto Rican Coral Reef from 1937-1979 Using Aerial Photo-Analysis”, by Roy Armstrong