Developing Recommendations for a Management Plan in La Playuela Beach, Puerto Rico

Sponsoring Agency:

Department of Natural and Environmental Resources

Submitted by:
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Abstract

This project, sponsored by the Department of Natural and Environmental Resources (DNER), seeks to propose aspects of a new management plan for La Playuela in Cabo Rojo, Puerto Rico. The project team analyzed the current state of the environment as well as social impacts on La Playuela. A proposal outlining steps to decrease environmental impact was presented to the DNER on December 14th, 2015. The team suggested a vehicle limit of 136 cars and additional management strategies for La Playuela.

Acknowledgements

First we would like to thank our ID2050 instructor Anna Jaysane-Darr, and our advisors, Dr. Karla Mendoza-Abarca and Dr. Frederick Hart, for their continued guidance before and during our time in Puerto Rico. We would also like to thank WPI's research librarian Laura Hanlan, who was a crucial help in choosing, finding, and citing a number of sources.

From the time spent with the DNER in Puerto Rico, we owe a huge thanks to María Rivera-Vázquez. She acted as our main contact person within the department and personally drove us all around the island, arranged meetings with personnel we had questions for, acted as our translator when needed, and much more. We would like to thank a number of the people we met with to collect data, information about La Playuela, or information about the Limits of Acceptable Change System. These are in particular Oscar Díaz-Marrero, Ernesto Díaz-Valázque and Edgardo González.

Finally, we would like to thank the two people who, primarily, requested that we do this project. Those are Juan Casanova, a land manager in Cabo Rojo, and Darién López, the director of the forest management division in the DNER. Without their concern, this project would not have begun.

Executive Summary

We are a team of students from Worcester Polytechnic Institute, who completed a project in coordination with Puerto Rico's Department of Natural and Environmental Resources (DNER). The purpose of the project was to produce recommendations regarding the specifics of a future management plan for La Playuela – a protected area within the DNER's jurisdiction, which they identified as critically in need of new regulation. This document is the final product of that project.

La Playuela is officially recognized as a National Natural Landmark for its unique geography, diverse collection of vegetation, and its importance as a habitat for a number of endangered or endemic species. At the same time, its small strip of beachfront is a frequent destination for local and international tourism alike. In the past 15 years especially, La Playuela has seen an unprecedented spike in visitors. This has resulted in proportional degradation to the ecology. Among the many problems: mangroves are dying, wildlife species are nesting less frequently, and litter is more abundant.

We used multiple methods in order to understand La Playuela's recent development, and develop educated strategies for its management. We conducted personal interviews with various personnel who either knew personally about the problems facing La Playuela, or who had previously worked on management plans in different regions of Puerto Rico. We constructed and administered a written survey to beachgoers to evaluate the level of public information on these issues, and to gauge what management strategies would be most well received. We compared satellite images of the area to observe shrinking plant life density. Lastly, we applied Geographical Information Systems (GIS) techniques to measure spatial parameters of the beachfront and calculate an occupancy capacity.

Initially, we considered recommending that the new management plan be modeled on a framework called the Limits of Acceptable Change (LAC). However, a main result of our interviews with experts on the LAC was that La Playuela is not an ideal candidate for an LAC management plan; the LAC is an excellent preventative measure, but La Playuela is not only in need of prevention - it is in need of restoration. The main result of our interviews with people who have witnessed La Playuela's degradation first hand was that the strip of mangrove forest adjacent to the beachfront is the area most critically in need restoration. Beachgoers frequently set up their equipment beneath the mangroves for shade, and to use the branches for hanging bags. This regular abuse has taken a major toll on the once dense strip of mangrove.

Our primary recommendation for the new management plan is that it disallow people from occupying the area within the mangroves – restricting them to stay on the beachfront. To accompany that restriction, we propose a proportional reduction in the maximum number of cars allowed by the parking facility, so to account for the reduction in usable beach space. By calculating the square footage of non-mangrove beachfront, considering the typical size of a group, and how much space they should need to be comfortable, we arrived at our proposed parking capacity: 136 cars. After that point, the beach does not have space to healthily accommodate everyone.

In addition to this occupancy limit, we proposed a number of alternative strategies that may help curb degradation without explicitly restricting access. The results of our surveys helped indicate which of these strategies will be the most well received by the public. Finally, we offered a few methods for evaluating, in future years, how successful a management plan has been in its restoration goals.

The project team produced the following video to give an overview of the project.
It can be opened in a browser by clicking on the picture below:

Authorship

The project team collaboratively wrote and edited this document. While preliminary writing for each section was completed by individual authors, contributions to each were made by all team members. Austin Rose documented our methodology structure and compiled interview results. Tim Marschall headed the research into the legal and political aspects of this project and led the team in creating our survey. Tyler Tao took on background research, focusing on the environmental aspect of the project, and aided the team in the translation of documents only published in Spanish. However, no part of this project or paper was completed exclusively by one member. This makes it impossible to distinguish the exact contributions of each individual.

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1. Introduction

Preserving nature is one of the most significant challenges of the 21st century. According to the World Wildlife Foundation (WWF), 46 to 58 thousand square miles of forest are eradicated annually. The negative human impact on nature has severe implications for the health of ecosystems all around the globe (WWF, 2015).

In Puerto Rico, natural degradation has historically been driven primarily by agriculture. Deforestation on the island reached a peak of 90% eradication in 1940. It has since been grown back to around 60% today. Deforestation is shrinking due to numerous projects dedicated to restoring the island's natural landscape (Miller & Lugo, 2009).

The Department of Natural and Environmental Resources (DNER) is the commonwealth's publicly funded governmental organization focused on conserving Puerto Rico's natural resources and promoting environmental sustainability. The DNER manages several protected areas on the island, one of them being the Boquerón State Forest. It fulfills its mission through a variety of means, such as gathering valuable demographic and environmental data, animal tracking, and regulating protected refuges in Puerto Rico (Resources, 2012).

In the case of La Playuela, a beach located in the southwest end of Puerto Rico in the municipality of Cabo Rojo, natural degradation is heavily correlated with human usage. According to Ernesto Diaz, Director of the DNER Coastal Zone Management Program, no more than 700 people should be on the beach at the same time, however Juan Casanova and Dárien López suggested that at peak times, there is up to 3000 people swarming the area (Casanova, 2015).

Figure 1 La Playuela with Boats and Visitors

In particular, the island's inhabitants use the beach as a recreational destination for weekend trips as seen in Figure 1. La Playuela is a part of the Boquerón State Forest, yet the use of the area does not follow the standards established in the regulations of the forest. The beach is first and foremost protected, yet people often treat the beach as public.

The DNER is well aware of the significant ecological degradation the La Playuela area has undergone in recent years. Even though the department has worked towards more regulation, for example by declaring parking zones and marking them with signs, they plan on implementing a more sensible management plan to minimize the human impact on the area. This plan has to be based on

scientifically founded recommendations for specific limits and alternative strategies to accomplish their sustainability goals. Finding a sustainable balance between the incentives for local tourism, and the need for ecological preservation, is the overarching goal of the project described here.

Existing limits on tourism in La Playuela are mainly based on the carrying capacity of the declared parking zones. Additionally, the DNER has rangers stationed at the entrance of the area, which are supposed to administer the amount of cars, close the gate when the facility is full, and check the beach periodically for violations of regulations, such as open fires. Due to personnel constraints, this practice has proven to be ineffective. Additionally, rangers often do not close the gate when they are supposed to, as the current limit has no enforceable basis such as an administrative order and no scientific background, but rather derives from experience. The DNER would like to implement a new plan which is not solely based on limits due to physical space available, but instead based on a scientific evaluation of what the ecology can sustain.

That particular goal - to change the usage of an area so that ecology and human use are in balance - is very common for any organization concerned with the environment. Thus, the United States Department of Agriculture (USDA) formalized a general framework that managers can use to guide their planning, called the "Limits of Acceptable Change (Cole, Frissell, Lucas, Petersen, & Stankey) System for Wilderness Planning." Even though the words "wilderness planning" appear in the title, the LAC is general enough to be applicable in planning for all types of land and usage, including beachfront tourism on La Playuela. The DNER has tasked our project team with applying this framework to help determine a specific, implementable set of limits and strategies for minimizing the negative impact of tourism on the ecology in La Playuela.

In particular, we proposed a limit 136 cars or 545 people that can be allowed at the beach at the same time. Additionally, we recommended implementing a more comprehensive educational campaign, a carry in carry out policy and lastly an information system for reservations on the beach. The data and suggestions we presented will guide the development of new rules and restrictions for La Playuela, meaning that this project has the potential to impact not only the ecological health of the area, but also its social and economic environment.

2. Background

Some preliminary information about La Playuela and the opposing ideals of unrestricted use to aid economic development and imposed regulations to preserve biodiversity are detailed in the following sections. A summary of the framework suggested by the DNER is provided as a general method to satisfactorily compromise the two ideals. The framework summary is followed by two case studies demonstrating how the framework can be applied.

2.1. Department of Natural and Environmental Resources

The Department of Natural and Environmental Resources (DNER) is a publicly funded agency of the government of Puerto Rico. It was established by law in 1972 to ensure the sustainability and conservation of Puerto Rico's natural resources ("Ley Orgánica del Departamento de Recursos Naturales," 1972, 20 June).

The DNER is responsible for the management of several public properties, one of them being the Boquerón State Forest which includes La Playuela (DRNA, 2009).

Depending on the declaration of the land, the DNER has the legal jurisdiction to enforce rules and regulations pertaining to protected areas through fines. ("Ley de Bosques de Puerto Rico," 1975, June 1).

2.2. Cabo Rojo Municipality

Seen below in Figure 2, the Municipality of Cabo Rojo is located in the southwest end of Puerto Rico. With a population of 50,917 in the last census (2010), Cabo Rojo makes up for around 1.37% of Puerto Rico's inhabitants. 47% of the population lives in poverty and only 67% possess a high school degree or higher, placing Cabo Rojo below the United States as well as Puerto Rico's averages (Bureau, 2010). The combination of poverty, lack of education in the area as well as a unique, endangered wildlife bears potential for conflicts between economic and environmental needs.

Figure 2 Cabo Rojo is the southwestern-most municipality in Puerto Rico

(Blofeld, 2010)

2.3. Boquerón State Forest

The Boquerón State Forest is composed of the protected areas in the Boquerón region of Puerto Rico and is managed by the DNER. In Cabo Rojo, the lands managed by the DNER include the coastal strips along La Bahia Salinas, La Bahia Sucia, and the area in between the two which includes La Playuela. The State Forest consists of roughly 6630 acres of land. It includes wetlands, salt marshes, seagrass beds, dry forests and coral reefs. Its flora includes, among others, several species of mangroves, the endangered Bariaco plant and the threatened Stahlia monosperma plant. Animals in the area range from endangered turtle species such as the leatherback and the hawksbill sea turtle, to the yellow-shouldered blackbird and the brown pelican (DRNA, 2009). In the map of southwest Puerto Rico shown in Figure 3, the areas of the Boquerón State Forest are highlighted in yellow.

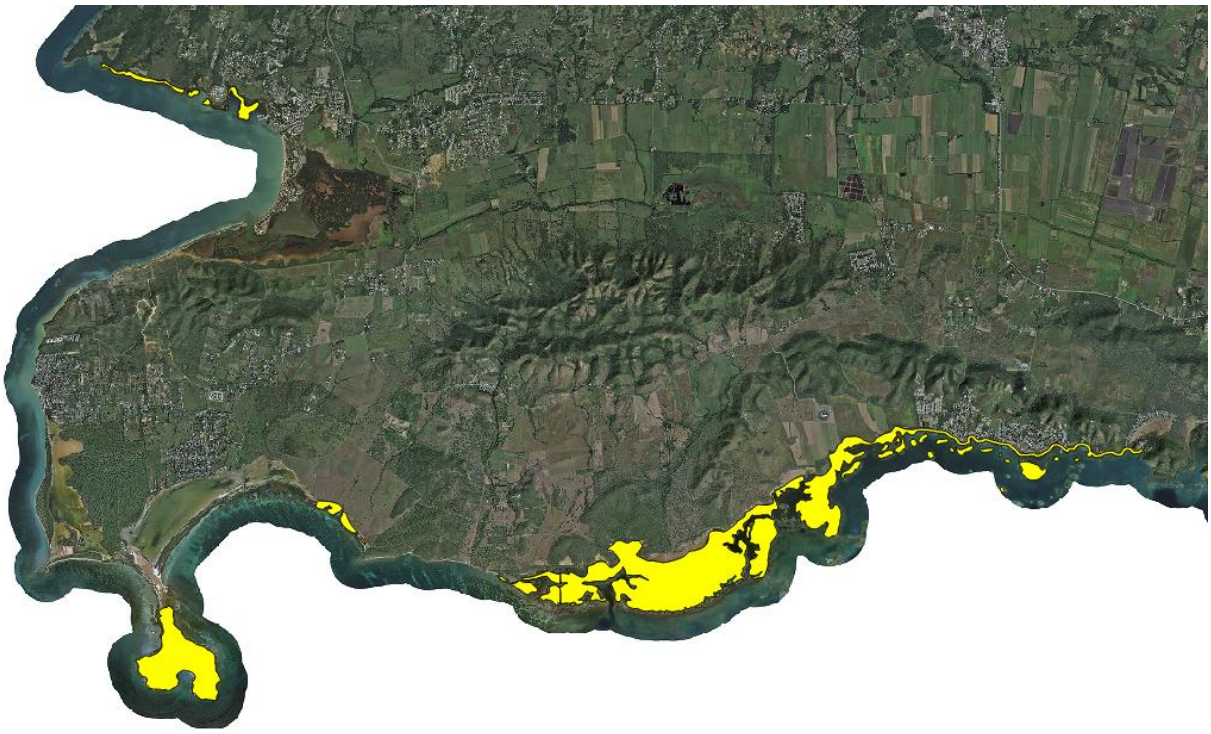

Figure 3 Satellite GIS image of Southwest Puerto Rico with the Boquerón State Forest highlighted in yellow (DRNA, 2010, AMBIENTALES CONSERVADOS AREAS NATURALES PROTEGIDAS 2010)

2.4. Cabo Rojo National Wildlife Refuge

The Cabo Rojo National Wildlife Refuge (NWR), managed by the United States Fish and Wildlife Service (FWS) begins directly north of La Playuela and stretches inland. All visitors arriving to La Playuela via land must pass by the Cabo Rojo NWR. One important distinction is that the DNER manages the coastal areas, while the FWS manages only inland areas in Cabo Rojo. The refuge encompasses 1836 acres of land. Due to its past use of cattle raising and agriculture, the area contains high levels of non-native plant species, though the FWS is gradually reintroducing native vegetation ("Cabo Rojo National Wildlife Refuge," n.d.). A large amount of the land is salt flats used in a commercial sea salt farming operation closely monitored by the FWS. The Cabo Rojo Salt Flats are a well-known migratory bird hotspot and are home to a few bird species year round (PRCCC, 2013). The Cabo Rojo NWR and La Playuela have closely linked ecosystems and changes in either will inevitably affect the other.

2.5. La Playuela

Figure 4 Satellite image of La Playuela

(DRNA, 2010)

La Playuela, shown in Figure 4, is located in the southwest corner of Puerto Rico and is a tombolo between La Bahía Salinas to the west and La Bahía Sucia to the east encompassing a total of 583 acres of land (Casanova, 2015). Limestone cliffs on either side of the beach allow hiking and the Los Morrillos lighthouse is located on the western side. The region hosts diverse ecosystems, including dry forests, mangrove forests, and sea flats (Service, 2015). Additionally, the area gained recognition as a National Natural Landmark as being an "excellent example of a tombolo (tied island) with double spit, mangroves, beaches, reddish cliffs, xeric vegetation, and seabird nesting habitat" according to a brief we obtained from Carolyn Morales, National Natural Landmarks Coordinator for the Southeast Region with the National Park Service (Appendix A).

Figure 5 View of the Beach at La Playuela

Cabo Rojo is well known for hosting some of the most beautiful beaches in the Caribbean. One of these is the beach at La Playuela, seen in Figure 5. It was chosen among the top beaches in

the Caribbean by users of the travel portal TripAdvisor (tripadvisor, 2015). Due to this, the area has seen a dramatic spike in visitors over the past few years (Casanova, 2015).

2.6. Local Usage of the Beach

Cabo Rojo with its attractive beaches serves the people of the island as a holiday refuge. Locals venture to the municipality, and in particular to the Boquerón State Forest, during weekends and over the summer. Forms of recreation at La Playuela include boating, hiking and, most obviously, swimming and relaxation. The threats to the area are a result of the overuse of the beach area (Casanova, 2015). The implications of this overuse are manifold.

Boating has implications for corals, as misplaced anchors can destroy reefs, which can be detrimental to the marine ecology. Additionally, boats are a direct threat to Manatees, which roam the bay. Hiking has resulted in several manmade paths throughout the area, without regard to ecology and long term sustainability. For example, one path along a cliff edge is becoming continuously more dangerous as erosion has made it increasingly narrower, making it more likely for hikers to trip and fall onto the sharp rocks in the bay. Most importantly, however, is the actual visitation of the beach for relaxation. A large amount of people uses the beach at once, particularly in summer during holidays such as the 4th of July. Visitors often disregard regulations, e.g. by cooking on an open fire on the beach, risking wildfires (Casanova, 2015). Another issue is trash disposal, as a significant amount of visitors leave their trash on the beach which subsequently gets taken into the wetlands and salt flats by the wind. It also has attracted stray cats, which are invasive to the area. Lastly, people tend to seek protection from the sun in the shade of the mangroves on the back end of the beach. The continued usage of that land has led to a significant decline in mangroves (Casanova, 2015). Posted signs indicate

what activities are and are not allowed in the state forest. There are two similar signs at La Playuela, one for the hiking area around Los Morrillos Lighthouse shown in Figure 6 below, and another for the beach itself.

Figure 6 Entrance to the Los Morillos Lighthouse

2.7. Wildlife

The US Fish and Wildlife Service has identified 76 endangered species that reside in Puerto Rico ("Listed species believed to or known to occur in Puerto Rico," 2015). The species identified by the FWS as residents of the Cabo Rojo NWR are the Yellow-shouldered Blackbird; two endangered plant species, Arustuda chaseae and Eugenia woodburyana; and one threatened plant species, Stahlia monosperma ("Threatened and Endangered Species on National Wildlife Refuges Database," n.d.). La Playuela and its surrounding waters in conjunction with much of the Cabo Rojo NWR and the Boquerón State Forest at La Playuela compose at least part time habitat of many species in addition

to those listed above including the Hawksbill sea turtle and Antillean manatee, both of which are endangered, and at least 22 species of shorebirds, many of which are threatened, protected or endangered (PRCCC, 2013; "Antillean Manatee Fact Sheet," 2013; "Hawksbill Turtle (Eretmochelys imbricata)," 2014). These species depend upon the stability of the area and the specific properties of the available land to nest and live for all or part of the year. In the past 100 years, large scale changes in the climate have increased dramatically in stark contrast to the relative consistency of past weather and oceanic conditions. Coupled with human interference, decreasing available food sources, and habitat area, environmental changes can easily outpace the species' individual capacities to adapt to change. This allows non-native species to gain a foothold and begin to overtake native species (PRCCC, 2013).

2.7.1. Threats to Wildlife

The overwhelming majority of threats to the livelihood and well-being of wildlife species are the direct result of human activity. At La Playuela beach, the DNER is primarily interested in degradation of the environment leading to habitat loss of endangered species, such as the Antillean manatee, the Hawksbill sea turtle, and the Yellow-shouldered blackbird, all shown in Figure 7. Both marine species reside at least part time in these waters, and the land is critical habitat for the blackbird. This section identifies some specific threats posed to each of these animals.

Figure 7 Clockwise from lower left: Yellow-shouldered blackbird, Antillean Manatee, Hawksbill Sea Turtle, Mangrove Roots

(Morel, 2010, Yellow-shouldered blackbird)(Kok, 2012, Manatee)(Rogers, 2011, Hawksbill Sea Turtle/ Carey de Concha)

Antillean Manatee Sometimes referred to as sea cows, manatees can vary widely in size and have a diet mainly composed of seagrass. In Puerto Rico, they are usually about 8-9 feet long and live to around 27 years ("Antillean Manatee Fact Sheet," 2013). Boat strikes are the most common cause of human related manatee deaths. In addition, boats can damage or kill seagrass beds, thereby reducing the amount of individual manatees that the area can support. Another danger to manatees is repeated

human interaction and feeding. Manatees can learn to swim nearer to boats looking for food, which increases their risk of being hit, knocked out, or struck by the boat's propeller. Some individual manatees may become dependent upon handouts and starve when the tourist season wanes and the animal cannot hunt for itself. Pollutants and chemicals discharged into the ocean can affect the composition of the water in certain areas making them uninhabitable and killing the manatees already living there ("Antillean Manatee Fact Sheet," 2013).

Hawksbill Sea Turtle Hawksbill sea turtles are medium sized sea turtles that can be found around the world with multiple nesting sites in Puerto Rico ("Hawksbill Turtle (Eretmochelys imbricata)," 2014). Pollution is one of the greatest dangers to sea turtles. Oil or chemical spills leave beaches unfit for nesting. Garbage such as plastics and discarded fishing gear can cause death from suffocation or entanglement. Hawksbill turtles often eat plastic bags as they mistake them for jellyfish. The turtle's stomach fills with plastic and it stops feeling hungry, eventually dying from starvation. Recreational watercraft, fishing vessels, and commercial ships can also pose a threat to sea turtles. Groundings and boat anchors dropped on coral can kill individual colonies or even the entire reef. Coral reefs provide shelter and a reliable source of sponges for turtles to eat and the loss of reefs can force them to move elsewhere (Recovery Plan for Hawksbill Turtles in the U.S. Carribean, Atlantic and Gulf of Mexico, 1993). Though all species of sea turtle can be found around the globe, many individuals return to the beach where they were born to nest. If the beach is unfit, or an acceptable nesting location cannot be found, the turtles may return to the ocean without laying their eggs or accidentally damage clutches of eggs previously laid decreasing the size of the hatchlings the following year ("Threats to Sea Turtles," 2014).

Yellow-shouldered Blackbird While the yellow-shouldered blackbird is not the only bird species endemic to Puerto Rico, it is unique in the fact that a majority of its current habitat is located in southwest Puerto Rico. Once found throughout the island, the blackbird is now in danger of extinction (Post, 2011). The species has been endangered since 1976 due to a combination of habitat loss, nonnative predators, and, most significantly, brood parasitism by the shiny cowbird. Rather than care for its own young, the shiny cowbird lays its eggs in the nests of other species, oftentimes destroying the eggs of the host birds (Lowther, 2011). In just a seven-year period from 1975 to 1982, the blackbird population declined by 85%. Due to human intervention reducing the population of shiny cowbirds, the number of blackbirds increased into the mid 2000's, but without funding to continue the reduction program, the blackbird population has once again begun to decline. Without a renewed plan to manage the shiny cowbird population, the yellow shouldered blackbird may become extinct within the next 50 years (Liu, 2015). Figure 8 is a map from the International Union for Conservation of Nature depicting the past range of the yellow-shouldered blackbird in red and the current range of the blackbird in yellow. Within the shown range, the blackbird will nest in various locations dependent upon the terrain and land features available (Post, 2011).

Figure 8 Range of the Yellow-shouldered Blackbird

("Agelaius xanthomus," n.d.)

Mangrove Forests Mangroves are an important forest type worldwide, though often overshadowed by rainforests. A 2012 article by Kathiresan and Sandilyan published in Biodiversity and Conservation explains why mangroves are such an important ecological feature. They begin with the general characteristics of mangroves; a comparatively high salt tolerance, the ability to withstand high wind speeds, and a preference for muddy soils. One major factor given to highlight the importance of mangroves is that they host a variety of species that rivals the diversity of rainforests. Mangrove ecosystems host 57 endangered, threatened, or vulnerable species worldwide and an individual ecosystem in India has been known to contain over 4,000 species. Over 90% of all marine species spend at least a portion of their life cycle living in mangrove areas and 80% of all fishing catch is dependent on mangroves.

In addition to being a habitat for many species, the scientists assert that mangroves are beneficial to humans. As with all forests, mangrove areas are carbon sinks, and they also act as pollutant sinks, in particular for heavy metals. They are a source for raw materials such as wood for construction and many bacteria used in the creation of antibiotics are found in mangrove forests. One of the most environmentally significant advantages for protecting mangrove areas is the ability of mangroves to protect the coast from severe weather. Mangroves have been shown to mitigate the effects of tsunamis, storms, floods, and erosion on coastal areas, potentially saving more money by preventing property damage than could be earned by selling the raw materials present, not to mention the lives saved by the reduced impact of these natural disasters (Sandilyan & Kathiresan, 2012). Despite all these benefits, global mangrove loss is estimated to be at 35%. This decrease has led to a decrease in marine species, most notably poorer coral reef health and fewer fish where mangrove area has been lost (Mumby et. al, 2004). Most threats are human caused and include the introduction of

non-native species, clearing for construction or agriculture, harvesting the trees for wood, or environmental changes such as altered river paths that affect the salinity of existing water bodies.

Figure 9 The mangrove area at La Playuela

Four species of mangroves have been identified in Puerto Rico; the Red Mangrove, Rhizophora mangle; the Black Mangrove, Avicennia germinans; the White Mangrove, Laguncularia racemosa; and the Button Mangrove, Conocarpus erectus. Figure 9 shows the mangrove area at La Playuela. While each of the species have a status of least concern (as opposed to threatened, vulnerable, endangered, or extinct), the population of each is declining ("Avicennia germinans," 2010; "Conocarpus erectus," 2010; "Laguncularia racemosa," 2010; "Rhizophora mangle," 2015). The link between mangroves, coral reefs, and seagrass has weightier implications. Mangrove health is critical

to the survival of many endangered and threatened species even though the mangroves themselves are not endangered or threatened.

2.8. Wildfires

In 2014, Puerto Rico had 3,647 wildfires that burned 16,292 acres (National Interagency Fire Center). As many as 90 percent of wildfires in the United States are caused by humans, according to the U.S. Department of Interior. Some human-caused fires result from campfires left unattended, the burning of debris, negligently discarded cigarettes and intentional acts of arson ("Wildfires," 2015). Wildfires are a growing problem in La Playuela. In the last 3 years on this one small tombolo, there has been at least one wildfire per year. A single fire in 2015 destroyed around 30 acres of land (Casanova, 2015). Whether due to negligence or malice, the broad majority of wildfires are the result of human use. In our time at La Playuela surveying people and observing the area, we noticed discarded charcoal, which was most likely used for cooking. This is despite the fact that open fires are expressly illegal in state forest areas ("Ley de Bosques de Puerto Rico," 1975, June 1). The dense volume of people using the area at peak times, combined with the single small road point of egress, make La Playuela an exceptionally dangerous place for a wildfire to occur. The main parking facility can hold up to 120 vehicles. When it fills, people continue to park on the road, on spaces which are explicitly marked as non-parking zones. Alternatively, visitors walk from much further away. In the event of a wildfire, it is impossible to efficiently evacuate the large amount of people and vehicles, before allowing a fire response vehicle to come through.

2.9. Limits of Acceptable Change Framework

The "Limits of Acceptable Change" framework, sometimes followed by "for wilderness planning" or "for managing national protected area," is a framework for balancing the needs of the environment with the impacts of tourism originally written by Cole, Frissell, Lucas, Petersen, and Stankey for the US Department of Agriculture. In this section, the Limits of Acceptable Change method will be described and evaluated as a management strategy for conservation of any area used by humans.

The LAC system is a framework for establishing acceptable and appropriate resource and social conditions in recreation settings. The LAC has been developed in response to the need of park managers for a means of coping with increasing demands on recreational areas in a progressive, measurable way. The LAC also represents a reformulation of the recreational carrying capacity concept, with the primary emphasis now on the conditions desired in the area rather than on how much use an area can tolerate (Cole et al., 1985).

At La Playuela beach, the natural desire for increasing consumerism and recreation exists at sharp odds with the sustainability of the existing natural resources (Morel, 2015, 9 November). Therefore, regulation in La Playuela is an obvious candidate for the application of LAC. Since the area only became a popular tourist attraction in recent years, there is a better opportunity for well-calculated regulations to prevent degradation from reaching a rate that is out of the control of the DNER.

2.9.1. Goals of LAC Plans

Implementing a plan developed using the Limits of Acceptable Change guidelines will allow conservation by limiting use of key areas before degradation of the environment advances to a stage

that cannot be repaired. The LAC provides a way to satisfactorily meet two conflicting goals. In most cases where the LAC is applied, including this case, meeting the demand for tourist activities and conserving the environment are the two conflicting ideals.

2.9.2. Key Principles

According to "Managing Visitor Impact" by the National Oceanic and Atmospheric Administration (NOAA), there are three main points to keep in mind when implementing the LAC method. They are:

1) Change in the environment is inevitable, so it should be managed;
2) There is a bare minimum level at which the environment can survive;
3) And that tourism should be allowed to impact the environment only until this minimum level is reached ("Managing Visitor Impacts," n.d.).

These three statements direct the creation of the conservation plan. Rather than using carrying capacity, which is a numeric visitor cap, to define the acceptable use of a site, the LAC approach examines the amount of impact caused by different types of activity. While sunbathing and use of recreational watercraft require vastly different resources, they are both viewed the same under the carrying capacity management framework. The impact of each tourist cannot be assumed equal. However, in any area used by humans, there will be an environmental impact associated with that use. The LAC approach acknowledges that both the state of the environment and unrestricted tourist use must be compromised in order to create the maximum benefits both economically and environmentally. In light of this fact, one objective, called the primary goal, is given priority over the other objective, the secondary goal. The primary goal is only compromised until the bare minimum

sustainable level is reached. The secondary goal is compromised as much as necessary to ensure the primary goal is being met. In almost all areas, the primary goal is maintaining sustainable environmental conditions since growth of the tourism industry outpaces natural regeneration of wildlife areas. Therefore, LAC limits touristic activities when there is a threat of irreparable damage to the environment ("Managing Visitor Impacts," n.d.).

Many documents describe the process of implementing a LAC management plan, though the original framework was written in 1985 by Cole, Frissell, Lucas, Petersen, and Stankey for the US Department of Agriculture. The general steps have been modified numerous times to fit the unique needs of different environments around the world. However, some of the basic steps remain the same.

Our modified version of the LAC plan for La Playuela consists of five steps displayed in Figure 10. First, the agency or managing body responsible for the care of the target area must identify the need for a conservation strategy and long term goals for the area. Next, the agency must gather information about the current state of the environment with particular focus on trends or specific concerns. Third, the agency should carefully select what indicators will be used to monitor the situation. The choice of indicators is dependent upon the technology, expertise of employees, and funds available to the agency. Then, the agency is able to determine the most effective time and manner to take action when the limit of each indicator is breached. This may involve multiple options for restoring environmental conditions to be chosen per indicator based on the situation. After every possible action is determined, the agency must evaluate the cost and feasibility of each while taking care to allow feedback from all stakeholders. Finally, continuous monitoring of the area and chosen indicators leads the agency to take appropriate measures to decrease impact when needed. At all steps in the process, the agency should regularly analyze the effectiveness of the program and make

necessary adjustments when there are changes in the environment (Drumm & Moore, 2002). After the concerns and goals have been established by the agency in charge of the area to be affected by the management plan, any of the subsequent steps can be undertaken by external bodies in conjunction with or working for the agency. Researchers or experts in the field of specific methods of data collection may be brought in to oversee the selection and monitoring of indicators. Community organizations may be able to coordinate the continuous monitoring required by the LAC framework. In the case of the La Playuela project, the WPI project team has been tasked with proposing indicators and action plans to rectify environmental degradation to the managing body, which is the DNER.

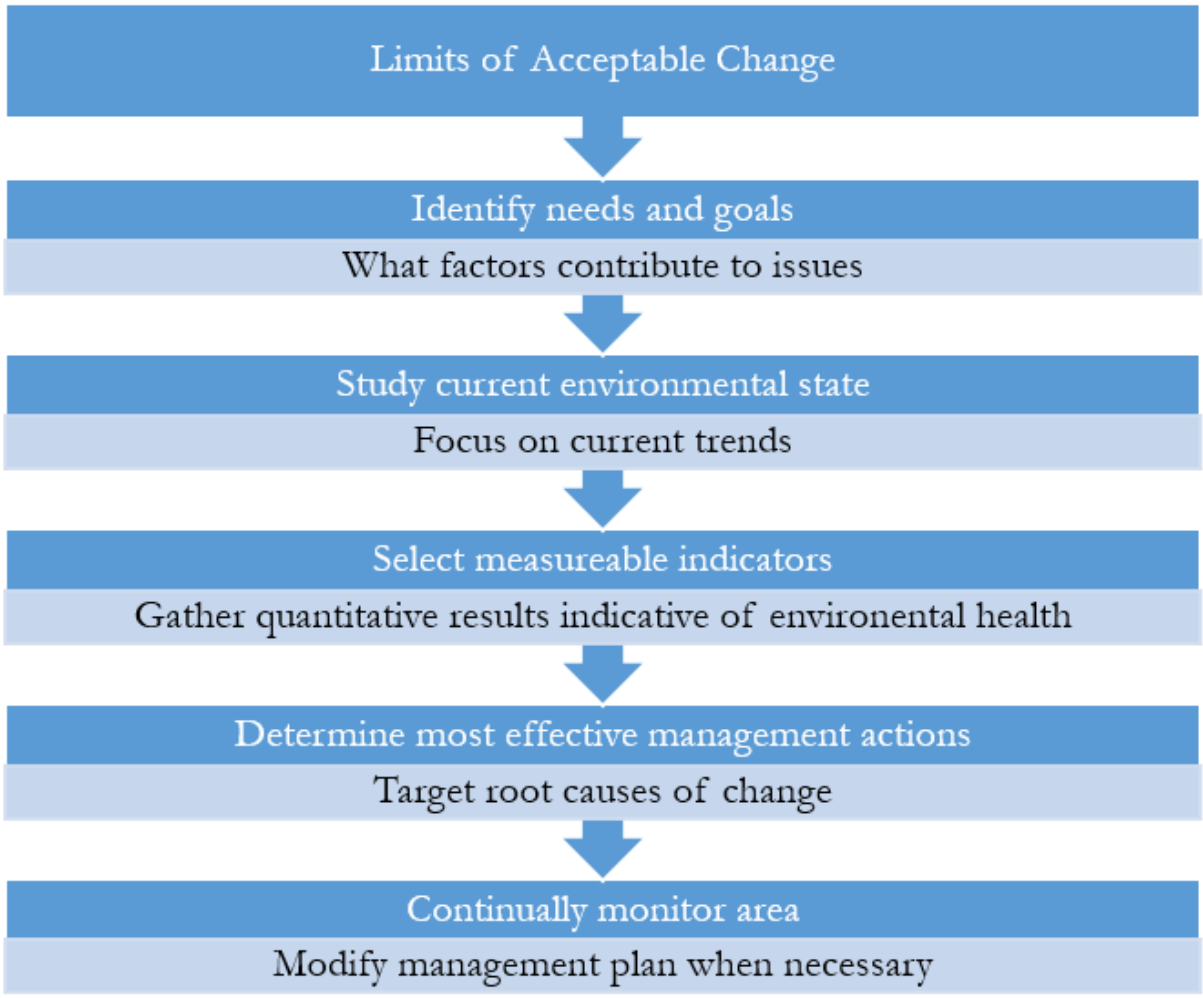

Figure 10 The five steps in our modified LAC plan

For the LAC approach to function, there must be an overarching entity that monitors the chosen indicators and has the power to limit tourist activity in the area. This can be a governmental organization, nonprofit organization, or a group of community members working for an agency with the authority to implement regulations and with the resources to consistently monitor the environment (Secretariat of the Convention on Biological Diversity, 2002). Indicators are chosen by the managing body and must be measurable. Quantitative measurements are preferred, as they reduce the chance of

biased data collection and make upper and lower limits are more straightforward. Though available technology and manpower may limit which properties can be measured, collecting data from diverse sources produces a more thorough understanding of changes that are occurring. Constant monitoring is required to ensure indicators do not fall outside the range of allowable levels. Regular data collection will highlight trends that foreshadow larger issues, possibly allowing the prevention of them altogether. The LAC is best suited to governmental agencies, as they have more resources and legal influence than smaller, local conservation groups. Management with the authority to implement changes regarding availability and allowed use of an area can more efficiently restore the environment to an acceptable state. In addition, governmental agencies have existing connections with the community affected by new regulations and the ability to clearly communicate these standards to the residents (Secretariat of the Convention on Biological Diversity, 2002).

2.9.3. Case Studies

The following subsections describe some case studies that illustrate how the LAC framework has been adapted to suit coastal areas rather than wilderness areas. They provide useful insight to the benefits of following the LAC method. Moreover, it is beneficial to see how other management teams have adapted the core plan to fit their individual needs.

Boating in Balearic Islands Spain This study conducted by Diedrich, Huguet, and Subirana in 2011 describes the creation of a management plan based on the Limits of Acceptable Change framework to regulate recreational boating in a bay, Calla Xinxelli, which is part of an island in the Mediterranean Sea. While the Limits of Acceptable Change original framework was intended

for protecting land, the concept is applicable to marine environments where the area of interest is well defined and the needs of the environment are at odds with human use of resources. Demand for recreational boating in Calla Xinxelli coupled with its small size poses a risk to the safety of tourists as well as the survival of a threatened species of seagrass.

The team identified the stakeholders as the government, private sector, and civil society. They used GIS and aerial photographs along with surveys to measure eight indicators including number of boats present, area of beach and sandy bottom, demographics of visitors, and visitor satisfaction. Based on the data collected, a maximum number of boats in the bay, minimum distance between boats, and damage to seagrass was incorporated into proposed solutions. Multiple solutions were proposed to allow the managing body to choose the level of importance of social factors as well as the amount of funding available (Diedrich, Huguet, & Subirana, 2011).

Managing Snorkeling Tourism in Thailand This study conducted by Roman, Dearden & Rollins (2007) aimed to reduce touristic impact to a coral reef in the Marine Protected Area of Koh Chang National Marine Park in Thailand. The study focused on reducing tourists walking on the coral, referred to by the researchers as trampling. Trampling can harm and kill coral colonies decreasing the habitat of many other marine species. The researchers identified a disparity in likeliness of being trampled based on the type of coral. In addition, in areas where the depth at low tide is greater than 3m, trampling cannot possibly occur. Therefore, the researchers sought to implement a plan such that high levels of tourism be allowed in areas with resilient types of corals or a low tide above the limit, making the problem nonexistent, while limiting tourism in more sensitive areas. The team used a

cartographical map in conjunction with the LAC framework to zone the area based on their respective conditions.

Zoning is a system that divides one large area into multiple sub areas with varying properties. The sections might be divided based on where certain plants or animals particularly sensitive to environmental changes reside or where each tourist activity takes place. Each sub area can then have its own subset of regulations dependent upon each section's specific needs such as restricting access to the most vulnerable areas and directing most tourism to more resilient areas. Using zoning enables the authorities to allow varying levels of tourism in each zone as well as monitor the at risk areas more closely.

The zoning plan in the study was created in the following order: First, vulnerable areas with high biodiversity were zoned as Conservation Areas with use limited to monitoring and research only. Using tourist feedback collected from surveys administered by the researchers, areas suitable for snorkeling tourism were sectioned into Tourism and Ecotourism Zones. The survey data suggested that tourists were most satisfied with a snorkeling experience located in waters with low coral mortality and high coral diversity with 35 or fewer others at the site. Under the LAC model, number of tourists per site and coral mortality were selected as indicators. An acceptable range for the coral mortality index for all sites was proposed to cap the maximum allowed mortality at 50%. The ideal number of snorkelers per site was chosen to be <30. Although coral diversity affected the experience of the tourists, it was not linked to touristic impact and was not chosen as an indicator. Ecotourism Zones contained somewhat vulnerable areas while Tourism Zones were comprised of low vulnerability corals. The recommended LAC values for the Ecotourism Zones were lower than the values for the Tourism Zones to ensure a lower visitor impact (Roman, Dearden, & Rollins, 2007).

Creating zones is not only beneficial for the wildlife. The distinction between zones enables visitors to choose the site offering their desired experience. Management becomes more effective under zoning plans. Rather than creating acceptable indicator limits for an entire area, at-risk portions can be given stricter limits while other sections that can support greater resource use bear the majority of the impact. In the area surrounding La Playuela, as well as on the beach itself, there are varying land structures and human use patterns. By separating the area into zones, it will be possible to limit access to areas that cannot withstand heavy foot traffic or that are primary habitats for protected and endangered species. Using zoning strategies combined with the LAC framework to create regulations for La Playuela beach will result in higher overall tourist usage while still providing the environment with adequate protection.

2.10. Summary

La Playuela has seen a drastic increase in popularity over the past decade. A sensible approach to regulation, balancing and combining the opposing incentives of touristic growth and wildlife preservation, is therefore crucial to prepare the protected area for the future. With an increase in human activity in the area, it is necessary to consider, estimate, and limit touristic effects, minimizing both direct and secondary threats to multiple endangered species.

Taking into consideration the manifold threats pertaining to the area and their causes, as well as the history and natural significance of this part of the Boquerón State Forest, allows for the recommendation of sensible limits to ensure a more sustainable future of the area. The Limits of Acceptable Change framework is a method for limiting the environmental impact of tourism that has been implemented worldwide. Its versatility allows it to be adapted to any area where there is both

wildlife and tourism. While it provides a structure and sequential steps, the LAC framework is broad enough to be useful to all management organizations. For these reasons, it can be a useful strategy to guide the DNER in creating new regulations in the La Playuela beach area.

3. Methodology

In order to make sensible suggestions, we developed an understanding of the area in a cultural, historical and ecological sense. This involved gathering and analyzing as much historic data about the area as possible, seeking related trends in touristic usage volume and ecological degradation. Sources of information included geographical data, photographs, reports generated by the DNER, as well as personal interviews with employees of the DNER and related organizations familiar with the area. The data served as the basis for a cartographical map highlighting the most critical zones in terms of tourism contribution to natural degradation. A firsthand look at La Playuela beach enabled us to collect valuable usage data through surveying and gain an understanding of local environmental issues in order to establish a baseline of usage levels to ensure sustainable ecological growth. This baseline then served as rationale for the suggestions we develop for the DNER.

This chapter describes the steps we followed in order to construct our recommendations for the DNER and their eventual management plan for La Playuela. We first identified the most significant management concerns affecting the area. We accomplished this through personal observation, by considering interviews with knowledgeable personnel, and by analyzing relevant historical data. We then evaluated how informed the beach-going public is about these management concerns, and how willingly they would abide by a selection of potential new management strategies. Finally, we combined these results to decide what regions of La Playuela can continue sustaining use,

and what regions should be explicitly preserved under a new management plan. With all of this information, we were able to propose a revised occupancy maximum given the spatial constraints of the usable area, and to propose which alternative management strategies - supplemental to an occupancy maximum – we found most likely to be effective. A graphic displaying these steps is shown in Figure 11.

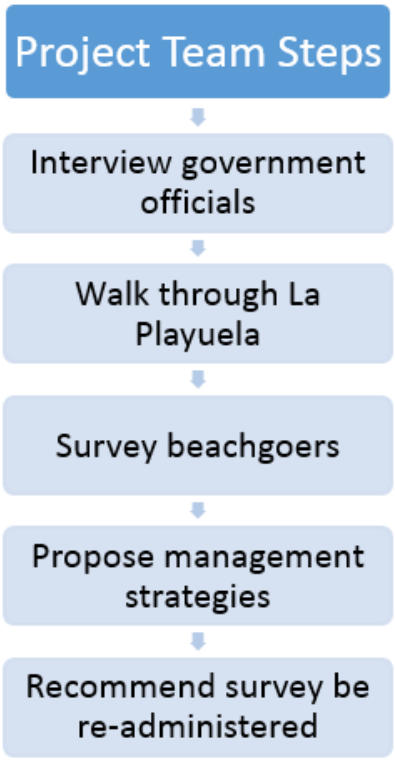

Figure 11 Flowchart detailing steps taken by the WPI team

3.1. Identifying Primary Area Concerns

The paramount goal of the project is to enable the DNER to implement a sensible regulatory framework ensuring that La Playuela beach as well as the surrounding area flourishes both from an environmental as well as from a touristic perspective. The first step in order to solve this issue was to

research the causes and patterns of degradation in the area. We needed to establish what specific problems we wish to solve, ensuring that we can keep a practical limit on the scope of our project, whether it is species losing habitats, flora being trampled, evacuation procedures being unsafe, or some combination of issues. The proceeding subsections detail various approaches involved in the collection of this information.

3.1.1. Personal Observation

Some usage problems, such as an abundance of litter, were obvious to identify upon visiting La Playuela. During the time we spent there, we hiked the entire area, making observations and taking photographs that would corroborate any additional historical perspective we could gain.

3.1.2. Interviews

The most abundant source of historical context regarding La Playuela's development came from meetings and emails with various directors, managers, and researchers working in the DNER or the FWS. Through these interviews, we were able to gain a firm understanding of the challenges of wildlife preservation and in particular the issues and approaches that have been taken at La Playuela and the problems they are trying to address. The proceeding subsections detail the goals and significance of each conversation.

Ernesto Díaz-Valázquez Mr. Díaz-Valázquez is the Director of the DNER's Coastal Zone Management Program. He has been involved in a number of land management plans regarding coastal

zones. From a discussion with him, we hoped to gain some insight about the steps involved in applying the LAC framework to a management plan.

Edgardo González Mr. González is the former Chief of the Forest Bureau at the DNER, and an expert on the use of the LAC framework in a wide variety of management plans. From a discussion with him, we intended to get an opinion of how the LAC might be adapted for relevance to La Playuela, given its history.

Oscar Díaz-Marrero Mr. Díaz-Marrero is the Manager of the Cabo Rojo National Wildlife Refuge, for the FWS, and has been for more than 10 years. From a discussion with him, we sought to learn about how La Playuela fits into the broader Cabo Rojo Wildlife Refuge. We asked about relevant past management plans in wildlife refuges, and about any further references he could point us to for numerical data concerning La Playuela wildlife.

Mike Morel Mr. Morel is a field researcher for the FWS. We were pointed to him as a good source for numerical data concerning nesting and migratory patterns of the various species in La Playuela. We inquired for this data, as well as for his personal observations about the trends in recent years.

Juan Casanova and Darién López Mr. Casanova and Mrs. López are the two people most responsible for noticing the need for a management plan in La Playuela, and requesting that this project take place. Juan Casanova is the DNER's Land Manager for La Playuela, and Darién López is the Director of their Forest Management Division. With over 10 years of managing La Playuela, Mr.

Casanova has had the most significant in-person exposure to the area over the years of anyone we talked to. From our conversations, we wanted to learn a number of details about the eventual management plan we would recommend for. We asked about the biggest problems directly resulting from tourism, why tourism has spiked so suddenly in recent years, about existing or previous efforts to curb overuse and manage the area, and finally about the resources and limitations that would be involved with the enforcement of any new policies.

3.1.3. Additional Data

In the many conversations we had to learn about the problems in La Playuela, we specifically sought out any data from previous research we could possibly get regarding the area over the past several years. It is important that the data we collected cover several past years, to ensure that any trends in the data could be correlated with the increased human usage La Playuela has seen in that time. The proceeding subsections detail what sources of data we were able to find.

Hawksbill Sea Turtle Nesting From our conversations with Mike Morel, we were referred to Dr. Carlos E. Diez, who is in charge of a program collecting Hawksbill Sea Turtle nesting data in Cabo Rojo. We contacted him to request access to any data relevant to our concerns in La Playuela.

Yellow Shouldered Blackbird Migratory Patterns To get a better understanding of the challenges and changes shorebirds experience at La Playuela, we contacted Katsi Ramos, field researcher and bird expert at the DNER. In particular, we looked for information on the yellow-shouldered blackbirds' migratory patterns, nesting and population statistics.

Marine Life Stranding The DNER referred us to Yamita Rodriguez who collects data when marine animals become stranded on shore. We contacted her to request access to any data relevant to our concern in La Playuela.

Satellite Photographs Assessing the state of degradation was a challenge, as the amount of data on the ecology at La Playuela is rather limited. One of the few tools we were able to acquire is satellite photos. The DNER is in possession of satellite pictures spanning over 60 years, up to the beginning of the new millennium. Additionally, we were able to obtain satellite pictures through Google Earth Pro and its sources. Lastly, we obtained a GIS dataset containing a high resolution image from 2010 alongside several layers of geographical data such as soil types and roads. Comparing these images allowed us to make an objective judgement of the degradation at la Playuela over time.

3.2. Public Opinion and Level of Information

The cultural impact of our project is a significant consideration. In order to assess the public's knowledge and opinion as well as openness to change, we spent two weekend days on the La Playuela beachfront surveying the visitors. November is a time of comparatively low tourism at La Playuela with not many people visiting. Due to the fact that there were not enough groups to utilize a sampling technique, we asked all beachgoers if they would be willing to complete our survey. Data was collected by asking one member from each group at the beach to fill out a short questionnaire, which is included in Appendix B. The survey was made available in English and Spanish. It included questions that helped us to assess several relevant social questions, such as, but not limited to, whether the public

understands that the beach is a protected area, what degradation they have personally noticed in recent years, and what subset of some potential new policies they would be most receptive to. The answers to these questions helped to inform our recommendations regarding whether an educational campaign should be a major part of this management plan and what alternative strategies for preservation may be the most successful. Surveys included some initial questions specifically to provide some context and legitimacy, such as questions regarding residency in the municipality and on the island as well as questions inquiring about the frequency and length of reoccurring visits of the beach. Additionally, we asked a question about group sizes in order to find how many people the average group consists of as well as a question about the time of year the participant is most likely to visit the beach in order to derive the peak season. The latter third of the questions inquired about change over time in litter and plant life, customer satisfaction and most importantly, which measures visitors are willing to participate in to enhance the quality of the beach.

3.3. Compilation of Deliverables

The last step to reach our goal of developing sensible recommendations was to analyze the data received and compile the results into easily readable, informational documents. The following points explain this approach to the deliverables in detail.

3.3.1. Developing a Map of Critical Zones

One of the deliverables was in form of a map containing the most critical zones, i.e. which zones of La Playuela can continue sustaining use, and what parts must be explicitly preserved under a new management plan. In order to provide an accurate assessment, we utilized a geographical

information system (GIS) based on data we received. In general, a geographic information system is "a facility for preparing, presenting, and interpreting facts that pertain to the surface of the earth" (Tomlin, 2013). Then, we applied GIS techniques to evaluate the spatial constraints within the boundaries of these continued-use areas. We used QGIS (formerly Quantum GIS), a free, open-source GIS program, as well as Google Earth Pro, to develop these maps.

3.3.2. Calculating a Base Limit

With the exact amount of available space known, we derived a figure for what should be the maximum occupancy at La Playuela – a number at which people entering should be turned away at the gate. In deriving this number, we considered the average group size according to our surveys, the size of beach towels, and the amount of space psychological studies suggest a human needs to be comfortable. Regard to fire safety as well as other advantages and disadvantages of the limit such as social impact must be taken into account in the evaluation of the number.

3.3.3. Developing Additional Recommendations

A single number is not going to solve all issues pertaining to the area. In fact, the LAC specifically refrains from just using a singular number, but instead tailoring management plans to the acceptable state of the ecology through various techniques. A crucial part of the project was to highlight which additional measures may be helpful to the area in the future and enhance the efficiency of the proposed limit, such as the development of an educational campaign. These suggestions were heavily dependent on the aforementioned survey results.

Lastly, we developed a set of indicators the DNER can keep track of in order to effectively apply the LAC framework in the future. As the framework is largely dependent on indicators and time-based data, we had very limited room to apply the framework with the current state of information. The development of these indicators for future use, however, can have a large impact on the efficient management of the area and therefore had to be part of the deliverables. All of our compiled analysis, limits and suggestions were compiled into a report to be delivered to the DNER.

3.4. Summary

As can be seen in the Gantt chart in Figure 12, we have allocated our time on site to each of the aforementioned tasks. While some were ongoing through most of the term, others, such as surveying, were undertaken at a single point in time.

Objective	Task	Week							
see details below		1	2	3	4	5	6	7	8
1	Research endangered species and area geography								
1	Employee Interviews								
1	Area Walkthrough								
2	Distribute Surveys								
2	Research past management plans and strategies								
2	Determine which strategies will combine to form the most effective management plan								
3	Photos/Filming for Videos								
3	Introduction/Background writing								
3	Methodology/Results writing								
3	DNER Proposal writing								

Objective #	Objective Description
1	Develop an understanding of the needs of wildlife, focusing on the endangered species, that resides at La Playuela and the current threats
2	Propose alternative solutions to limiting the number of visitors allowed at La Playuela based on past regulations and willingness of visitors to participate in new programs
3	Create documents to be submitted to the DRNA and to WPI detailing our work on the project and resulting findings

Figure 12 Gantt chart of tasks to be completed while in Puerto Rico

In creating our report for the DNER, we took into account many factors that influence the viability of our suggestions. Through interviews with many professionals concerned with the wellbeing of La Playuela and the wildlife it contains as well as surveying members of the community who will be affected by new regulations, we formulated a report which will be used to guide future legislation ensuring new regulations will benefit both the town and environment.

4. Findings and Analysis

The results in the following section serve the purpose of providing the DNER with an overview and scientific analysis on La Playuela beach. In order to guide the agency in the development of a management plan, the findings have been compiled into a report including history, analysis and suggested steps for enhancing the ecological situation in the area. Using various data sources, we were able to derive numbers for the amount of parking spaces that should be offered to address the manifold challenges pertaining to the sensible usage of the beach. Additionally, our suggestions targeted infrastructural, ecological and educational shortcomings in order to enhance both the ecological situation as well as the touristic experience on the beach. Lastly, we developed a set of several meaningful indicators to be monitored by the DNER in order to be able to apply the LAC framework in future years with relevant data. All suggestions are subject to resources available to the DNER and their feasibility will have to be taken into consideration at the point of development of the management plan.

4.1. Assessment of the Ecologic Situation at La Playuela

The first part of our analysis centered on the ecological state of la Playuela and its surroundings. Most of our conclusions derived from personal interviews with experts on the area. An assessment of the ecological state of the area would have been dependent on data over the time. There merely was not enough of this time based data available to draw detailed conclusions aside from personal interviews and historical, aerial photographs.

4.1.1. Analysis of Historical Photographs

The DNER supplied us with several high quality aerial photographs spanning sixty years of La Playuela's development, up to 1996. These photos gave us an insight as to how mangrove density and distribution have changed over this time. Additionally, we used Google Earth Pro to collect several more satellite photos of the area, to fill the gap between the 90's and present day. Between these sources, we observed and analyzed a comprehensive picture of how the ecological features of La Playuela have changed. Figure 13 shows the difference between three select photos, 1936, 1996 and 2015. The loss of mangroves is particularly obvious in the circled zone. The connection between the parking area in the lower left corner and the beach strip was entirely filled with mangroves, sharply distinguishing the two. 60 years later, the mangroves have become scarcer and the connection is very obvious. Today, another 19 years later, this trend has continued and even less mangroves can be found growing on the beach despite the fact that parking is no longer allowed in the area adjacent to the beach.

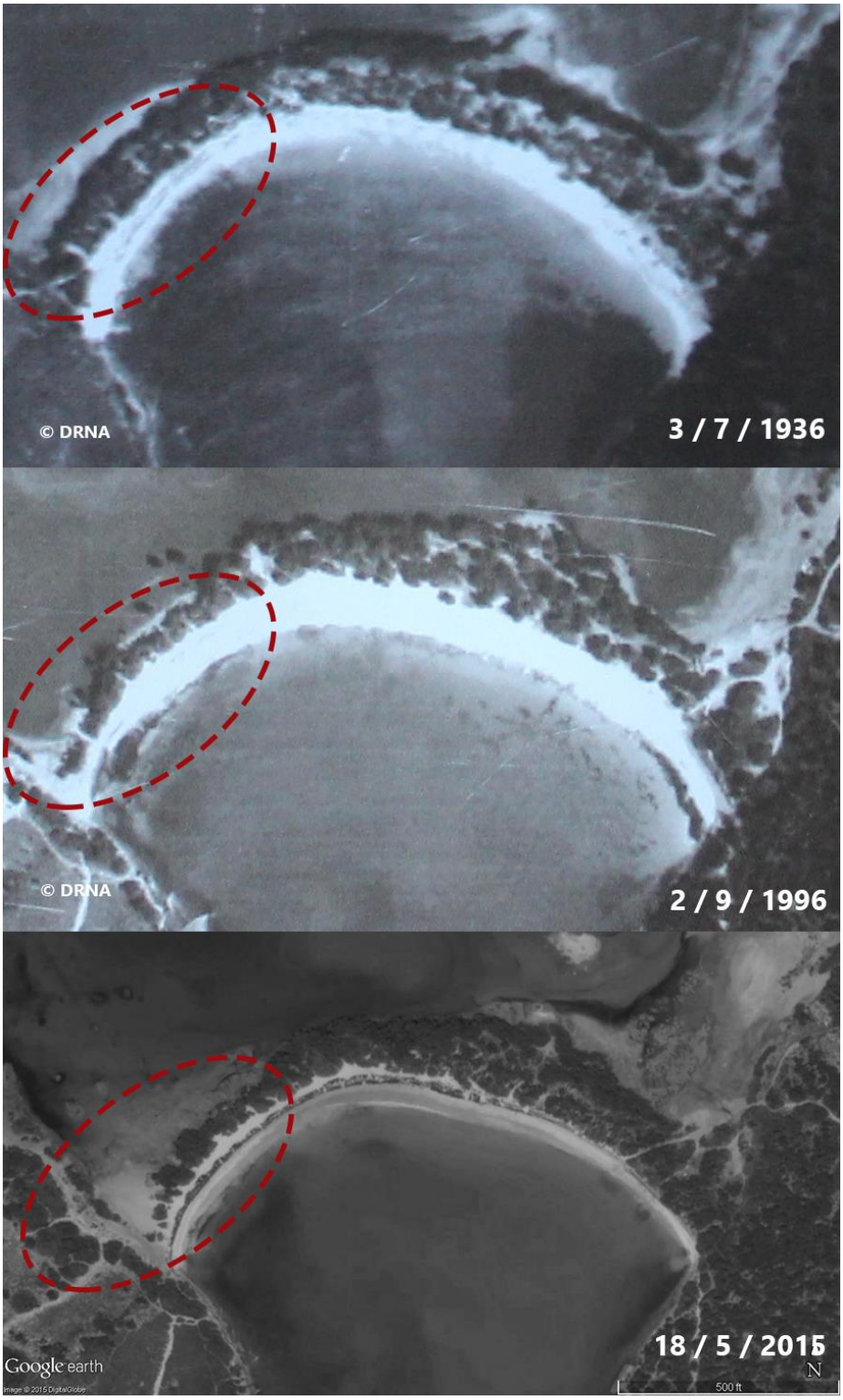

Figure 13 Comparison of Satellite Photographs of La Playuela

4.1.2. Interviews

The project team conducted in person and email interviews with many professionals within both the DNER and the FWS. More detailed findings from our communications can be found in Appendix D – Appendix H. Both governmental organizations manage land in Cabo Rojo and have many scientists working on conservation and research in the area. We spoke to individuals possessing a variety of job titles, many of whom work in the field daily and have observed changes in social and environmental conditions firsthand. From the DNER we spoke to Ernesto Díaz-Valázquez, Juan Casanova, Dárien López, and Edgardo Gonzáles. In addition, we met Oscar Díaz-Marrero and Mike Morel from the Fish and Wildlife Service in Cabo Rojo.

There was a general consensus among all individuals we interviewed that environmental conditions at La Playuela have begun to degrade rapidly in the past decades. Wildfires, littering, and damage to the marine ecosystem in the bay from boating were mentioned as growing issues by all familiar with the area. All of these problems negatively affect the wildlife; Mr. Morel noticed a much smaller bird population in 2015 than in years prior. Mr. González noted the absence of amenities such as restrooms and plentiful trash barrels offered at public beaches at La Playuela, though the DNER has no intentions of adding either. Human activity on the beach is causing change at rates that cannot be sustained for much longer.

Dárien López and Juan Casanova work regularly at La Playuela and were able to share with us the most information about the area. Both emphasized that La Playuela is first and foremost a protected area and the needs of plants and animals are put first by the DNER. They have been

opposed to adding more facilities and waste collection areas because they are an eyesore that detracts from the beauty of the landscape. As the beach is not public, they are not obligated to do so. In fact, adding them would not necessarily benefit the environment. So far, the beach has remained free of any man-made objects, save for a few signs.

However, many of their observations indicated that the general public does not take the same care in protecting the beach. Though the rangers enforce a car limit, Mrs. López explained that visitors simply park along the road in front of the gate and walk to the beach, taking shortcuts through the vegetation. She spoke about wildfires in the area, caused unintentionally by those who illegally cook on open flames or by arsonists with criminal intent. Perhaps the most prevalent issue is litter. Everything from single napkins to entire shopping bags of trash were seen left on the beach during our visit. About five years ago, the mangroves were thick enough that the wetlands behind could not be seen, according to Mr. Casanova. Now, he said, the wind can carry the trash throughout the forest. These issues combined with an inability to control the number of people contributing to them created a situation in which it is impossible for park rangers to adequately patrol the beach.

Ernesto Díaz-Valázquez and Edgardo Gonzáles both advised us to develop potential management strategies for the area as a more effective way of controlling degradation at La Playuela than a visitor cap. While both are familiar with the LAC framework, Mr. Gonzáles acknowledged that using a LAC plan is not the only option available, nor will we necessarily attain the best results by strictly adhering to the LAC format. He said, for example, if the conditions are already past an acceptable point, taking action should be top priority with less focus on environmental indicators. At La Playuela, it is already known that degradation has occurred past acceptable levels. From our

conversations with both Mr. Díaz-Valázquez and Mr. Gonzáles, we decided to look into potential management actions in addition to calculating a proposed numeric visitor limit.

From our communications, we determined that the DNER does not possess the resources needed to develop and implement a complete LAC management framework for the area at the current time. However, we learned that implementation of a visitor cap by itself is unlikely to be sufficient action to allow the wildlife at La Playuela to flourish as it did in years past. Therefore, the visitor cap must be combined with additional management strategies for the maximum benefit.

4.2. Assessment of the Usage of La Playuela

The second component of our analysis focused on the usage of the beach. Apart from data gathered through interviews and very limited data on the amount of visitors, we were unable to establish other external data sources. However, it was crucial to the project to have knowledge on the usage of the beach. In order to address this issue, we developed and administered a survey among visitors. Alongside with research on the effectiveness of education, the aforementioned visitation statistics, an analysis of comparable evacuation times in case of a fire, we were able to develop coherent numbers on the amount of cars that the DNER should allow in the area.

A successful management plan involves the larger picture including a full diagnosis of the area, alongside historical and cultural significance. By understanding the conflict, the area, the legal and institutional framework attached to the area and by developing management objectives, it becomes possible to offer a larger set of solutions.

4.2.1. Survey Response

As the degradation of the ecology at La Playuela is caused by human influence, it was of utmost importance to gather information on the perception of the beach in the public; knowledge about the area, in particular pertaining to the protected status of it; and lastly the willingness to follow measures to enhance the ecological state of the beach.

We designed a survey in Appendix B to gather this data. It was distributed to visitor groups on the beach during the weekend of the 14th and 15th of November, 2015. Even though this weekend falls outside the tourist season and thereby limited access to willing participants, we were able to gather 28 responses over the two days. The participant selection was solely limited by the physical presence on the beach and the property of one response per group.

The main problem the beach incurs is an overbearing amount of visitors at the same time. In order to address this issue, we mainly considered three factors in our survey. The first was growth in reoccurring visitors, as it gives a sense of the increase in visitation over time. The second was frequency of visitation, as it provides an understanding of how important beachgoers consider visiting this specific beach is as well as how impactful an educational campaign can be. Throughput is the last factor we considered, as it helps to realize how the beach becomes overcrowded and which countermeasures are most effective. La Playuela is considered to be a special venue, as the beach is visited less than once a month by the largest group of participants in our survey and because the timeframe of visitation has peaks between two to three hours and more than five. The pattern is even more prominent in returning visitors. Figure 14 shows a line diagram displaying the categories we used for time spent on the beach on the x-axis, while the y-axis shows the percentage of participants.

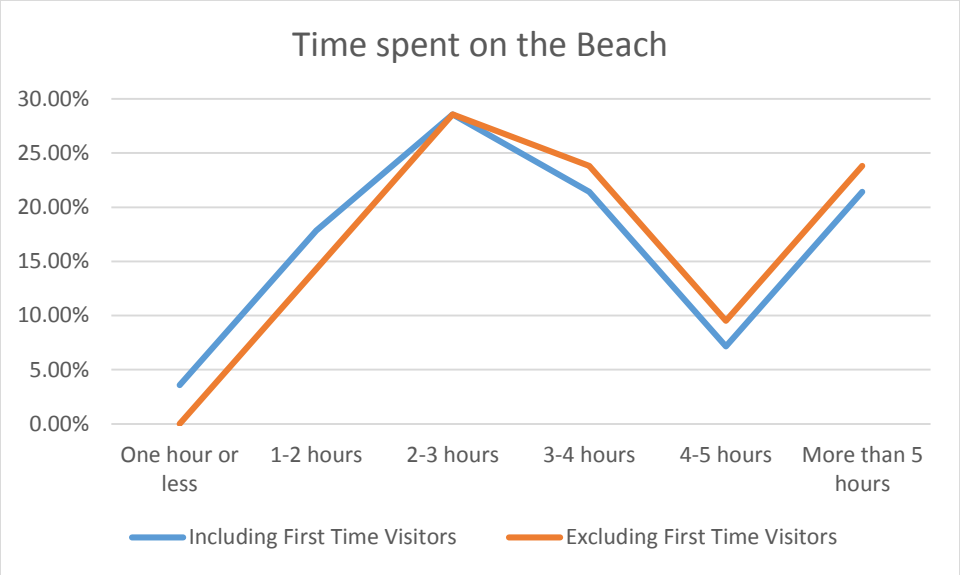

Figure 14 Time spent by beachgoers on La Playuela

This suggests that, while most visitors do not visit on a frequent basis, if they do, they stay for a long time and thereby enhance the potential of visitors compounding throughout the day. A low visitation frequency additionally suggests that beachgoers have to be properly educated before their visit, contrary to areas in which repeat visitors come on a more frequent basis and thereby possess an understanding of the rules and regulations. This becomes even more significant during the summer season in the third quarter of the year, which is the most popular time to visit according to our survey data.

The pressure on the beach is constantly growing and with it, the need for an effective management plan. We were able to find a linear growth in returning visitors throughout time and a comparatively high number of first time visitors (25%), therefore our data does not show any sign of relief for the beach. This conclusion is to be taken while bearing in mind that we surveyed on a

weekend outside of peak times and may change when more data becomes available, as long time visitors could be avoiding peak times on purpose.

La Playuela is said to be a weekend and holiday venue mainly for Puerto Ricans, who drive there from all across the island. We found that 89% of participants live in Puerto Rico, but only 29% were from Cabo Rojo. This bears conflict potential, as it suggests that visitors incur a substantial drive specifically to visit the beach, thus making them less likely to accept going to other venues if necessary. Our data shows that only 40% of the Puerto Rican group were willing to visit another beach if the gate is closed. A solution to this issue therefore has to address the need of an information system that allows visitors to determine available space before making the drive. Figure 15 displays the different proposed measures on the x-axis with bars. The group of all respondents is in orange, solely returning visitors in yellow and solely Puerto Rican residents in green. The y-axis displays the percentage of respondents that expressed their willingness to participate in the respective measure.

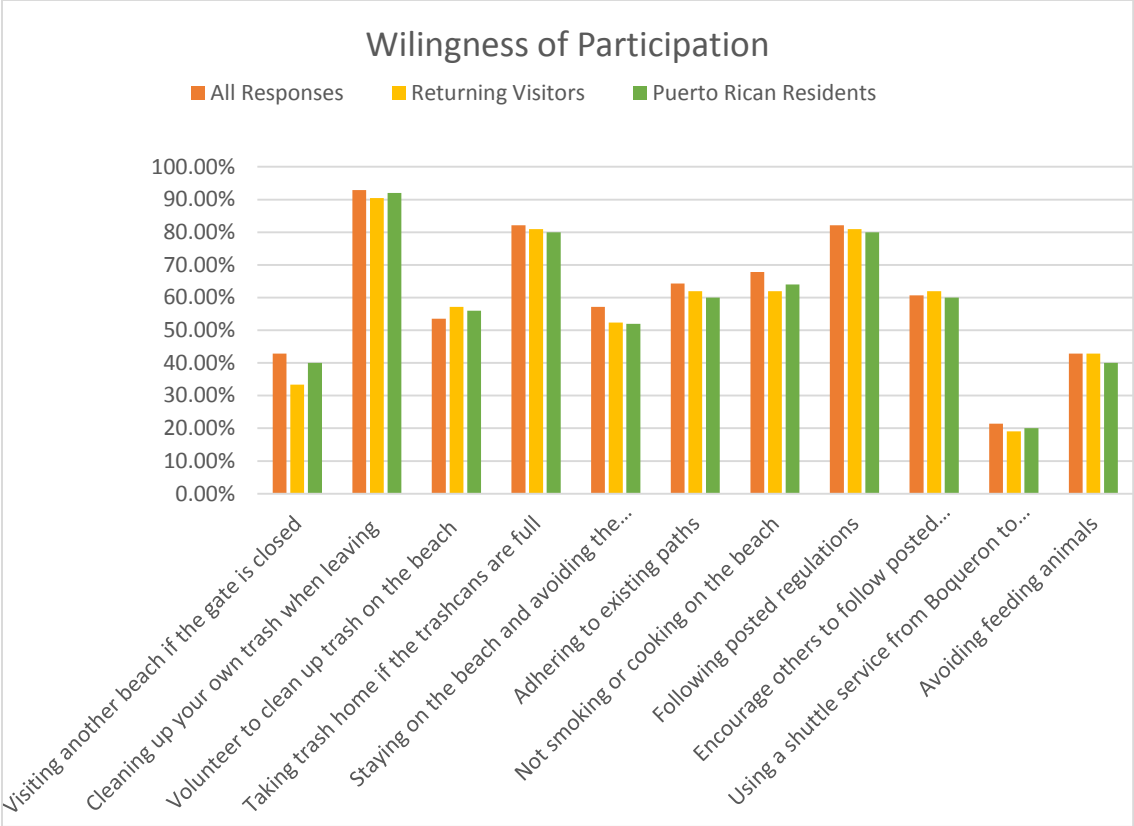

Figure 15 Willingness of beachgoers to participate in different measures

In order to address the aforementioned concerns, we saw the need to assess the willingness of participants to take part in alternative measures which have the potential to enhance the ecological state on the beach. While the most valuable conclusions from this data are explored later in this report, it is necessary to mention that the least prominent measure determined was taking a shuttle service from Boquerón town to La Playuela. Less than a third of all participants were willing to use such a service. In order to make this offer attractive, one would have to offer enough parking around the pick-up area in Boquerón, a cheap or even free price, and a reliable, frequent schedule. We therefore excluded this option from our recommendations as it requires an in-depth research on effective

schedules, parking capabilities in Boquerón, as well as financial, legislative and organizational concerns. We did, however, recommend bearing the option in mind for long-term management.

As previously stated, our survey days fell during a time of low tourism and the visitor count on the beach was much lower than peak times. In fact, we confirmed the most attractive tourist season is during the summer and early fall, as most returning visitors usually go to the beach in the second or third quarter of the year (52.38% and 76.19%, respectively). Therefore, the resulting data is not necessarily representative of all visitors over the course of a year. We recommended that the DNER re-administer the survey during the summer months to gain a more comprehensive understanding of the varying views held by beachgoers.

4.3. Assessment of La Playuela's Capacity

The third component of our analysis focused on determining the size of the area at La Playuela that should remain available for the public, after the most critical areas have been declared for restoration – prohibiting beachgoers from entering the area. Then we translated that capacity into a limit on the number of cars which should be permitted in the parking facility by considering the space that a typical car's group would need to be comfortable. The number we arrived at represents an absolute maximum which, if exceeded, would guarantee that tourists are occupying the restoration zone.

Figure 16 below uses Google Earth Pro to superimpose a polygon representing this available-use area onto a satellite photo of the La Playuela beachfront. Figure 17 shows the Google Earth 'more info' window with the spatial parameters of that polygon, including the area: 1567 meters squared.

Figure 16 Polygon in Google Earth Pro encapsulating available-use zone

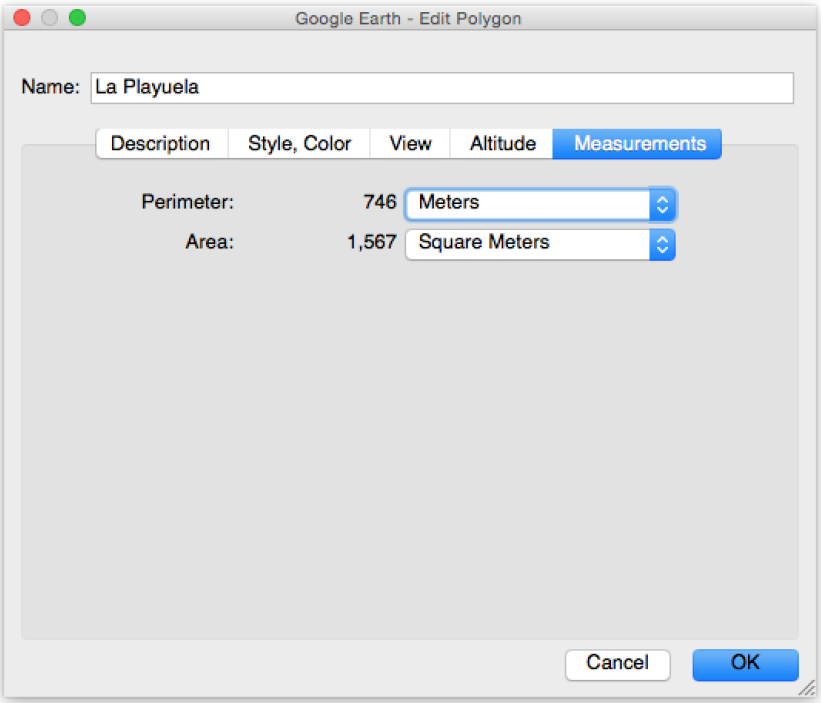

Figure 17 Spatial parameters of available-use polygon

To convert this number into a maximum number of vehicles, we considered how many people a typical car will hold, and thus what square area that group should have available to be comfortable. Our survey results indicate that, unsurprisingly, the typical car brings roughly four people. We assumed that each person brings a beach towel for themselves, measuring in at 30 inches by 70 inches, or 1.355 meters squared (D. C., n.d.). The group can be reasonably expected to be comfortable with 3 feet of space around them (Augustin, 2014). Altogether, with four towels next to each other and 3 feet of buffer space, we get that each car's group will occupy an average of slightly over 5.4 square meters of the 1567 available. Dividing these two results yields the capacity: there should be no more than 136 cars allowed at once, which equates to approximately 545 people.

We used Mathcad software to illustrate the process and result of these calculations, shown below in Figure 18.

$$group\_size := 4 \qquad buffer\_distance := 3ft \qquad beach\_area := 1567m^2$$

$$towel_{length} := 70in \qquad towel_{width} := 30in$$

$$area_{person} := towel_{length} \cdot towel_{width} = 1.355m^2$$

$$area_{group} := group\_size \cdot area_{person} = 5.419m^2$$

$$area_{buffer} := 2 \cdot towel_{length} \cdot buffer\_distance \ldots = 12.17m^2$$
$$+ 2group\_size \cdot towel_{width} \cdot buffer\_distance \ldots$$
$$+ 4 \cdot buffer\_distance^2$$

$$group\_limit := \frac{beach\_area}{area_{group} + \frac{1}{2} area_{buffer}} = 136.208$$

$$visitor\_limit := group\_size \cdot group\_limit = 544.831$$

Figure 18 Calculations to determine parking capacity

4.4. Future Legislation

As the DNER is a governmental body, it seeks to create new laws and regulations for La Playuela to decrease the amount of degradation. The Forest Act of Puerto Rico, Law 133, created in 1975, grants the government the authority to create regulations as deemed necessary to protect the environment and the ability to issue fines when any regulation created under the law or the law itself is broken ("Ley de Bosques de Puerto Rico," 1975, June 1). There are a variety of legislative options available to the DNER, though all actions are limited by the available funds and personnel. However, the project team was unable to analyze the resources necessary for implementing our proposed strategies. Upon identifying the need for additional managerial action, the DNER would perform the analysis and select the most effective strategy. Creating explicit conditions through regulations for

what is acceptable and what is not allows the vigilantes and rangers to enforce the agreed upon limits consistently. The most immediate proposed change resulting from this report is a strict limit in the number of visitors allowed at La Playuela.

4.4.1. Educational Campaigns

One issue we found surveying was that while most people (85.71%) do know that the beach is in a protected area, they are not aware of why it is protected and what regulations pertain to it. For example, only 92.86% of participants were willing to clean up their own trash and merely 64.29% are willing to adhere to existing paths. Additionally, less than half of all beachgoers we asked considered to avoid feeding animals as an option. This poses a threat to the ecosystem at La Playuela, as invasive species, in particular stray cats, are having a detrimental impact on shorebirds (Bies, 2014)

Therefore, we suggested running an educational campaign aimed at making visitors aware of the regulations and the effects of different actions on the beach. In particular, we advised implementing in the campaign:

Reasons for the Protected Status An effective campaign educates visitors as to why the area is protected, thereby enabling them to understand the reasoning behind regulations. In this case, it must highlight that La Playuela and its surrounding area are a habitat of several endangered species, living in a unique ecosystem which even gained recognition as a National Natural Landmark. We advised that all endangered species, their relevance, dangers to their habitat and the unique geographic situation be included.

Regulations at the Beach As to the lack of education on the rules that apply in the area, we advised that the most relevant rules be posted in a visible space on the beach entrance. We considered these to be all regulations pertaining to the prohibition of open flames, wildfires and arson, trash policy and, if implemented, the avoidance of the shady mangrove areas on the beach. Only 40% of returning beachgoers who participated in our survey realized that the plant life at the beach had declined. It is thereby crucial to display the difference of how the beach used to look before major human influence and its current status.

Invasive Species Another important educational gap existed in the impact of invasive species on the ecosystem. We recommended that a campaign include an explanation of the negative results of feral cats on the area, in particular on birds, in order to keep people from feeding them.

Educational signs were suggested to be placed at the entrance of the beach, where the path from the lighthouse and parking meet. It currently carries a mono-lingual sign denoting what is allowed in pictograms with very little informational text. Additional signs, once put up, clarify and give rangers the ability to specifically point to them when monitoring the beach.

4.4.2. Declaration of Restoration Zones

We suggested declaring all mangrove areas on the beach as restoration zones and not allowing any visitors to be within the zone at any time. In multiple interviews, we were told that the mangrove area has been declining as a result of increased use. This is supported by analysis of the historic satellite photographs provided by Juan Casanova. While humans continue to sit beneath the mangroves for

shade and disturb the vegetation, the plant population will continue to decline. Reduced mangroves have already affected the integrity of the beach and have allowed litter to be spread much more readily by the wind. Mr. Gonzales expressed a need for a buffer zone between areas integral to the wellbeing of vegetation and areas approved for heavy human use. Disallowing human activity in mangrove areas promotes an increase in tree density and creates additional habitats for wildlife.

Signs marking the beginning of the buffer zone have to educate people on the significance of mangroves to the natural area as well as the difference in tree density throughout the time, as only 40% of returning beachgoers who participated in our survey realized that the plant life at the beach had declined. It is thereby crucial to display the difference of how the beach used to look before major human influence and its current status.

Without the availability of mangrove areas providing shady locations to relax, beachgoers are likely to spend less time at La Playuela per visit, increasing the throughput of the beach. Other beaches offering more amenities and fewer restrictions provide alternative locations for those who require shelter from the sun. Implementing this strategy has the potential to benefit the entire beach, not only the restoration areas.

4.4.3. Carry-In Carry-Out Trash Policy

Litter is a big problem at La Playuela. When the beach first became popular, the amount of garbage left on the beach skyrocketed. In more recent years, litter has declined, but remains an issue. The DNER is unwilling to increase the number of trash receptacles or place them in more easily accessed locations as it would detract from the scenery (Casanova, 2015). There are currently two sets of receptacles, located in each main parking area. This means that there are no receptacles on the

beach or hiking trails. Unfortunately, some visitors leave their trash behind as they exit the area rather than carry it to the appropriate location.

Carry In Carry Out is a trash policy used in certain other parks throughout the United States including all state parks in Maryland and southwest Pennsylvania, most state parks in Wisconsin and Delaware, and some state parks in Ohio, Virginia and Washington D.C. ("Being Green at our Parks and at home," 2009; "Carry in / carry out," 2013; "Delaware State Parks Rules," n.d.; "Leave no Trace," n.d.; "Picnic Areas & Shelters in Ohio State Parks," 2015). The program consists of removing all trash receptacles from the area and instead providing small bags for visitors to place their trash in and bring it home with them. This program aligns with the DNER's vision for preserving the beauty of the area by eliminating trash receptacles altogether which are eyesores and food sources of stray animals. The responsibility of trash collection is clearly and directly placed on the visitors themselves. While all refuse collected at La Playuela is currently regarded as trash and treated as such, a Carry In Carry Out policy may indirectly lead to an increase in recycling. In bringing their waste home, visitors may be inclined to use reusable containers and recycle their cans rather than throw them in the trash ("Delaware State Parks Rules," n.d.). In an interview with an employee of the state of Delaware working with the state parks, the Carry In Carry Out policy in Delaware is enforced by the Park Natural Resources Police. Signs are posted about the policy and bags are provided for collecting waste for transportation out of the park. Savings from eliminating trash removal in the Delaware parks have amounted to $55,000 (Wilson, 2015). Our survey clearly showed that people are willing to clean up their trash (92.86%) and most are willing to take their trash home if the trashcans are overflowing (82.14%). This leads us to the conclusion, that a Carry In Carry Out policy is feasible at La Playuela, as long as visitors are sufficiently educated on the matter.

4.4.4. Reservation Ticketing System

Suggested by Mr. Diaz, an online reservation system would allow rangers to more easily keep track of the number of visitors to La Playuela. He proposed that such a system would make the demand and limited availability more visible, therefore highlighting conservation efforts in the area. Considering that 89% of visitors in our survey were Puerto Rican, but 71% were not from Cabo Rojo, led us to the suspicion that most incur a substantial drive, especially in combination with the result that 60% are not willing to visit another beach if the gates are closed. A reservation system addresses this problem. The system has to inform visitors about availability at the beach during the time frame they want to visit, which not only leads to an effective limitation on visitors, but also provides the auxiliary benefit of a decreased number of cars turned away at the gate resulting in higher visitor satisfaction. In order for this to be effective, people will have to be informed that there is no entry without reservation at least during the peak season. The reservations need to be checked by rangers upon entry. An additional advantage is that this provides the DNER with accurate visitation statistics during high frequentation times. However, the logistics involved in developing such a system are not insignificant. Time, money, and expertise are needed to get such a website functioning properly. For one, it has to be responsive in order to enable visitors to make a reservation on site if there is space available. The system can track visitor statistics, which requires data collection capabilities. Overall, we deemed such a system as an incredibly valuable option, if implemented correctly.

4.4.5. Indicators to effectively implement the LAC in the Future

As stated earlier, we were not able to apply the Limits of Acceptable Change framework due to a lack of relevant data over time on the area. In order to address this issue, we proposed to the DNER to record the following sets of data:

Tree Density Throughout our research, we found that a major issue in the area is that less mangroves exist on the backside of the beach, due to the unsustainable use by beachgoers (Casanova, 2015, Morel, 2015, 9 November). Objectively recording data on tree density therefore serves as a basis of a sensible recommendation of an acceptable limit in this matter. Tree density is measurable by counting the number of stems at the beach and dividing the area by this number (Sampling Trees, 2011). The density should be tracked periodically, once a year at minimum.

Nesting Data Another particular useful measure is nesting data, as it provides another objective measurement of the ecological state in the area. Bird nesting data serves as an indicator of species diversity and enables analysis of trends over time. The same applies to turtle nests. All data has to be recorded periodically and taking into consideration the different nesting seasons the species follow.

Visitor Statistics Periodical visitor statistics are another measure that helps to establish usage patterns, core seasons and accurately quantifies overcrowding. This data can be gathered most easily and reliably through a well-established information system, but alternatively can be collected by manual counting. In addition to these counts, a survey can be administered annually during the peak season to establish the effectiveness of measures.

Trash A more unconventional measurement we propose is to collect trash on the beach monthly and weigh it. This allows for an objective comparison of the effectiveness of the Carry In Carry Out policy proposed and enables the establishment of a basic acceptance level in the area. Additionally, it helps to develop more effective educational campaigns.

Pictures Determining change in an ecological system is not necessarily obvious, as vegetation changes by season. Annual pictures, taken in the exact same conditions such as date, time and location, allow for a differentiation of changes over time. While satellite pictures are preferred, they are harder to obtain, in particular in exact same conditions. We therefore propose taking pictures from the top of the lighthouse towards the beach, which provides an insightful overview of the area, in which changes are detectable. Pictures should be taken once during summer and once during winter, to see differences during and outside of peak times.

5. Conclusion

The result is clear from our findings, that La Playuela cannot healthily sustain the volume of visitors that it currently experiences. The most obvious manifestation of this issue is seen in the increasing trash and decreasing density of the mangroves immediately adjacent to the beach. Our primary recommendation for La Playuela's management plan is that it prohibit tourists from setting up under the mangroves. As it stands now, beneath the mangroves is the very first place tourists seek to occupy – since their canopy offers the only shade around, and their branches offer support for

hanging bags. It's a natural location for beachgoers to occupy, so they will continue to do so unless explicitly prohibited.

However, it would be counterproductive to reduce the available space on the beach without adjusting the maximum number of simultaneous visitors accordingly. To determine a reasonable occupancy cap, we measured the square footage of usable beachfront which does not fall under the mangroves and applied considerations for how many people a typical car brings as well as how much room is needed for a group to be reasonably comfortable. We measured the usable area to be 1567 m^2. Our surveys indicated that a typical car will bring four people to the beach. A normal beach towel – one for each person – measures in at 30 inches x 70 inches, or 1.355 m^2. Each group can be reasonably expected to be comfortable with 3 feet of space around them. This means the typical car's occupants should take up slightly over 5.4 m^2 of the 1567 m^2 of beach space available. Dividing these two results yields the capacity: there should be no more than 136 cars allowed at once, approximately 545 people.

To reduce the number of visitors turned away at the gate, a reservation system is a promising option. Although it requires knowledge of computer systems to implement, if offers many benefits to the rangers on patrol and the visitors. Beachgoers will be able to reserve spots in advance and know if the beach has reached capacity before arriving. Rangers will not have to guess when the beach is full. Once implemented, visitor statistics such as number of people per group and exact number of visitors per day can be easily recorded and stored digitally by the municipality or the DNER.

An educational campaign accompanying any new regulations will inform visitors of the acceptable uses of the beach and explain why certain conditions are problematic. Instances of accidental wildfires may be reduced by explaining their causes. To combat the issue with litter at the

beach and in the surrounding forest, we suggest implementing a Carry In Carry Out policy in which the trash barrels are removed and beachgoers are instead provided small plastic bags to bring their refuse home with them. Signs denoting which activities are allowed and disallowed in text as well as pictograms will clarify existing regulations. Educational materials explaining why La Playuela is protected and that its wellbeing is dependent upon the conscientiousness of all visitors involves the community in the conservation efforts.

Additionally, we suggest that the DNER starts collecting data on several indicators which will help to establish minimal acceptable limits of the ecological state in the future. We recommend the following four indicators: tree density, which gives an objective measure of change in larger timeframes and should be assessed yearly; turtle and bird nesting, which helps assessing animal populations and trends and needs to be assessed during species relevant nesting times; visitor statistics, which indicates popularity of the beach and should be assessed continually, particularly however in peak season; and lastly, amount of trash, which should be assessed monthly in order to understand how much trash accrues on the beach and how that changes through seasons. Additionally, the DNER should administer a survey during different seasons to gather information on demographics, the attitude of visitors towards the beach and proposed measures, as well as knowledge about the area.

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Appendix A: National Natural Landmark Cabo Rojo Brief

U.S. Department of the Interior
National Park Service
National Natural Landmarks Program

Name: Cabo Rojo

Location: Puerto Rico

Description:

The boundaries for this 593-acre site include the Y-shaped tied island (Complex tombolo) Cabo Rojo and the surrounding sea. It is situated at the extreme southwest tip of Puerto Rico. The site is actually two islets composed of Miocene Ponce Limestone joined to each other and the mainland by sand spits. The spit, which joins the islets to the mainland, is about .6 miles in length. The spit, which joins the two islets to the south, encloses a salt water lagoon. The islands are about 65.5 feet in elevation and present steep cliffs to the south.

Rainfall on the tombolo is about 30 inches per year. The vegetation is of the degraded coastal type (seasonal formation of thorn woodland, cactus scrub, and desert), which a typical savanna type being well preserved on the eastern island. This includes the grass *Unida variegata*, a rare orchid (*Tetramicra elegans),* cacti and thornbush.

On the western island there are small breeding colonies of least terns and the only known colony of snowy plovers. Other breeders include black necked stilt, Wilson's plover, yellow shouldered blackbird, osprey, and peregine falcon.

Significance:

The site includes an excellent example of a tombolo (tied island) with double spit, mangroves, beaches, reddish cliffs, xeric vegetation, and seabird nesting habitat. The site is also exceptionally scenic.

Ownership: Commonwealth of Puerto Rico

Designation: April 1980

Evaluation: Gail Baker, U.S. Fish and Wildlife Service; Frank Wadsworth, U.S. Forest Service; and John Weaver and Jose Vivaldi, University of Puerto Rico.

Natural Landmark Brief April 2014

Appendix B: Surveys

The team offered the survey in both English and Spanish to increase participation.

English ▼

Tourism at La Playuela Beach

You are being invited to participate in a research study about assessing tourism at La Playuela beach. This study is being conducted by Tyler Tao, Tim Marschall and Austin Rose under supervision of Dr. Karla Mendoza-Abarca from the Foisie School of Business at Worcester Polytechnic Institute. It is part of an undergraduate student project in cooperation with the Department of Natural and Environmental Resources (DRNA).

There are no known risks if you decide to participate in this research study. There are no costs to you for participating in the study. The information you provide will be used to develop a management plan for La Playuela. The questionnaire will take about 3 minutes to complete. The information collected may not benefit you directly, but the information learned in this study should provide more general benefits.

This survey is anonymous. Do not write your name on the survey. No one will be able to identify you or your answers, and no one will know whether or not you participated in the study. Individuals from the DRNA and the Institutional Review Board may inspect these records. Should the data be published, no individual information will be disclosed.

Your participation in this study is voluntary. By completing, you are voluntarily agreeing to participate. You are free to decline to answer any particular question you do not wish to answer for any reason.

If you have any questions about the study, please contact:

Tyler Tao
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401-533-3158

Austin Rose
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Dr. Karla Mendoza-Abarca
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330-357-2873

The Worcester Polytechnic Institute Institutional Review Board has reviewed our request to conduct this project. If you have any concerns about your rights in this study, please contact the WPI IRB at irb@wpi.edu.

Do you live in Puerto Rico?

Yes No

Do you live in Cabo Rojo?

Yes No

How long have you been coming to the beach?

Less than a year Less than five years Less than 10 years More than 10 years

How often do you come to this beach?

Never been here before	Less than once a month	Once a month	Once a week	More than once a week

How many people do you usually come with?

1	2	3	4	5	More than 5

How much time do you usually spend on a visit?

One (1) hour or less	1 - 2 hours	2 - 3 hours	3 - 4 hours	4 - 5 hours	More than 5 hours

Are you aware that the beach is part of a natural protected area?

Yes No

What time(s) of the year do you usually visit the beach? (You may choose multiple answers)

January - March	April-June	July - September	October-December

How has the plant life changed at La Playuela since you first visited?

It has increased (There are more plants)

It has stayed the same

It has decreased (There are fewer plants)

How has the amount of litter changed at La Playuela since you first visited?

It has increased (There is more litter)

It has stayed the same

It has decreased (There is less litter)

Compared to your last visit to La Playuela, were your expectations met today?

- ○ Yes
- ○ No

If not, why?

What activities are you willing to participate in to improve the quality of the beach?

- ☐ Visiting another beach if the gate is closed
- ☐ Cleaning up your own trash when leaving
- ☐ Volunteer to clean up trash on the beach
- ☐ Taking trash home if the trashcans are full
- ☐ Staying on the beach and avoiding the tree areas
- ☐ Adhering to existing paths
- ☐ Not smoking or cooking on the beach
- ☐ Following posted regulations
- ☐ Encourage others to follow posted regulations
- ☐ Using a shuttle service from Boqueron town to the beach instead of driving
- ☐ Avoiding feeding animals

Do you have any comments or suggestions to the DRNA?

Español ▼

Tourism at La Playuela Beach

Está invitado a participar en una investigación sobre el turismo en La Playuela. Esta investigación está conducida por Tyler Tao, Tim Marschall, y Austin Rose bajo la supervisión de la Dra. Karla Mendoza-Abarca en la Universidad de Negocios Foisie de Worcester Polytechnic Institute (WPI). Es parte de un proyecto escolar en conjunto con El Departamento de Recursos Naturales y Ambientales (DRNA).

No hay ningún riesgo conocido si decide participar en esta investigación. No hay ningún precio por participar. La información va a ser usada para desarrollar un plan de manejo para La Playuela. El cuestionario va a tomar más o menos tres minutos para completar. La información no le proveera beneficios directos, pero la información aprendida en esta investigación debe proveer beneficios generales.

El cuestionario es anónimo. No escriba su nombre en el cuestionario. Personal del DRNA y la Junta de Revisión Institucional de WPI puede que examinen las respuestas. Si la información es publicada, la identidad de los participantes no sera revelada..

Su participación en este cuestionario es voluntaria. Al completarlo, está aceptando participar voluntariamente. Puede rechazar a responder cualquier pregunta si no desea responderla por cualquier razón.

De tener dudas o preguntas, favor contactar a:

Tyler Tao
tetao@wpi.edu
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El Junta de Revisión Institucional de Worcester Polytechnic Institute ha revisado nuestra solicitud a llevar a cabo esta investigación. Si tienes preguntas sobre tus derechos, contacta al Junta de Revisión Institucional de WPI a irb@wpi.edu.

¿Vives en Puerto Rico?

Sí No

¿Vives en Cabo Rojo?

Sí No

¿Por cuántos años has visitado a La Playuela?

Menos de un año Menos de cinco años Menos de diez años Más de diez años

¿Con qué frecuencia visitas La Playuela?

Es la primera vez	Menos de una vez por mes	Una vez por mes	Una vez por semana	Más de una vez por semana

¿Con cuántas personas llegas, usualmente?

1	2	3	4	5	Más de 5

¿Cuánto tiempo pasas en cada visita?

Una (1) hora o menos	1-2 horas	2-3 horas	3-4 horas	4-5 horas	Más de 5 horas

¿Eres consciente de que La Playuela es un área protegida?

Sí No

¿En qué época del año usualmente visitas La Playuela? (Puedes elegir múltiples respuestas)

Enero – Marzo	Abril – Junio	Julio – Septiembre	Octubre – Diciembre

¿De qué manera han cambiado las plantas de La Playuela desde su primera visita?

Han aumentado (hay más plantas)

No han cambiado

Ha disminuido

¿De qué manera ha cambiado la cantidad de basura en La Playuela desde su primera visita?

Ha aumentado

No ha cambiado

Ha disminuido

¿Basado en su última visita, La Playuela ha cumplido sus expectativas?

- ○ Sí
- ○ No

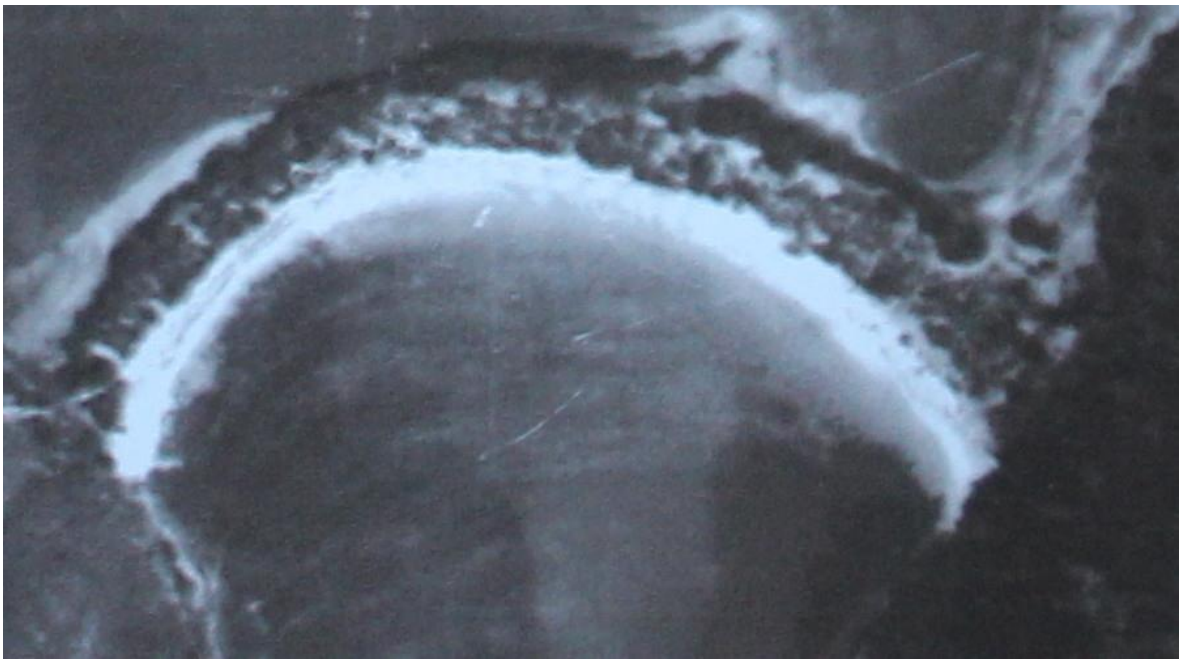
¿Si no, por qué?

¿En qué actividades está dispuesto a participar para mejorar la calidad de la playa?

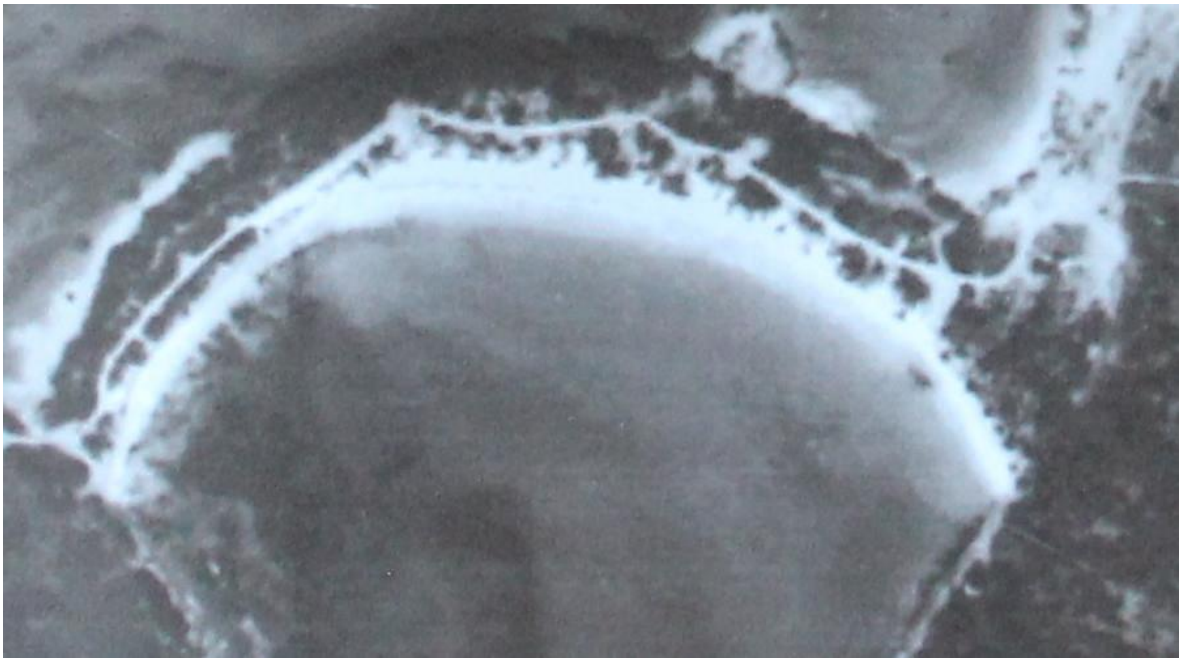
- ☐ Visitar otra playa si el portón está cerrado
- ☐ Recoger su basura cuando salga
- ☐ Trabajar de voluntario para limpiar la basura en la playa
- ☐ Llevarse la basura a su casa si los zafacones están llenos
- ☐ Mantenerse en la arena y evitar las áreas del bosque
- ☐ Mantenerse en los caminos existentes
- ☐ No fumar o cocinar en la playa
- ☐ Seguir las reglas publicadas
- ☐ Fomentar que los demás sigan las reglas publicadas
- ☐ Usar un medio de transporte público de Boquerón a La Playuela en vez de conducir
- ☐ Evitar alimentar a los animales

¿Tiene otros comentarios o sugerencias?

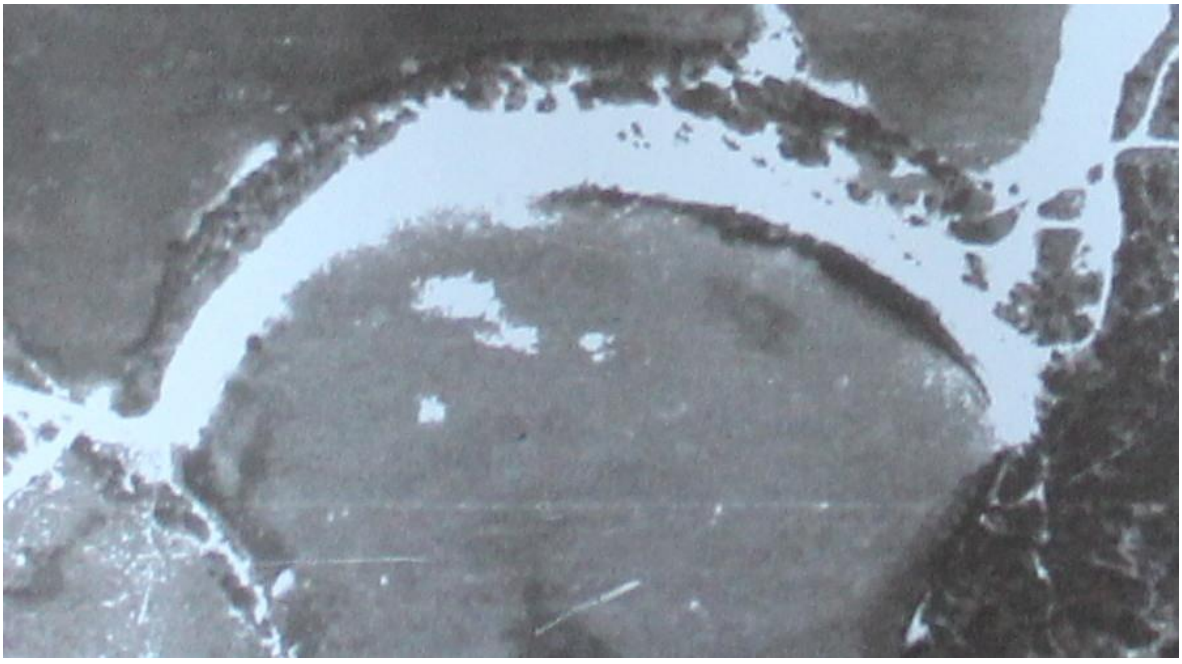
Appendix C: Satellite Photographs



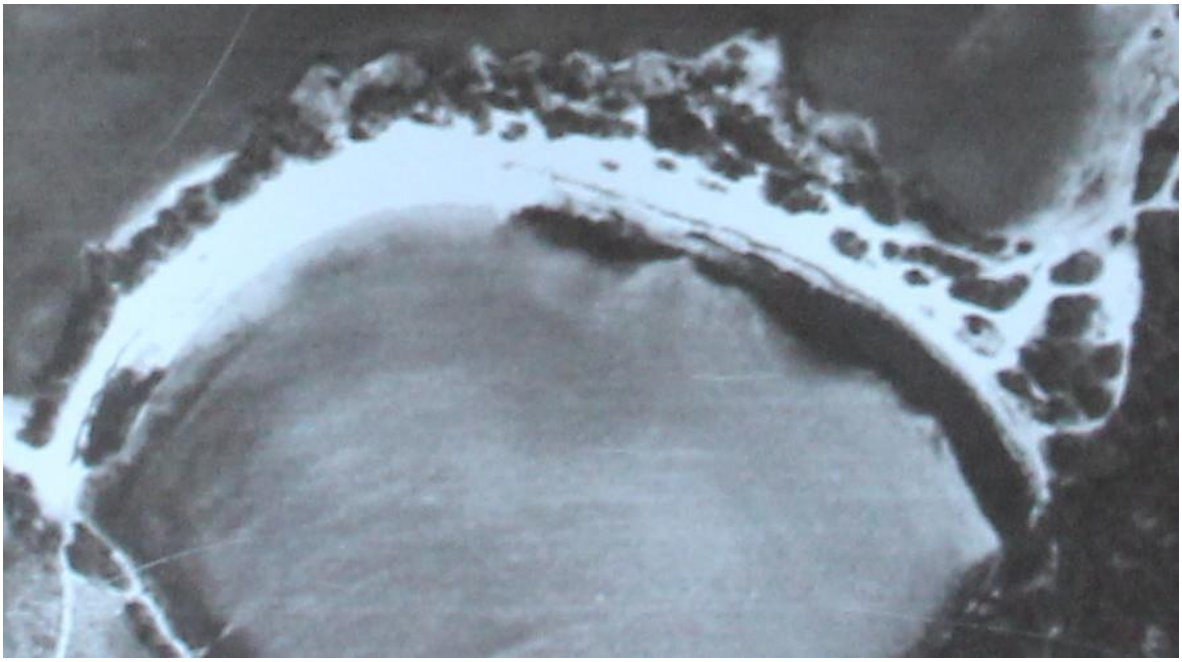
1936
Courtesy of the DNER
(1936, Cabo Rojo)



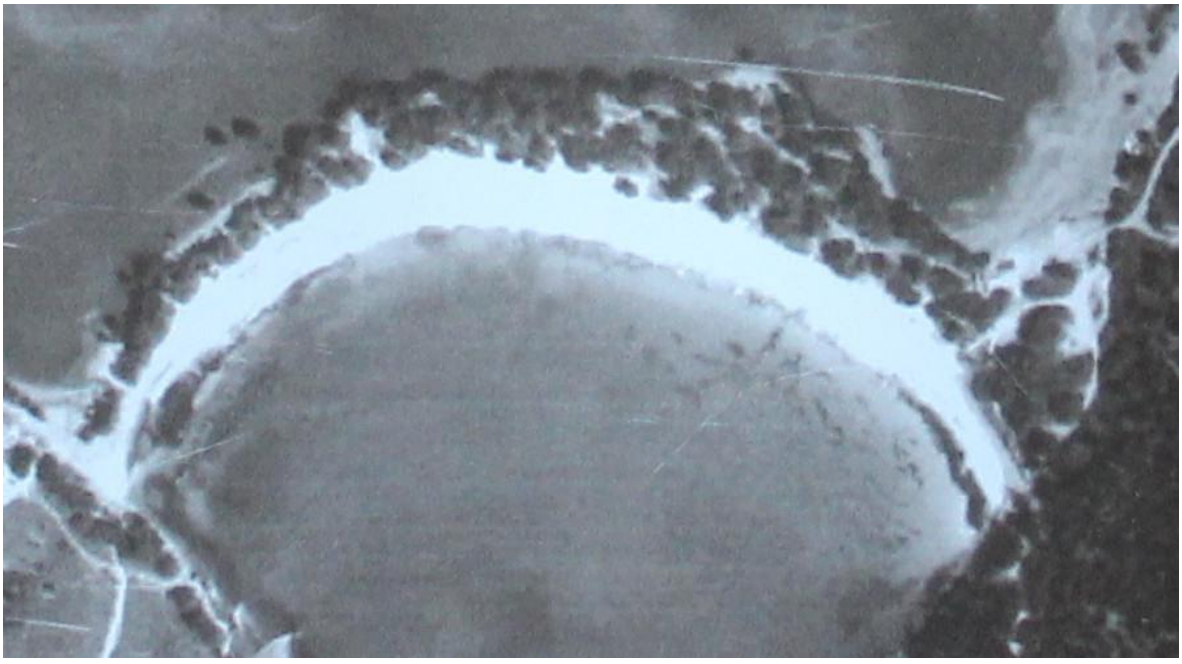
1963
Courtesy of the DNER
(1963, Cabo Rojo)



1977
Courtesy of the DNER
(1977, Cabo Rojo)



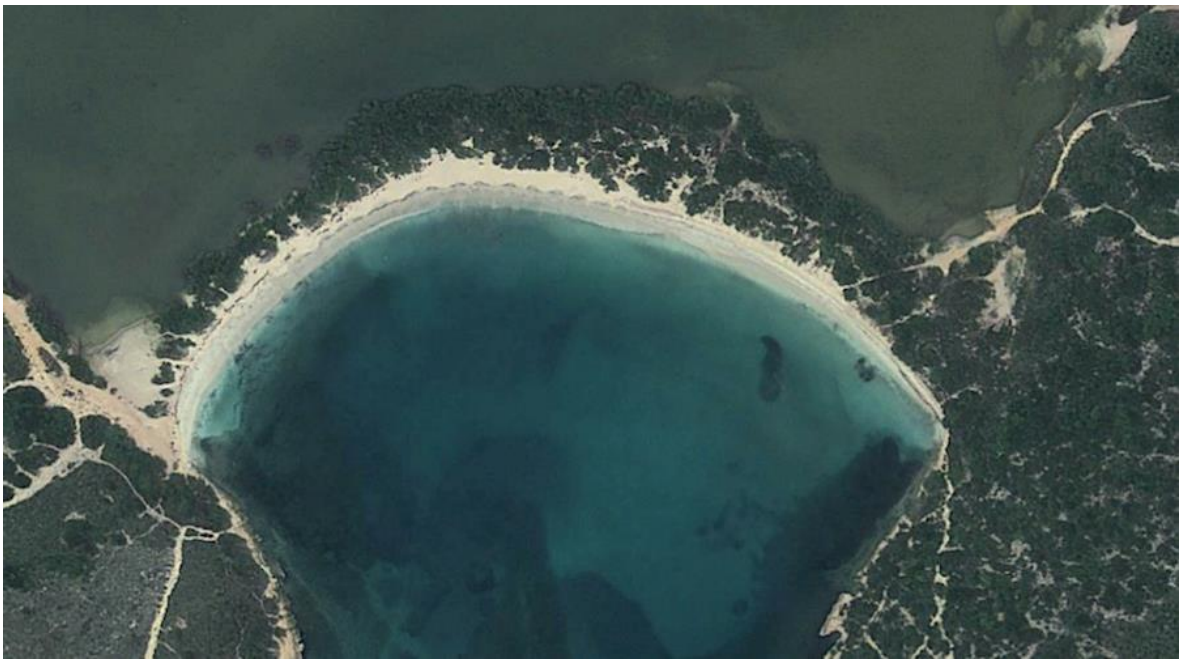
1983
Courtesy of the DNER
(1983, Cabo Rojo)



1996
Courtesy of the DNER
(1996, Cabo Rojo)

2009
Obtained from Google Earth Pro
(DigitalGlobe, 2009)

2010
Obtained from Google Earth Pro
(DigitalGlobe, 2010)



2012
Obtained from Google Earth Pro
(DigitalGlobe, 2012)

Appendix D: Interview with Oscar Diaz-Marrero

Mr. Diaz met with us on 4th November, 2015 at one of the US Forest Service Offices in Cabo Rojo. Wildfires at La Playuela have been killing native species and cannot be easily controlled. He mentioned a native species of grass, Arustuda chaseae, and detailed the current actions being taken to reintroduce it to La Playuela. This native grass is fire resistant, slowing the progression of wildfires because it grows in dense clumps, unlike the invasive African grasses that currently dominate the area. He pointed out that the grass is not, however, completely fire proof. Mr. Diaz informed us that of all the beautiful sights in Puerto Rico, La Playuela is one of only four National Natural Landmarks as designated by the National Parks Service for its unique geography. At the end of our interview, he pointed us to Mike Morel, who we should ask for turtle data.

Appendix E: Interview with Ernesto Díaz-Valázquez

We met Mr. Díaz-Valázquez on the 5th of November 2015 in the main office of the DNER in San Juan. Throughout our interview, he helped us understand more about the development process of a management plan. In particular, he highlighted that a limit on the amount of visitors alone is not going to solve the problem in the area. More general thresholds should be used to restrict environmental change. Mr. Díaz-Valázquez identified forest fires, drug smuggling, and anchoring of jet skis and boats as some of the current issues at La Playuela. He informed us that there is a shuttle service from the town of Boquerón to La Playuela, but it is unreliable and not often utilized. Also that the busiest times of year are Easter week, Fourth of July weekend, long weekends, and May through August. In addition, he pointed us toward Edgardo Gonzáles who worked on the most recent LAC plan in Puerto Rico.

Other resources suggested to us by Mr. Díaz-Valázquez were the website for the Carribean regional ocean partnership, carribeanllcc.org, caricoos.org, pr1930.revistatp.com for images dating back to 1930, and Google Earth to view areal images dating back to 1993.

Appendix F: Interview with Juan Casanova and Dárien López

Juan Casanova and Dárien López met with us on the 6th of November 2015 at La Playuela. Mr. Casanova works full-time in Cabo Rojo, managing La Playuela and the other protected areas in the surrounding municipalities since 2010, while Mrs. López oversees many protected areas in varying locations. Mrs. López acted as a translator for Mr. Casanova, as well as shared her own knowledge of the area with the project team.

They discussed many problems related to enforcing the current visitor limit. The current car limit is 120 cars, approximately equivalent to 750 people. Mrs. López explained the limit was increased from 80 cars due to pressure from the mayor's office. After the limit is reached, people park along both sides of the road leading into La Playuela and walk to the beach. As they walk, littering and shortcuts through vegetation increase the damage to the area. Unfortunately, neither Mr. Casanova nor Mrs. López have any statistics regarding arrivals to the area by car or boat. In the past, the area was only visited by locals who used the area to camp. It did not become a tourist destination until students from the University of Mayaguez posted pictures online and tourism companies created the tagline "If you don't visit La Playuela, you didn't visit Puerto Rico." During the summer, the southwest of Puerto Rico is the center for tourism with 60-80 thousand visitors present in a single weekend.

The salt flats north of La Playuela host most of the migratory birds in Puerto Rico. When the sea level rises, the ocean connects with the wetlands directly behind the beach. The increased salinity alters plant life with the potential for affecting species distribution. Mr. Casanova noted that approximately 5 years ago, it was not possible to see the wetland from the beach through the mangrove. The team observed that it is now possible to easily see through the mangroves from any

location on the beach and even walk directly through to the wetlands. He informed us that one of the largest implications of this is that trash now is taken by the wind and distributed throughout the wetlands. Another issue is wildfires. Earlier this year, there was a 30 acre wildfire; last year, a total of three wildfires occurred. In Puerto Rico, 95% of all fires are caused by human activity, either accidental or criminal. Rangers do not always patrol the beach and, due to lack of personnel, cannot be expected to constantly monitor beach activities.

In our development of recommendations, Mr. Casanova and Mrs. López had some requests. They do not wish to add more trash receptacles or place them in conspicuous locations at the beach. As the DNER has recently decreased in size, the department does not have many available resources for implementing new strategies. Keeping this in mind is an integral component to suggesting relevant management strategies for future action.

Appendix G: Interview with Mike Morel

We had the chance to have a brief exchange with Mike Morel via e-mail. Mr. Morel has been living in Cabo Rojo since 1973 and has visited La Playuela many times over the decades. He described the beach as being rarely visited up until approximately the new millennium. He observed that the Brown Pelican has moved out of the area due to the destruction of their habitat. Stray cats have become more prevalent, which are a harm to nesting birds and may pose a threat to emerging sea turtles as well.

In terms of beach usage, he sees an issue in the lack of bathroom facilities, the allowance of too many people on the beach and poorly managed trash disposal. Overall, Mr. Morel believes the area is in "dire need of a management plan".

Appendix H: Interview with Edgardo González

Our meeting with Mr. Gonzáles took place on the 10th November, 2015 at the DNER Forest Service office in San Juan. He discouraged using a simple visitor cap as a primary method to restore the area and told us not to be confined by the LAC model. He suggested exploring alternative strategies to a visitor cap such as creating a map denoting what should become a zone of restoration along with an educational campaign to ensure the public will respect the restored areas. We spoke about the importance of prioritizing the condition of the environment and the benefits of creating buffer zones between areas of restoration and areas approved for human use. Between the zone of restoration and areas for visitor use, Mr. Gonzáles emphasized a buffer zone for areas that used to have wildlife activity, i.e. sea turtle nesting. Along with any restoration strategies, an accompanying educational program serves to maintain what has been restored through clear explanations of why the area is protected and the importance of conservation efforts at La Playuela. In any of our suggestions, specific criteria for the vigilantes monitoring the beach is necessary. He gave the example of closing the entrance when people on the beach pass the buffer zone. Mr. González suggested including our recommendations for an administrative order in addition to a carrying capacity.

Appendix I: Survey Response

These are the results we obtained from the survey we conducted on November 14th and 15th, 2015.

Do you live in Puerto Rico?			
	Yes	No	**Total Respondents**
	25	3	**28**
Percentage	89.29%	10.71%	**100.00%**

Do you live in Cabo Rojo?			
	Yes	No	**Total Respondents**
	7	18	**25**
Percentage	28.00%	72.00%	**100.00%**

How long have you been coming to the beach? (Excludes first time visitors)					
	Less than a year	Less than five years	Less than ten years	More than ten years	**Total Respondents**
	4	5	5	7	**21**
Percentage	19.05%	23.81%	23.81%	33.33%	**100.00%**

How often do you come to this beach?						
	Never been here before	Less than once a month	Once a month	Once a week	More than once a week	**Total Respondents**
	7	12	6	3	0	**28**
Percentage	25.00%	42.86%	21.43%	10.71%	0.00%	**100.00%**

How many people do you usually come with?							
	One person	Two persons	Three persons	Four persons	Five persons	More than five persons	**Total Respondents**
	5	7	5	4	3	4	**28**
Percentage	17.86%	25.00%	17.86%	14.29%	10.71%	14.29%	**100.00%**

How much time do you usually spend on a visit?							
	One hour or less	1-2 hours	2-3 hours	3-4 hours	4-5 hours	More than 5 hours	**Total Respondents**
	1	5	8	6	2	6	**28**
Percentage	3.57%	17.86%	28.57%	21.43%	7.14%	21.43%	**100.00%**

How much time do you usually spend on a visit? (Excludes first time visitors)							
	One hour or less	1-2 hours	2-3 hours	3-4 hours	4-5 hours	More than 5 hours	**Total Respondents**
	0	3	6	5	2	5	**21**
Percentage	0.00%	14.29%	28.57%	23.81%	9.52%	23.81%	**100.00%**

Are you aware that the beach is part of a natural protected area?			
	Yes	No	**Total**
	24	4	**28**
Percentage	85.71%	14.29%	**100.00%**

What time(s) of the year do you usually visit the beach? (You may choose multiple answers)					
	Jan-Mar	Apr-Jun	Jul-Sep	Oct-Dec	**Total Respondents**
	7	11	16	8	**21**
Percentage	33.33%	52.38%	76.19%	38.10%	**100.00%**

How has the plant life changed at La Playuela since you first visited? (Excludes first time visitors)				
	It has increased	It has stayed the same	It has decreased	**Total**
	6	6	8	**20**
Percentage	30.00%	30.00%	40.00%	**100.00%**

How has the amount of litter changed at La Playuela since you first visited? (Excludes first time visitors)				
	It has increased	It has stayed the same	It has decreased	**Total**
	6	6	9	**21**
Percentage	28.57%	28.57%	42.86%	**100.00%**

Compared to your last visit to La Playuela, were your expectations met today? (Excludes first time visitors)			
	Yes	No	**Total Respondents**
	16	5	**21**
Percentage	76.19%	23.81%	**100.00%**

What activities are you willing to participate in to improve the quality of the beach?						
	Visiting another beach if the gate is closed	Cleaning up your own trash when leaving	Volunteer to clean up trash on the beach	Taking trash home if the trashcans are full	Staying on the beach and avoiding the tree areas	Adhering to existing paths
	12	26	15	23	16	18
Percentage	42.86%	92.86%	53.57%	82.14%	57.14%	64.29%
	Not smoking or cooking on the beach	Following posted regulations	Encourage others to follow posted regulations	Using a shuttle service from Boqueron to the beach instead of driving	Avoiding feeding animals	**Total Respondents**
	19	23	17	6	12	**28**
Percentage	67.86%	82.14%	60.71%	21.43%	42.86%	**100.00%**

What activities are you willing to participate in to improve the quality of the beach? (Excludes first time visitors)						
	Visiting another beach if the gate is closed	Cleaning up your own trash when leaving	Volunteer to clean up trash on the beach	Taking trash home if the trashcans are full	Staying on the beach and avoiding the tree areas	Adhering to existing paths
	7	19	12	17	11	13
Percentage	33.33%	90.48%	57.14%	80.95%	52.38%	61.90%
	Not smoking or cooking on the beach	Following posted regulations	Encourage others to follow posted regulations	Using a shuttle service from Boqueron to the beach instead of driving	Avoiding feeding animals	**Total Respondents**
	13	17	13	4	9	**21**
Percentage	61.90%	80.95%	61.90%	19.05%	42.86%	**100.00%**

What activities are you willing to participate in to improve the quality of the beach? (Only Puerto Ricans)						
	Visiting another beach if the gate is closed	Cleaning up your own trash when leaving	Volunteer to clean up trash on the beach	Taking trash home if the trashcans are full	Staying on the beach and avoiding the tree areas	Adhering to existing paths
	10	23	14	20	13	15
Percentage	40.00%	92.00%	56.00%	80.00%	52.00%	60.00%
	Not smoking or cooking on the beach	Following posted regulations	Encourage others to follow posted regulations	Using a shuttle service from Boqueron to the beach instead of driving	Avoiding feeding animals	**Total Respondents**
	16	20	15	5	10	**25**
Percentage	64.00%	80.00%	60.00%	20.00%	40.00%	**100.00%**