Nautical Community Mooring Buoy Utilization in Puerto Rico

A study on boating behavior in sensitive benthic habitat locations

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Submitted to:
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Abstract

The Department of Natural and Environmental Resources in Puerto Rico has installed 290 mooring buoys in sensitive benthic habitats (coral reef, seagrasses, and mangroves) in order to curb damage caused by anchoring vessels. The team analyzed a collection of aerial photographs of popular keys to determine tendencies of boat-securing methods, specifically mooring buoy utilization. Onsite observations were conducted at the photographed areas to verify the photographic data and further observe behaviors. A standardized survey was also administered to the nautical community to determine their knowledge, habits, and opinions towards the mooring buoy system. Results were analyzed to determine reasons behind boating behaviors and draw recommendations on how to improve those behaviors.

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Contributions

All four authors edited each section as a team. The following is a list of the primary writer(s) of each section.

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Abstract	MS
Executive Summary	TB
1.0 Introduction	DL
2.0 Background and Literary Review	
2.1 Coral Reef Overview	DL
2.1.1 Importance of Coral Reefs	DL
2.1.2 Threatened Organisms	DL
2.2 Seagrass Overview	TB
2.3 Mangroves	TB
2.4 Stressors to Benthic Communities	
2.4.1 Non-Environmental Stressors	DL
2.4.2 Environmental Stressors	TB
2.5 Nautical Tools	
2.5.1 Types of Nautical Aids	VP
2.5.2 Mooring Buoys and Alternatives	VP
2.6 Coral Reef Preservation Case Studies	
2.6.1 British Virgin Islands	TB
2.6.2: Florida Keys National Marine Sanctuary	VP

Table of Contents

List of Tables

List of Figures

Executive Summary

Introduction

The Department of Natural and Environmental Resources (DNER) of Puerto Rico has installed 290 mooring buoys to date in sensitive benthic locations (coral reef, seagrass and mangrove) around the island. The purpose of these mooring buoys is to eliminate the necessity for vessels to anchor, alleviating damage done to benthic habitats. The DNER wants to protect these habitats because of the immense biodiversity they support, and the monetary value they provide for the island through tourism and fishing. The DNER has recorded and analyzed minimal data on the behavioral impact and effectiveness of the mooring buoy system, and the related educational efforts focused on protecting the benthic communities. This lack of available data has motivated this project's two primary research questions: 1) How effective is the mooring buoy system in Puerto Rico? 2) How effective have past DNER educational efforts been in changing behaviors to encourage mooring buoy usage? The team used three main methods of data collection in order to answer these two research questions.

Methodology

Photographic Assessment

The team analyzed a collection of aerial photographs previously taken by the DNER. The photographs selected for analysis were taken above five small islands, called keys, with high boat traffic. Four of the keys were in the La Parguera municipality, and one key was in the Guánica municipality. We designed a photographic assessment tool to extract data from this collection of historical photographs containing images from 1994 to 2012. We determined that the most reliable data were contained in photographs taken from 2006 to 2012, due to the frequent flyover sessions conducted by the DNER. From these photographs, we recorded the numbers and sizes of boats, boat-securing behaviors (anchoring, mooring, or mooring and anchoring), and severity of scarring of coral reefs and seagrass communities in the visible area. Boats were categorized as stationary if no wake was visible. Stationary boats in the close vicinity of a mooring buoy were categorized as "moored," stationary boats not in the vicinity of a mooring buoy were categorized as "anchored," boats stationary along a wooded coast were categorized as "tied to mangrove," and any other behavior was categorized as "other" (e.g. in motion). Anchor lines were difficult to distinguish in the aerial photographs, so we could not determine if a boat was moored and anchored simultaneously. Also visible from the photographs was a behavior termed rafting. Defined by the DNER, rafting occurs when multiple boats tie themselves together, hull to hull, and each boat typically drops anchor. In some instances, the raft was attached to a mooring buoy, and in other instances the raft was only anchored. The team designed an Excel database to record the photographic data.

Onsite Observation

The team also created an onsite observational tool, similar to the photographic assessment tool, to verify the information extracted from the aerial photographs. Anchor lines were visible, which allowed us to record instances where a boat was moored and anchored simultaneously. Onsite observation was conducted at the four keys of La Parguera on March 29, 2013. The gathered data were recorded in an onsite observational Excel database.

Surveying

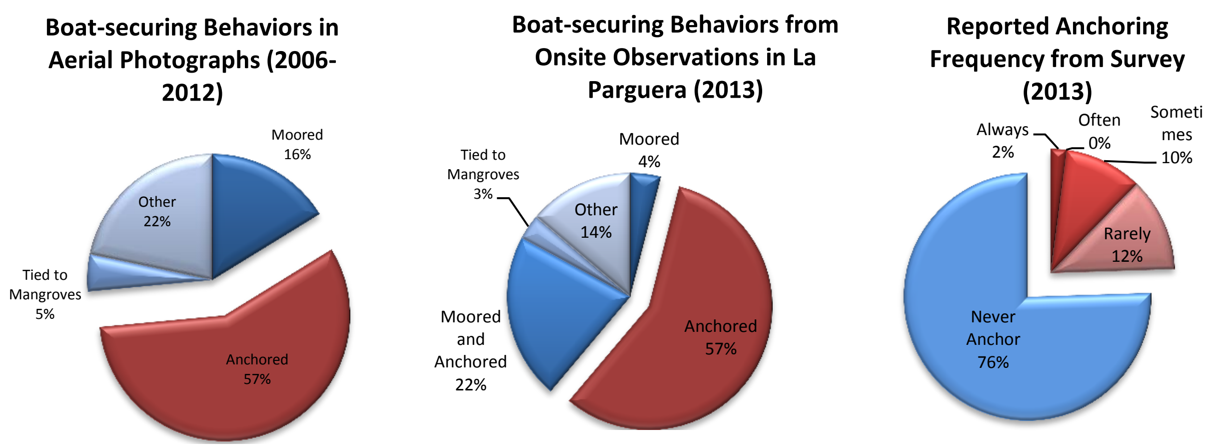
To form our survey for the nautical community, we starting by taking into account our previous background research, and the information collected from interviews with DNER staff. Preliminary drafts were edited for content and comprehension by our advisors and also by DNER personnel. Survey questions consisted of Likert scale, multiple choice, and open responses. Questions inquired about boater's knowledge on mooring buoys and benthic habitats, behaviors in mooring buoy areas, perception of the mooring buoys and their effectiveness, and any other suggestions on improving the mooring buoy system. Surveys were administered primarily in the DNER boater registration office (San Juan), in San Juan and Fajardo marinas, and in the La Parguera keys. A total survey sample size of 100 was accumulated, and the responses were recorded in our survey-specific Excel database. All results and analysis from each data gathering method were organized according to research question.

We used a combination of all three data sources to evaluate mooring buoy and educational effort effectiveness, supply the DNER with reproducible methods of data collection, entry, and analysis, as well as infer aspects of boating behavior. We produced technical documents for the DNER staff with step by step instruction on how to enter data into the photographic assessment and onsite observation Excel databases. Reproducibility was a crucial aspect of this project so that the DNER can apply our team's data collection and archiving methods to update and record new data for other keys.

Results and Discussion

Mooring Buoy Effectiveness

Mooring buoy effectiveness was examined using all of our data sources. In both photographic assessment and onsite observations, anchoring was recorded as the most frequent method of securing a boat, at 57% of boats observed. However, according to the survey question inquiring how often participants used anchors, 76% responded they never anchor. The charts below show the discrepancy in anchoring between the three methods of data collection.



Results from Aerial Photographs, Onsite Assessments and a related survey question illustrating anchoring frequencies

From our survey results, we inferred a further collection of behavioral tendencies from the boating community. Community members responded that they most frequently use mooring buoys as their method of securing a boat. As previously stated, aerial photographic and onsite observations contradicted the survey responses and revealed anchoring as the most frequently used method of securing a boat. One possible explanation of the difference between actual and reported buoy use might be that the population believes the buoys are being used more than they have been observed to be. If it is public belief that the buoys are commonly used, it might lead boaters to assume they are already taken upon arriving to a crowded key, leading them to anchor instead.

In the ten photographs analyzed in Caracoles Key from 2006 to 2012, 90% showed at least one occurrence of rafting. Onsite observation in Caracoles showed that 20% of all the boats present were rafting. Partying is one activity that encourages rafting behavior. The boaters may want to be in close proximity to engage in this social partying behavior, and in onsite observations 100% of the boats present were there for recreational purposes. Survey responses also report that the most frequently selected activity at the keys was partying, possibly further encouraging the rafting behavior. With further examination, we considered the relationship between educational materials and methods of securing a boat.

Educational Effort Effectiveness

Retention of Specific Information

Survey questions asked about information presented in the DNER's boater registration course as well as in DNER educational materials such as brochures, posters, service announcements, and signs. It is evident from survey results that boaters did not learn key information from the registration course and other materials. Responses to a question regarding the largest fine imposed on boaters anchoring in mooring buoy areas were largely incorrect. A statistical test showed that the proportion of questions did not differ significantly in the comparison between responses about fines, and whether or not the participant had seen DNER educational materials. If the educational material had been sufficient, we would expect there to be statistical significance. This result may possibly suggest that boaters are not effectively learning information regarding anchoring laws and regulations from DNER educational materials. Future educational materials may need to focus on the regulations and fines associated with anchoring in prohibited areas. Lack of fine enforcement could be another possible explanation of the boater's unawareness. Interviews with two DNER maritime rangers confirmed that these fines are rarely being issued due to uncertainty regarding costs of fines and the circumstances under which they should be issued.

Educational Impact on Mooring and Anchoring

Our survey also assessed the cumulative effectiveness of the DNER's various educational courses. We compared the results of two survey questions: "How many DNER educational courses have you had on mooring buoys?" and "How often do you only moor?" This comparison provided a statistically significant correlation ($R=0.259$, $p=0.009$), suggesting that those who had taken more educational courses on mooring buoys were more likely to only use mooring buoys than those who had taken fewer educational courses. This connection may suggest that the educational efforts effectively encouraged mooring buoy use, and that education may be related to boating behaviors.

Concluding Explanations on Reviewed Behaviors

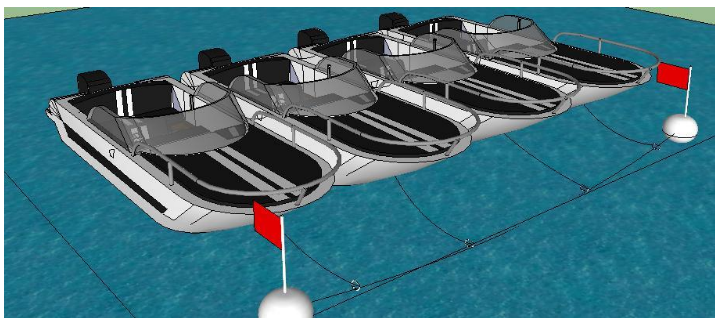
We have discussed boating behaviors and how the relate to education, and the causes of those behaviors may be explained using survey responses. Seventy-five percent of respondents agreed that mooring buoys were useful, and 52% agreed that mooring buoys are in convenient locations. Despite these results, we have seen that the buoys are not used by the majority of boaters. A separate survey question shows us that 81% of participants agreed that they would like to see more mooring buoys. The frequent anchoring observed in photographic assessment and onsite may be attributed to an insufficient number of mooring buoys for the population that wants to utilize them, leading boaters to anchor. If the boaters are unaware of anchoring regulations, an increase of fines issued for violations may prove helpful. By providing an external force in attempt to facilitate change to the majority, issuing fines could potentially lead to a more substantial decrease in anchoring behavior. If we apply groupthink theory, it is unlikely that individual boaters will begin to abide by these regulations if the vast majority of boaters disregard them (previously discussed in "Mooring Buoy Effectiveness"). Education can provide the nautical community with information connecting mooring buoy use and how it relates to preserving benthic habitats.

Recommendations

From our background research, results, and analysis, we provided the DNER with a compilation of solutions addressing both of our research questions.

Mooring Buoy Effectiveness

We recommend that the DNER implement the team's rafting mooring buoy design. This recommendation is based on the high numbers of observed rafting instances. Rafting is currently prohibited because each boat in the typically raft drops anchor, and rafting also places higher amounts of stress on the mooring buoys. Instead of trying to change this particular boater behavior, we designed a way to safely raft boats to two mooring buoys without the necessity of dropping anchor. With this new system, boaters would be able to raft different size boats without any repercussions to the benthic communities or the mooring buoy system. The figure below shows a prototype of our design.



Rafting Mooring Buoy Design

Additional recommendations to improve mooring buoy effectiveness:

- **Increased Mooring Buoys in Caracoles** – From photographic and onsite results, this key appears to be too full to host any additional boats to those we have observed. All current mooring buoys in the area tended to be occupied; however, the boaters mooring represented only a small population of the total number of boats present. If Caracoles is going to continue hosting an average of 150 boats, additional mooring buoys would allow more boats present to moor without a significant increase in total boat traffic.
- **Fine Enforcement** – Issuing more fines for violations of regulations that prohibit anchoring in mooring buoy areas can provide an external pressure to alter anchoring behavior. DNER Rangers can act as external leaders, interjecting contrasting ideas about anchoring to the nautical community to disrupt the observed consensus that anchoring is acceptable (groupthink theory).

Educational Effort Effectiveness

We recommend that the DNER implement an educational refresher course. The solution consists of a refresher course that could be mandatory every two years during license renewal at the DNER. Alternatively, the course could be administered to boaters given a fine for anchoring in a no-anchor zone. The refresher course would be a brief presentation comprised of two parts. One section would be educational, centering on how to correctly use the mooring buoy system and the negative environmental impacts of anchoring on benthic communities. The second section would describe the ongoing preservation projects by the DNER, suggesting what individuals can do to aid in project success.

Additional recommendations to improve educational effectiveness:

- **Video presentation** - There is a flat screen television in the DNER registration office that could be playing instructional videos or public service announcements about mooring buoy usage instead of the current cable channels or tourist videos. The boating registration office is an ideal venue for the instructional videos because the boaters are the target audience.
- **Additional Informational Signage** – Placing large signs at docks instructing proper mooring buoy use and outlining the fines associated with not complying with regulations, or on the water warning boaters of nearby benthic communities, will remind the boaters. Repetition of information is important for increasing retention rates (Bonwell Ph.D., 2000).

Further Recommendations

- **Restricted Key Access -** In order to more effectively save large amounts of benthic habitats, the DNER may have to shift efforts and close off entire keys to any boat traffic. Keys that have been determined as unrecoverable benthic habitats can host the displaced boating activity. (Velazco, 2013)
- **Commercial Sponsor -** The DNER may not be able to reach this audience with the intended level of success. A commercial sponsor (e.g., energy drink corporation) that better connects with the observed partying demographic of boaters might be a more influential figurehead than a government agency.

1.0 Introduction

Environmental concerns have been increasing for decades, leading many government and private agencies to propose new solutions in order to alleviate these pressures. The United States Environmental Protection Agency (EPA) budgeted $9 billion in 2012 to spend on conservation efforts (Environmental Protection Agency, 2012a). Currently, there are programs seeking to address issues such as reducing carbon emissions, solid waste management and water purification. One of Puerto Rico's main environmental concerns is benthic ecosystem conservation and sustainability. As an island, the surrounding environment is an important source of sustenance and revenue. A substantial portion of this revenue is provided by aquatic tourism, making the preservation of the various benthic communities economically and ecologically imperative (Planetary Coral Reef Foundation, 2002).

Coral reef ecosystems are aquatic environments that provide economic strength and ecological diversity. These habitats are the most bio-diverse places on earth, often referred to as "rainforests of the sea." One-fourth of all fish species inhabit reefs worldwide, and all of this biodiversity is contained in less than 1% of total ocean area (The Nature Conservancy, 2012b). Coral reefs and their beauty are also a large tourist attraction. The tropical ecosystem, with its exuberant colors and unique species, is a common recreation area for locals and tourists alike. Seagrass communities increase biodiversity by making the environment more hospitable for other organisms. Roots anchor the nutrient-rich sea floor sediment and the tall, leafy bodies slow ocean currents (Phillips & Menez, 1988).

Various non-environmental and environmental stressors pose threats to the sustainability of coral reef ecosystems. An estimated 24 percent of coral reefs worldwide are at risk of being unrecoverable, with another 26 percent moving towards the same ends (Precht & EnvironetBase, 2006). Mechanical damage from boating activity is a prevalent source of coral reef and seagrass degradation. Anchors dropped from boats break off pieces of coral structures, and hulls and propellers cut through seagrass meadows (Engeman et al., 2008). Coral grows between 0.5 and 2 centimeters per year, up to

4.5 centimeters given ideal conditions, making the time it takes to recover from the damages very considerable (National Oceanic and Atmospheric Administration, 2013d). The Department of Natural and Environmental Resources (DNER) of Puerto Rico has implemented mooring buoys in sensitive benthic areas to limit these types of damages. Research suggests that the buoys are commonly misused or even ignored completely (McNally, LaSante, Greer, Coffey, & Lemone, 2009).

The purpose of our project was to analyze boating behavior in mooring buoy locations, create a profile of mooring buoy usage by boaters in five specific areas of the La Parguera and Guánica municipalities (Caracoles, Collado, Enrique, Mata La Gata and Guánica Keys), and assess the nautical community's knowledge of proper mooring buoy usage and the importance of benthic communities. Through the analysis of aerial photographs supplied by the DNER, interviews with DNER staff and Rangers, standardized surveys administered by the team and onsite observations of the nautical community, the team gathered data regarding mooring buoy usage and nautical community awareness. A database was created to store the data gathered from photographic observations and survey responses, and analyze these data in order to reach conclusions on boater's behaviors and knowledge. We developed two primary recommendations that would address specific problems that our research identified in order to improve mooring buoy and educational effort effectiveness. One identified issue was rafting, a behavior in which boaters tie their boats hull-to-hull in order to be in close proximity with one another that often leads to anchoring. A new design for a mooring buoy was created, focusing on allowing boaters to participate in rafting behavior without the use of anchors. An additional recommendation was the creation of an educational course, which was outlined from the gathered data. The intent of the course was to inform members of the nautical community about the significance of benthic ecosystems and mooring buoys in Puerto Rico. The course focused on specific areas of nautical information that were determined to need improvement according to survey results and assessment of previous DNER educational courses. The course focused on details of the laws and regulations regarding mooring buoys as well as on benthic communities.

The state of the marine ecosystems in Puerto Rico has been in constant deterioration, and this deterioration is directly related to boating activity in these areas. This project provides the DNER with the means to assess mooring buoy effectiveness throughout the island and more effectively preserve benthic communities.

2.0 Background and Literary Review

2.1 Coral Reef Overview

Coral reefs support an amazing diversity of organisms including 25% of all fish species while comprising less than 1% of the Earth's oceans. It is estimated that coral reefs provide billions of dollars in goods and services worldwide (The Nature Conservancy, 2012b). Coral is part of the phylum Cnidaria, and is composed of tiny organisms called polyps, living in large communities known as reefs that are typically located in the upper layer of the ocean. Coral polyps share two main characteristics with the other organisms in their phylum: a gastro vascular cavity and a circle of tentacles. The gastro vascular cavity acts as the "mouth," taking in food and also expelling waste, while the circle of tentacles helps to capture food, which is plankton. Tentacles also provide the coral with a level of defense. Symbiotic algae, zooxanthellae, are also contained within the coral. The algae are provided with a protected environment as well as the compounds necessary for photosynthesis. These compounds are used by the algae and, in turn, the algae provide the coral with oxygen and help to remove waste. Products of the algae's photosynthesis are also used in the synthesis of calcium carbonate, which makes up the skeleton of the coral (National Oceanic and Atmospheric Administration, 2013d).

With so many beautiful colors, unique growths, and groupings of fish and other animals, the reefs are naturally a popular attraction. This section aims to identify the major threats to coral reefs, seagrasses, and mangroves (benthic habitats), outline successful conservation campaigns in benthic habitats worldwide, and provide other related information to understand our project.

2.1.1 Importance of Coral Reefs

The conservation of coral reefs is important due to their significant contributions to surrounding communities and various industries. According to the Planetary Coral Reef Foundation (PCRF), reefs are a basis for 10% of the world's diet, protect the coastlines of 109 countries from severe ocean conditions, and are an underutilized pharmaceutical resource. The Coral Reef Alliance goes further in supporting their importance, indicating that coral reefs are worth $375 billion every year in goods and services. There is consistent and sustained agreement among professional organizations on the benefits of coral reefs and the necessity to preserve them. (Costanza, 1998; Freedman, 2004; Planetary Coral Reef Foundation, 2002)

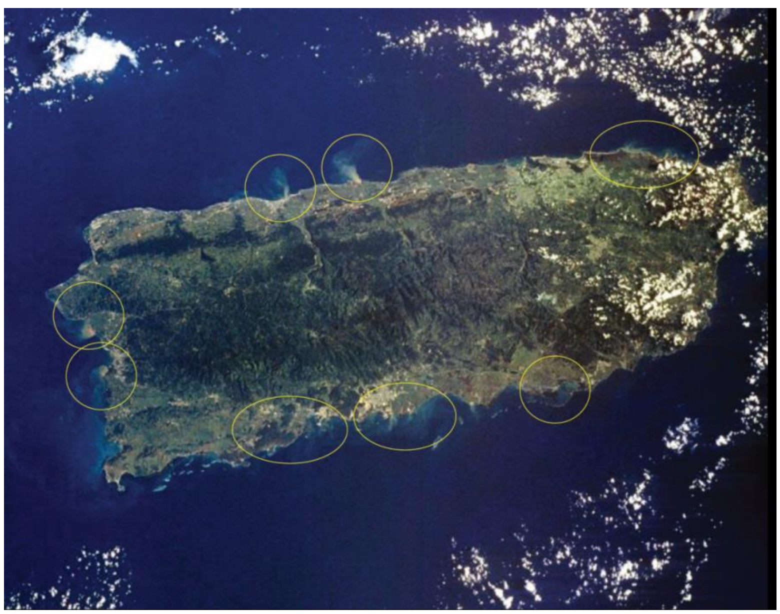


Figure 1 - Locations of coral reefs around Puerto Rico are marked with yellow circles (DNER, 2005)

Coral reefs support a very significant portion of the Puerto Rican economy. Tourism brought in 6.2 billion dollars to Puerto Rico in 2012 and the reefs, outlined in Figure 1, are undoubtedly a major attraction. People utilize the aesthetic appeal of the reefs for employment as tour guides, snorkel and scuba diving instructors, and many other positions. Another large source of income is commercial fishing. The coral reefs provide a home for a large number of commercially traded fish. From an economic point of view, over 57,000 Puerto Ricans rely on coral reefs and other tourist activities for their livelihoods. (Freedman, 2004; World Travel & Tourism Council, 2013; Puerto Rico, 2001)

2.1.2 Threatened Organisms

Coral reefs are extensive aquatic ecosystems that make up the largest living structures on earth; they are economic staples, and vital natural resources that must be protected. The National Oceanic and Atmospheric Administration (NOAA), a branch of the U.S. Department of Commerce, proposed in December 2012 that 66 coral species be added to the Endangered Species List. The list is under the Endangered Species Act (ESA), run by a branch of the National Oceanic and Atmospheric Administration and the U.S. Fish and Wildlife Service (National Oceanic and Atmospheric Administration, 2013a). Of the 66 species, seven are found solely in the Caribbean, and despite conservation efforts by the NOAA, hundreds more species are at risk globally (Planetary Coral Reef Foundation, 2002). Figure 2 illustrates the percentage of Puerto Rico's coral reefs at risk to various causes of degradation. Overfishing and integrated threats, which include boating and tourism, threaten 90% of the reefs in Puerto Rico. Also, according to the Planetary Coral Reef Foundation, about two-thirds of coral reefs worldwide are currently being threatened. If coral reefs were not spread out across the globe, it is possible that they would already be extinct. Coral, however, is not the only aquatic life whose growth is hindered by these disturbances.

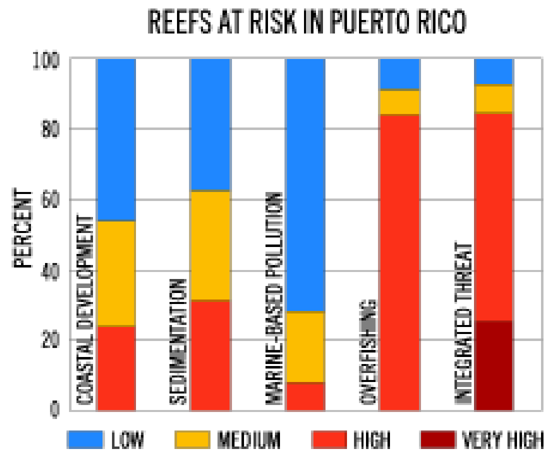


Figure 2 - Reefs at Risk (World Resources Institute, 2004)

2.2 Seagrass Overview

Seagrass has been identified as a vital component involved in an ocean's ecosystem (Burfeind & Stunz, 2006). It provides many functions in shallow coastal regions across the Atlantic, Pacific and Indian Oceans. The characteristic ribbon-like, grassy leaves are what give seagrass its name. The grasses typically grow in shallow, soft-bottomed marine environments. Seagrasses have stems, roots and veins like most plants, and grow to be up to seven meters long. The reproduction cycle of seagrass can be either sexual or asexual; sexual reproduction entails the growing of flowers and transfer of pollen from male to female flowers (McKenzie, 2013). Seagrass roots anchor ocean floor sediment that would otherwise be relocated by ocean currents. Nutrients are retained, allowing other floral and faunal organisms to inhabit these areas (Engeman et al., 2008). Seagrass roots can withstand tropical storm and hurricane force currents, adding stability to the ecosystem (Burfeind & Stunz, 2006). Seagrass, working in unison with the coral reefs, supplies shelter for many commercially traded fish (Phillips & Menez, 1988).

A worldwide decline in seagrass has been acknowledged (Burfeind & Stunz, 2006; DNER, 2011-2012; Engeman et al., 2008). Seagrass is especially susceptible to boat propellers, which cut up the seagrass in shallow coastal waters. Boating activity has increased with increasing tourism, leading more seagrass beds to be disrupted. Propellers of boats passing over seagrass meadows shred through the rhizomal mat, or subterranean bed of stems, of a seagrass bed creating three types of injuries: propeller scars, hull impressions and hull scars. An injured seagrass community may not recover depending on the extent of the damage. It can take up to sixty years for a seagrass community to fully recover (Burfeind & Stunz, 2006). Regrowth can be stifled by recurring stressors, which fall into two categories: non-environmental and environmental stressors. These stressors are in section 2.4.

2.3 Mangroves

Mangroves are formed from dense collections of mangrove trees and are located along one-quarter of all tropical, muddy coastlines, and salt marshes around the world (Encyclopædia Britannica Inc, 2012; Wier, Tattar, & Klekowski, 2000). The most common mangrove in Puerto Rico is Rhizophora Mangle, also known as the red mangrove (Wier et al., 2000). Mangroves act as essential habitats for fish nurseries and also stabilize sediment. Mangrove's roots, or props, grow upward from the ground and extend into shallow waters, as shown in Figure 3, providing shelter and nutrients for the nurseries (Perry, 1988). In addition to aiding aquatic life, mangroves provide shelter to island communities from waves and winds caused by storms (Polidoro et al., 2010).

Figure 3 - Mangrove community in Puerto Rico (Boricuaeddie, 2007)

Mangroves have been under significant stress due to an increase in coastal development. Damaging human behavior, such as tying boats to the props and cutting mangroves down for firewood, or simply for more convenient waterways, have added to the overall loss. Areas that are near extinction have displayed irregularities in the ecosystem. In response to these findings, the DNER has deemed mangroves an endangered species in Puerto Rico, and laws protecting them have been put in place. Tying vessels to mangroves, uprooting mangroves, and any other destructive behavior towards mangroves are each illegal (Torres Rodríguez, 2003). It is well documented that mangroves need to be protected in order to sustain the aquatic ecosystems surrounding the island (Polidoro et al., 2010).

2.4 Stressors to Benthic Communities

There are factors that threaten the health of benthic communities. The two main categories of these threats are non-environmental and environmental stressors. This section focuses largely on the human threats that can be altered, and also provides details regarding natural threats.

2.4.1 Non-Environmental Stressors

2.4.1.1 Pollution

Pollution stems from a wide variety of larger issues. Construction along the coast results in sedimentation, which are the small remnants of various materials that cause water to appear foggy. Sediment suspended in the ocean blocks light from reaching the coral, inhibiting photosynthesis. Figure 4 depicts a sediment plume in a costal marine environment. Sediment runoff is a serious and widespread stressor on coral reefs, ranging from Hawaii and the Mariana Islands to the U.S. Virgin Islands and Puerto Rico. (United States Geological Studies, 2012)

Figure 4 - Flowing sediment plumes ((National Oceanic and Atmospheric Administration, 2013c))

There is a wide variety of pollution from runoff. The agricultural industry, the construction industry, and boat owners frequently use varieties of chemicals that can easily contaminate the water. Chemical runoff is detrimental to any aquatic wildlife. Runoff can cause disruptions such as algae boom, which is a large growth of algae that is harmful for the other surrounding plant life. Land-based sources of pollution include pesticides, petroleum hydrocarbons, pharmaceuticals, heavy metals, pathogens, and excess nutrients (National Oceanic and Atmospheric Administration, 2013c). On a small land mass such as Puerto Rico, it is especially important to keep in mind that such materials and substances can migrate into the ocean. Pollution is also caused by boats and boaters, commonly including petroleum product spills and trash dumped into the water. In certain sensitive aquatic areas, such as wetlands, even the wakes of boats moving through the water can damage the surrounding environment. (United States Geological Studies, 2012)

Pollution also increases the likelihood of disease outbreaks in coral reef communities. Diseases such as Black-band disease and White Syndrome have been found in coral off the coast of Puerto Rico. Black-band disease deteriorates coral tissue and leaves behind the bare calcium carbonate skeleton. The prevalent effect of disease has contributed to the deterioration of many aquatic environments. (National Oceanic and Atmospheric Administration, 2013b)

2.4.1.2 Tourism

People come from all over the world to visit Puerto Rico but, unfortunately for the wildlife, tourists are often uninformed. Scuba diving and snorkeling are not intrinsically harmful, but often times the smaller reefs are damaged by constant disturbances. It is common for divers and even just exploring beachgoers to break off pieces of coral as souvenirs, or to walk on top of the structures. The DNER reports that an entire coral community can be destroyed in one tourist season solely due to these activities. With annual increases in international tourism, coral reef areas are inevitably subjected to increased boating traffic. Due to this increase in boating traffic, all non-environmental stressors are intensified. The anchoring of these boats also becomes an issue. (Velazco, 2013)

2.4.1.3 Damage due to Anchoring

An additional threat to the coral reef and seagrass ecosystems is the anchoring of motorboats and other personal watercraft. Anchoring secures a personal watercraft within open water. The average anchor is usually constructed of a steel alloy, weighing between fifteen and twenty-five pounds. When in open water, the watercraft operator deploys the anchor simply by throwing it over the side of the watercraft, most likely a boat, in a suitable location. After the anchor reaches the seafloor, it drags along until it becomes set. The weight of the anchor is often not enough to stabilize the boat, especially in open water; because of the light weight, the anchor is designed specifically to grab the ground with a fin shaped piece, known as the fluke. Often, the fluke will be properly secured once it has grabbed an object of substantial mass, such as a large rock. When the operator is done anchoring in the area, he/she brings up the anchor; however, occasionally the anchor will set too well and is abandoned rather than removed. (Dinsdale & Harriott, 2003)

While the process of anchoring may seem harmless from the ocean surface, the damage done to coral reef and seagrass ecosystems can be catastrophic. When an anchor is dropped directly over a reef, it causes severe damage to the brittle coral structures. Further damage can be caused during the setting of an anchor. As an anchor is dragged across the seafloor, it can be dragged across reef and seagrass areas, fracturing and destroying coral and ripping up seagrass. Finally, when removing the anchor, extensive damage can be caused due to potential flipping or removing of coral structures while the drawing the anchor up to the surface. This process can be exacerbated through the use of electronic anchor winches, now commonly equipped on many types of personal watercraft to ensure the proper retrieval of set anchors. (Dinsdale & Harriott, 2003)

2.4.1.4 Overfishing

It has already been stated that a large portion of the Puerto Rican economy is based upon aquatic environments, and coral reefs house a significant amount of fish species. Overfishing is the result of excessive fishing, recreational and commercial, leaving the reefs with non-sustainable populations of certain species of fish. The overall effect of overfishing results in an unequal distribution of various species (International Encyclopedia for the Social Sciences, 2008). In Jamaica, for instance, coral-eating mollusks are in excess due to the overfishing of their predator, the spiny lobster (Burke & Maidens, 2004).

Northern Jamaica's coral reefs have been so severely impacted by overfishing that the reefs are almost non-existent. The consequences can already be observed by the loss of predatory species such as sharks, snapper and grouper fish, and also by the reduction of herbivore size (Broad, 1994). The fishing industry has plummeted to the point that fish eggs are being harvested in place of grown fish (Best & Moore, 2001). The value of fish catches in Jamaica declined from $65.8 million in 1996 to $34.3 million in 2005 (World Resources Institute & Nature Conservancy, 2011). It is important to stress the significance of coral reefs on a country's economy, and the loss of Jamaica's coral reefs should be motivation to ensure the protection of Puerto Rico's coral reefs.

2.4.2 Environmental Stressors

The ecosystem of coral reefs is sensitive due to the complex food chain it supports. Arguably, climate change has the most dramatic effect on the sustainability of these ecosystems. Global climate change has caused average ocean water temperatures to increase. The temperature of the top layer of ocean water has been rising 0.2°F every decade (Environmental Protection Agency, 2012b). Figure 5 illustrates the rise in average ocean top layer water temperature from years 1880 – 2010. Coral reefs are found in depths of 30 meters on average, which is within this top layer of the ocean.

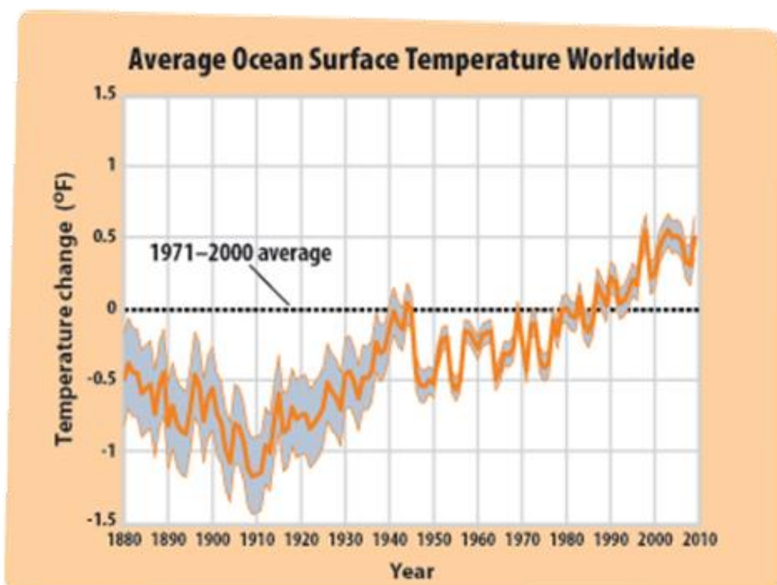


Figure 5 - Average ocean temperature from 1880-2010 (EPA's Climate Change Indicators, 2010)

Rising ocean water temperatures increase the probability of coral bleaching events. Coral bleaching is an occurrence that has caused widespread damage to reefs documented since 1980. Zooxanthellae algae, a single-celled plant inhabiting the coral, have been damaged by various stressors. When the zooxanthellae stop producing energy for the coral, the reef terminates the symbiotic relationship and rids itself of these algae. The algae give the coral their intense coloration, and without them the coral appears white, giving rise to the term “bleaching.” Coral reefs can recover from short-term bleaching (less than one month); however, any bleaching event extending over one month can result in extermination of the coral. (Brown, 1997; Sims, 2003)

Bleaching is caused by a number of stressors and environmental changes including: disease, excess shade, increased levels of ultraviolet radiation, sedimentation, pollution, salinity changes, exposure to air, and increased water temperatures. Coral reefs are extremely sensitive to changes in water temperature, only growing in temperatures between 77-84^{o}F (25-29^{o}C). Climate change further aggravates this issue of temperature sensitivity (Brown, 1997; Sims, 2003).

Bleaching has been reported in the coastal waters of over 60 countries, including the Caribbean. Over the span of nine months in 1998, an estimated 16% of coral reefs were lost globally to bleaching. The extent of the damage was only believed to have occurred in shallow water, but reports have shown damages in depths as low as 164 ft. (50 m). (Sims, 2003)

Infectious disease outbreaks in coral populations occur naturally, but environmental stressors increase the likelihood and severity of these epidemics. Over the last 20-30 years, disease outbreaks have become more rampant in coral communities worldwide. A research study was conducted over six years on 48 reef sites on the Great Barrier Reef (Australia). The study sought to discover plausible causes of the increase in white syndrome-related coral mortality. White syndrome creates bands of exposed coral skeleton, creating divisions between sections of living coral. Researchers discovered increasing trends of this infectious disease in coral reef populations in areas with higher ocean water temperatures. White syndrome appeared on reef locations in warmer water areas after abnormally warmer summers, while leaving reefs in cooler locations unscathed. The average temperature difference between heavily diseased and uninfected reef sites was a mere 1-2 °C (Bruno et al., 2007). Figure 6 presents the relationship between white syndrome outbreaks in coral reef colonies and localized temperature increases. In areas with warmer than average water temperatures, white syndrome is more prevalent. In contrast, areas with average water temperatures experienced a lower number of affected coral colonies.

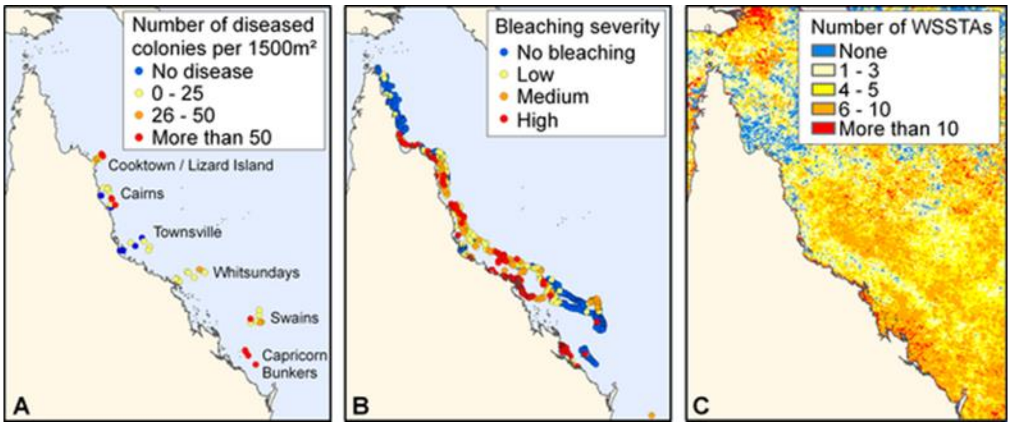


Figure 6 - (A) Frequency of white syndrome cases from March 2002 to March 2003; (B) bleaching intensity for scleractinian coral in March 2002 (C) Weekly temperatures increases in °C in 2002 (Bruno et al., 2007)

Carbon dioxide (CO_2) emissions are thought to be the primary human-related cause of climate change due to their greenhouse effect in the atmosphere (William, 2011). The ocean absorbs an estimated 50% of all excess CO_2 produced by human activity, which has increased annually by 2 billion tons. The CO_2 accumulates in the upper layer of the ocean (less than 1000 meters in depth). Carbonic acid is formed by a naturally occurring reaction when ocean water contacts excess CO_2, causing ocean acidification. Due to this process, ocean levels have already dropped 0.1 units on the pH scale, resulting in about 30% higher acidity. Ocean acidification decreases coral's ability to produce its calcium carbonate skeleton by reducing the availability of elements necessary for its process, slowing its overall growth (Hoegh-Guldberg et al., 2007). The cycle of CO_2 production, emission, absorption, and ocean acidification is depicted in Figure 7.

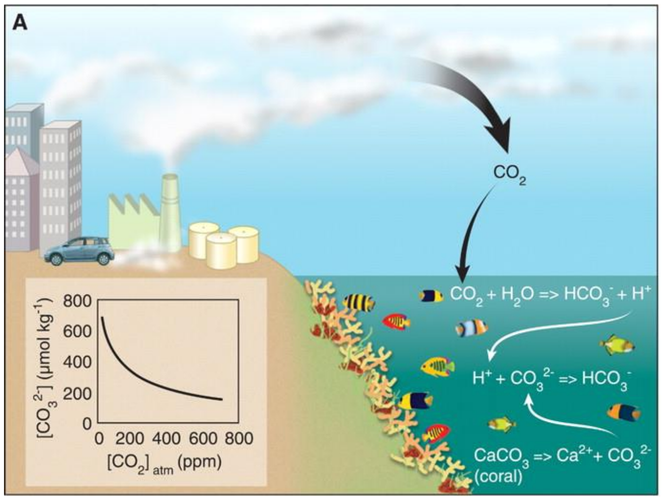


Figure 7 - Linkages between the buildup of atmospheric CO2 and the slowing of coral calcification due to ocean acidification (Hoegh-Guldberg et al., 2007)

The natural occurrence of hurricanes is adding to the damage already being sustained by coral reefs and other marine ecosystems, and these occurrences are said to be linked with the previously stated rising ocean temperatures. As a hurricane travels across the ocean, destructive waves and currents extensively damage the coral reefs. Hurricanes disrupt the ocean's temperature and upset the ecological balance of the coral reef. When hurricanes hit land, debris is thrown into the ocean further polluting ocean waters. (Environmental Protection Agency, 2012b)

2.5 Nautical Tools

2.5.1 Types of Nautical Aids

When operating a vehicle, it is important to know the rules and regulations. This knowledge is especially pertinent while operating a motorboat or other type of personal watercraft. When navigating the open water, it is important to be able to quickly identify the navigational aids and understand their specific meanings to safely traverse various marine environments. These navigational aids have very distinct meanings and are easily identified by their unique colors and shapes. Figure 8 is a reference that outlines each of the common open-water markers, their specific meanings, and the directions that each is trying to communicate to the boater. (Vance, 2012)

ON THE WATER	ON THE CHART		ITS MEANING	PASSING BY
Always green and odd numbered	G C"3"	GC = Green Can "3" locates it (and you) in your surroundings	You're in a secondary channel on an inlet or river	Keep it on your left when entering an inlet or river
Always red and even numbered	R N"2"	RN = Red Nun "2" = location	It marks the safe channel of an inlet or river	Keep it on your right when you enter the channel into the current
Green buoys are always odd numbered	G"1" Fl G 4s	G = Green w/ green light Fl G 4s = flash is green at 4-second interval	It marks the left (port) side of the safe channel when entering	Keep it on your left returning, on your right going out
Red buoys are always even numbered	R"2" Fl R 4s	R = Red w/ red light Fl R 4s = flash is red at 4-second interval	It marks a channel leading to harbor or port	Keep red on your right returning (to port)
Red over green or green over red are lettered	RG "B" Fl (2+1) R 6s	RG = Red Green/red light Fl (2+1) R = red flash (dot dot dash) 6 seconds long	It marks the preferred channel entrance	Red on top, go left or to port; green on top, go right or to starboard
Red triangles are always even numbered	R "4"	"4" = location	It marks the side of the ICW closest to the mainland	Keep it on your right when traveling clockwise around the U.S. in the ICW
Green squares are odd numbered	G "5"	"5" = location	It marks the side of the ICW closest to the ocean	Keep it on your right when following the ICW counter-clockwise around the U.S.

Figure 8 - Table of Navigational Aids (Vance, 2012)

2.5.2 Mooring Buoys and Alternatives

Navigational aids are not the only nautical tool on the water. A mooring buoy is another type of nautical aid and can be simply explained as a nautical parking spot, where one boat is supposed to be assigned to one mooring buoy. A traditional mooring buoy is attached to a large weight. This weight is often a large, square, concrete block that is dropped onto the seafloor in order to act as a permanent anchor. However, the large weight can be replaced by a variety of different forms. The process for creating a mooring of the simple, concrete block design is very low cost; however, these moorings are subject to dragging when multiple boats are attached. When a mooring is dragged, it causes substantial damage to the seafloor or, potentially, the benthic ecosystem. Figure 9 displays four mooring buoy anchor designs that may help to reduce damage, each embedded into the seafloor using slightly different means. All of these mooring systems require professional installations and can cost from $500 to $1,000 for a single mooring buoy. (National Oceanic and Atmospheric Administration, 1996-2005)

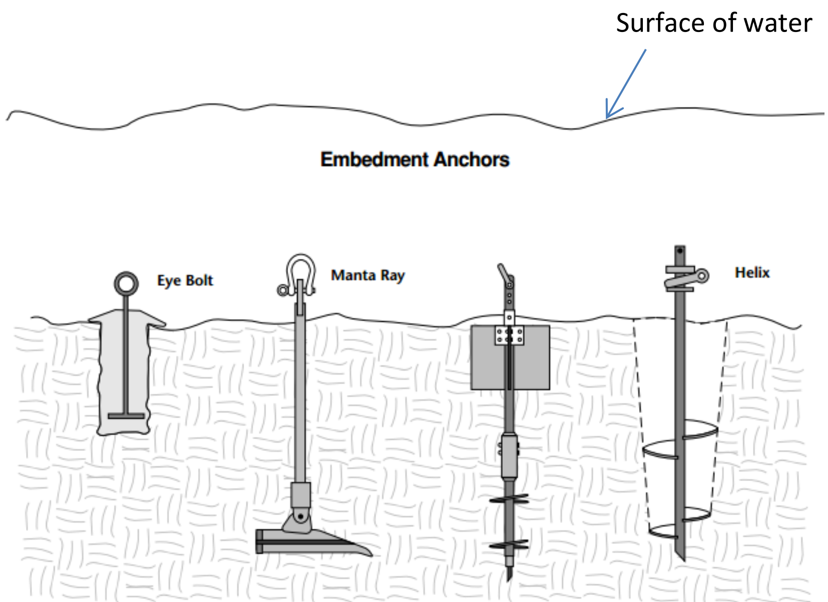


Figure 9 - Types of mooring buoys (National Oceanic and Atmospheric Administration, 1996-2005)

Included in Figure 9 is the manta ray type of mooring buoy, the style implemented by the DNER. As a part of the mooring evaluation, the NOAA tested the holding strength of the manta ray mooring buoy. A high strength cable with a strain gauge was attached directly from the embedded mooring to a 65 foot tug boat. The tug boat attempted to pull the mooring from the ground. This style of mooring was able to withstand a tension of 7500 pounds with no damage to the system.

2.6 Coral Reef Preservation Case Studies

Areas such as the British Virgin Islands, the Florida Keys, the Great Barrier Reef and Maui are realizing the extent of damage done to coral reefs. Multiple organizations have designed programs and regulations to control fishing, boating, and recreational activities in these waterways. The following case studies contain useful information to be learned that may be applied to Puerto Rico's own reef system.

2.6.1 British Virgin Islands

The British Virgin Islands are positioned about 62 miles east of Puerto Rico. Similar to Puerto Rico, they have an abundance of coral reefs. The coral reefs have been devastated by a series of hurricanes in the past two decades. Boat anchoring, coastal development and a bleaching event in 2005 that bleached 90% of all coral, have all had an impact on the reef's health. In response to these threats, Marine Protected Areas (MPAs) were developed to protect the British Virgin Island's coral reefs, as seen in Figure 10. (The Nature Conservancy, 2012a)

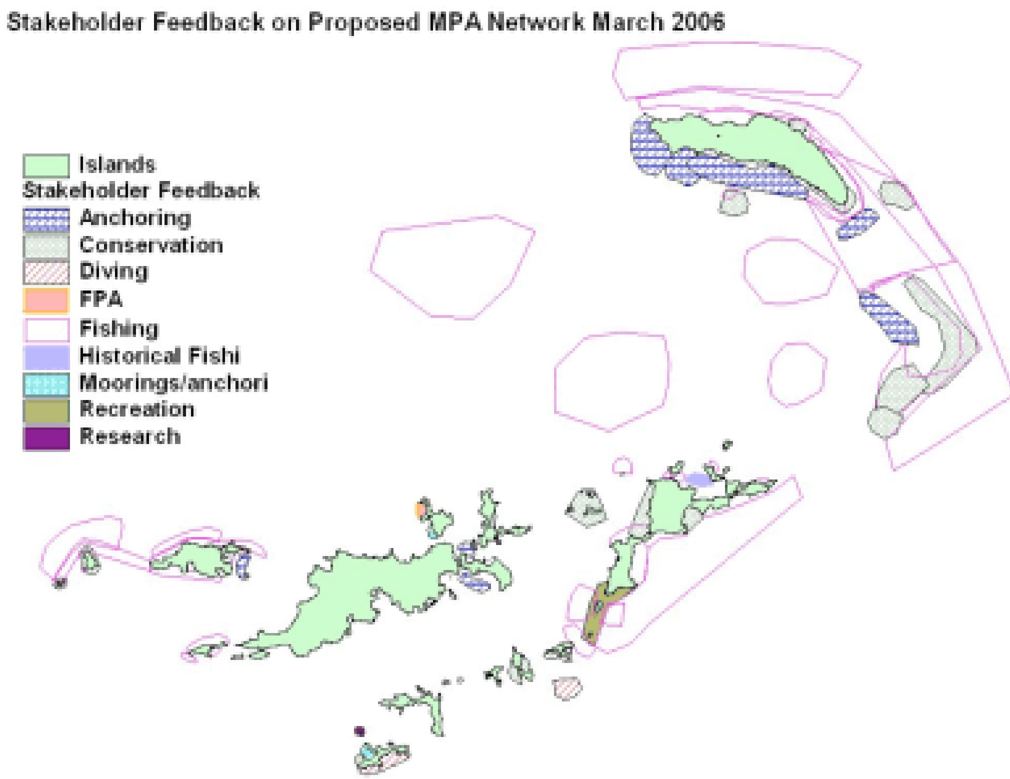


Figure 10 - Map of Marine Protected Areas ("Coral Reef Case Studies," 2012)

The main goal of the MPAs was to create a data set consisting of all documented coral reefs and to establish safe-zones around the island. The National Parks Trust of the Virgin Islands collaborated with the Conservation and Fisheries Department and used MARXAN Software to update the Geographic Information System (GIS) dataset. The National Parks Trust cooperated with local fisheries by holding meetings in which they presented brief PowerPoint presentations of the MPAs to show where fishing, diving, and anchoring are permitted. After the MPAs were presented, the stakeholders stated what areas they utilized for fishing and diving. The National Parks Trust and local stakeholders negotiated what areas would be preserved and what areas would be controlled by the stakeholders. The National Parks Trust used these data to create new MPAs conducive to conservation of the reefs and utilization of their resources. (The Nature Conservancy, 2012a)

Many positive influences arose from the project. Relationships between the government and local fisherman grew. Awareness of the need for a change was shown to be successful in educational meetings held for the community. The GIS was proven to be a very effective tool for mapping the coral reefs. Scientific researchers were able to train local organizations on the mapping system, ensuring long-term success. The MPAs are still thriving and protecting the coral reefs. (The Nature Conservancy, 2012a)

2.6.2: Florida Keys National Marine Sanctuary

In fall of 1990, the United States began to see widespread destruction of the coral reef areas off the coast of Florida in the region known as Key West. This area had been unregulated, and was seeing widespread disease outbreaks as well as widespread death of various marine species. These outbreaks spurred the creation of the Florida Keys National Marine Sanctuary. The sanctuary is an area stretching from just south of Miami to the Dry Tortugas National Park, protecting over 2,900 square nautical miles of coral reefs and seagrass beds. The sanctuary is home to over 6,000 different species of marine life and encloses the world’s third largest coral reef ecosystem, providing a valued natural resource. Currently, much of the sanctuary is restricted to research access only; however, over 470 mooring buoys have been strategically placed to allow boaters to moor in the vicinity of the sanctuary without disturbing the surrounding areas by anchoring. Furthermore, specific color-coded and size-coded mooring buoys have been placed throughout the sanctuary to distinguish research areas from tourist areas. The sanctuary does encourage visitors, but rules and regulations are in place to ensure proper practices and behaviors that will not interfere with the marine ecosystems. The rules and regulations strictly prohibit the discharge of any waste or any disturbance to the seafloor or ecological structures, such as coral reefs. (The Nature Conservancy, 2012a)

In an attempt to enforce the rules and regulations within the preservation, the NOAA has developed a three-year plan to outline the various types of enforcement necessary to ensure the success of the preservation. In the preservation project, the use of uniformed officers was implemented in order to establish an authoritative presence within the sanctuary. Officer presence was largely managed by the United States Coast Guard patrol personnel in the immediate area. The primary focus of enforcement in the sanctuary was the implementation of the Community Oriented Policing and Problem Solving (COPPS) program. This program aims to gain support for the sanctuary through community education and involvement. Officers and sanctuary officials distributed educational materials to boaters during their regular patrols in an effort to personally connect with those using the sanctuary. (National Oceanic and Atmospheric Administration, 2010b)

In addition to the regulations that have been established, the NOAA and the Florida Keys National Marine Sanctuary have created a program known as the Blue Star Program. The program requires participants to renew their membership annually in order to be compliant with the Blue Star Program, and grants local businesses and partners Blue Star decals and placards. By displaying one of these placards, a business is demonstrating their support for safe diving and boating practices in the sanctuary. The campaign is supported by fourteen of the major scuba and snorkeling expedition companies in Key West and southern Florida areas. (The Nature Conservancy, 2012a)

2.6.3 Great Barrier Reef, Keppel Bay, Australia

Keppel Bay, Australia is teeming with a delicate weave of coral reef systems. The area represents a portion of the Southern Great Barrier Reef. In some regions of Keppel Bay, coral communities can cover up to 70% of the ocean floor. Over the past 20 years, the area has been subjected to constant disturbances causing mass bleaching events, depicted in Figure 11. Flooding and major storms are the primary offenders. In the summer of 2006, a concentrated warming event occurred, and the majority of coral locations lost 30% of their reefs to bleaching. Figure 11 is a photograph taken in 2006 of a bleached coral community in Keppel Bay (Maynard et al., 2007).

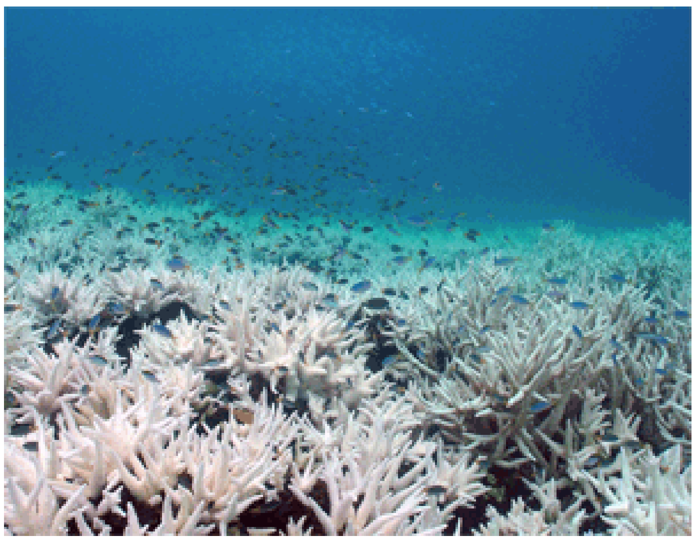


Figure 11 - A bleached landscape from the severe bleaching event in the Keppel Bay in early 2006. Photo © Great Barrier Reef Marine Park Authority (Maynard et al., 2007)

In an effort to understand the full detrimental effects of these disturbances to the coral reefs, the Great Barrier Reef Marine Authority (GBRMA) took measures to secure reef health and prevent bleaching events. The GBRMA implemented the construction of a more detailed network of marine protected areas and an extensive Reef Water Quality Monitoring Program. Restrictions were also put in place against recreational and commercial fishing of herbivorous species occupying the reef. An unexpected result was the success of the voluntary no-anchoring zones. The community became heavily supportive of the preventative acts of the GBRMPA, and followed non-enforceable anchoring boundaries. All previously damaged coral were steadily recovering within no-anchoring zones, and there were seldom instances of further destruction (Maynard et al., 2007). The GBRMPA mapped coral reef areas by specific coral reef habitat type and current zoning regulations, shown in Figure 12.

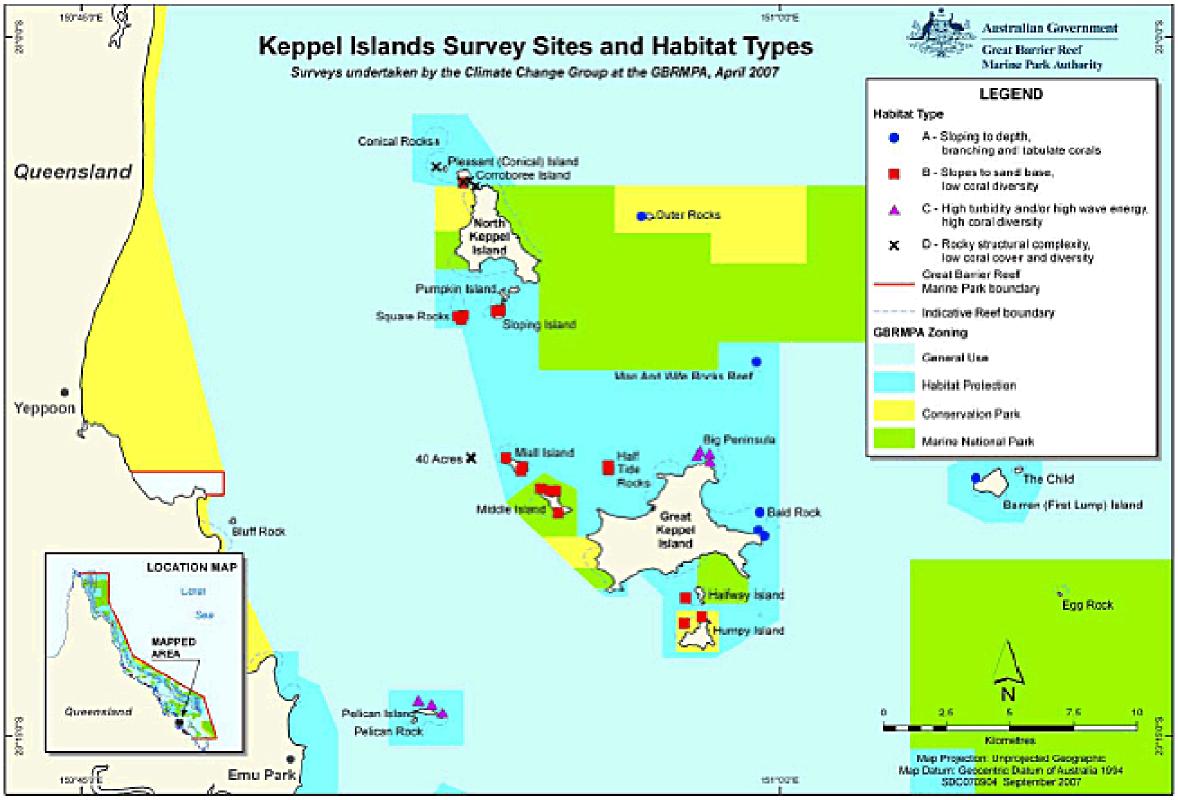


Figure 12 - Marine Park Zoning within the Keppel Bay as of March 2008. Survey sites and habitat types from biophysical assessment of the reefs of Keppel Bay: a baseline study April 2007, written by the Climate Change Group, Great Barrier Reef Marine Park Authority (Maynard et al., 2007)

2.6.4 Maui, Hawaiian Islands

The Hawaiian Islands are home to almost 1.3 million residents, and see upwards of 7 million tourists visiting the island in a given year (Lim, 2012). The marine ecosystems can be easily affected by this influx of people. Hawaii is a focal point for marine and coral reef conservation groups, with some of the most diverse and beautiful coral reefs and marine ecosystems in the world, containing a large number of species native to only the islands. On the small island of Maui, conservation groups focused on community educational practices, as well as community involvement, to create an environment where local residents were the primary caretakers of the reef ecosystems.

The campaign started because of Maui's size and location. The island has a relatively small rural population, keeping it sheltered from most of the tourism and pollution with the exception of its major port at Hana Bay, which was still subject to degradation. The primary issue causing reef and marine ecosystem degradation was overfishing, predominantly by local fisherman. Scientists and conservationists partnered with local leaders to develop educational campaigns combining Hawaiian traditions with scientific facts. This helped create an integrated campaign that would be culturally accepted by the members of the local community. The next step was the creation of Locally Managed Marine Areas (LMMAs) as well as an advisory committee consisting of fisherman and local leaders to regulate and help educate the community about the reef ecosystems. Currently, six major areas have been identified as protected zones. The committee is working with officials and conservationists to expand these areas as well as their education programs to create an environment where the native Hawaiians are on the forefront of the conservation efforts. (The Nature Conservancy, 2012a)

Through this campaign, the conservationist groups witnessed increased community involvement and awareness achieving the integration of cultural knowledge and scientific fact. The University of Hawaii conducts monthly public presentations, called Reef Talks, to raise community awareness on conservation efforts in the area. Community-based conservation groups allow concerned individuals to participate in coral reef protection. By educating the locals in a way to which they could relate, conservation groups were able to pass on the vital knowledge that will lead to a healthier and more diverse marine ecosystem throughout the island (Clark, Miyasaka, & Ramsey, 2007).

2.6.5 Puerto Rico

Puerto Rico implemented a five to seven year program in 2009 aimed towards preserving their benthic ecosystems, facilitated by the NOAA Coral Reef Conservation Program. The NOAA worked with a core group of designated coral reef managers in Puerto Rico to articulate a set of strategic goals. The program was divided into four sections: scope, strategic management priorities, relationship to NOAA goals, and other strategic priorities not previously listed (National Oceanic and Atmospheric Administration, 2010a).

A final set of priorities was agreed upon by the core managers group. The core managers group was comprised of field experts from local conservation organizations involved with preserving the coral reefs in Puerto Rico. Through a series of interviews with various managers, the NOAA gathered professional perspectives on threats to benthic communities. The information was used to instill an initial set of goals that are defined as follows:

1. Implement land-use planning at the watershed scale to minimize water quality impacts to the coral reef ecosystem.
2. Control and reduce pollutant transport to the marine environment.
3. Strengthen enforcement and engage stakeholders through education to reduce pollutant transport to the coral reef ecosystem.
4. Protect the coral reef ecosystem from large-scale and small-scale fisheries impacts through an informed planning process.
5. Enhance enforcement and management programs to reduce fishing impacts to coral reef ecosystems.
6. Utilize enforcement and education to encourage public compliance with fishing regulations and reduce impacts of fishing.
7. Manage the recreational and maritime uses of marine and coastal areas to reduce the impacts on coral reefs.
8. Enable and promote sustainable development practices in the coastal zone and upland areas of Puerto Rico that are associated with priority coral reef areas.

In addition to the defined goals, areas of interest were determined by three criteria: biological value, degree of risk and threat, and viability. These criteria consider the biodiversity and size of the habitat, the amount of human activity and environmental stressors, and the potential to preserve the area while calculating the probability of community support (National Oceanic and Atmospheric Administration, 2010a). The above criteria led the core managers group to select the following four sites in order of priority: Culebra, North East Reserves, Cabo Rojo, and Guánica and Marine Extension in Guánica. The NOAA will use this new set of preservation goals to ensure future protection of Puerto Rico's coral reefs. No updates on this project have been posted to date. (National Oceanic and Atmospheric Administration, 2010a)

2.7 The F-27 Project

The F-27 is a supplementary project that deals with the protection of benthic communities and the placement of mooring buoys throughout Puerto Rico. The project has documented the condition and boating traffic around Puerto Rico through the use of aerial photographs. The photographs were analyzed multiple times to determine locations throughout the island in need of further observation or mooring buoys. The specific locations of the mooring buoys are evaluated in order to assess where boats prefer to anchor, and buoys may be placed or repositioned accordingly. This project also explains past seagrass restoration efforts used in an attempt to combat the extensive scarring in the seagrass meadows. Additionally, educational materials were produced and distributed at boat shows and local marinas to inform boaters of the restoration efforts and mooring buoys. These materials consisted of pamphlets, handouts, DVD's, and a website. These materials included information on Law 147, "Law for the Protection, Conservation and Management of Coral Reefs in Puerto Rico." Law 147 states the fines associated with the violation of anchoring in areas with designated mooring buoys as well as the removal or damaging of these designated mooring buoys. The fines are a minimum of $500 and a maximum of $10,000. The F-27 is an ongoing project at the DNER.

2.8 Surveying

In order to create a successful conservation program, certain information is required. Surveys are a method of extracting semi-quantitative information from target populations. Ideas and concepts are converted to comparable data through the use of specific phrasing techniques. Questions must be worded very simply, allowing for easy comprehension and, in turn, more accurate data. Confusing questions may result in less accurate data due to misunderstanding. Bias must also be absent from all survey questions. Any bias in the wording of a question could result in what is called a “leading question,” which sways the subject towards a certain answer. Wording also needs to be adjusted so as not to ask “double-barreled” questions, which are questions that address more than one concept at once. Double-barreled questions are confusing, and supply data that cannot be used because only one answer is given for what is essentially two questions. (Colorado State University, 2013; UTexas, 2011)

Answers to surveys are often given in scales, allowing for easy comparisons. Scales come in many varieties, including ranges of numbers and personal standings. The following are two examples of basic five-point Likert scales, shown in Figure 13.

1)	*Strongly Disagree*	*Disagree*	*Neutral*	*Agree*	*Strongly Agree*
	☐	☐	☐	☐	☐
2)	*0*	*1*	*2*	*3*	*4*
	☐	☐	☐	☐	☐

Figure 13 - Sample Likert Scales

The first scale is used to measure opinion through levels of agreement with provided statements. The second scale is utilized to extract numerical data in a multitude of fashions. An advantage of using simple scales is that they may be converted to numerical or quantitative data and then analyzed. Questions of opinion thereby become statistical data that can be portrayed using graphs, revealing trends that could not be identified simply by using the qualitative answers themselves. (Center for Civic Partnerships, 2007; Chambliss & Schutt, 2013)

2.9 Education

2.9.1 Designing and Assessing Educational Materials and Effectiveness

One use of survey data is to show trends, such as those that reveal gaps in public knowledge, to designate where any educational materials should be focused. In 1988 the state of California enacted a raise in the tobacco tax in order to fund one of the largest multimedia campaigns ever conducted by a single state. The twenty-five cent tax increase per pack of cigarettes allowed the state to direct 26 million dollars in revenue between April 1990 and June 1993 to produce television, radio and billboard advertisements towards the prevention of smoking in the state. In 1991, the state conducted phone interviews with smokers within the state to assess the effectiveness of their educational campaign (Hu, Sung, & Keeler, 1995). The interviews featured two distinct questions to determine the effectiveness of the state-produced materials. The first question was an open-ended question designed to determine whether or not smokers were attempting to stop smoking, and what influences were motivating their behavior. The second question determined the effectiveness of the educational materials. The interviewer asked the participant if he or she could recall seeing or hearing one of the advertisements that was put out by the state earlier that year. It was determined that 34 percent of smokers in the area that quit were influenced by the media. The state was later able to extrapolate that 173,000 former smokers quit between 1990 and 1991 due to some amount of influence from the state sponsored media. (Hu et al., 1995; Popham et al., 1993)

The success of educational campaigns is very dependent on how they are structured. A successful program needs to have objectives, a clear audience, and an effective means of communication (New South Wales Government, 2011). All of the aspects contributed to the success of California's 1988 anti-smoking campaign. The audience and objective were clear: individuals who smoked and to stop those individuals from smoking, respectively. In this respect the campaign worked very simply, and the focus was on the means of communication. Television, radio and billboards were a few of the main methods of advertising in 1988, making them the most effective in reaching the largest population of smokers. This particular campaign also found a way to raise money using its own audience, through the tobacco tax, making it more self-sufficient. Despite the simplicity, anti-smoking campaigns have been going on for years because of their ability to culturally adapt. (Hu et al., 1995; Popham et al., 1993)

2.9.2 Active Learning

In addition to the effectiveness of campaign based education, active learning has become common practice when educating older audiences. This educational method focuses on teaching skills through interactivity rather than strictly verbal methods seen in traditional teaching styles. In a study of Active Learning Workshops conducted by Dr. Charles C. Bonwell, it was determined that active learning was an effective practice due to the involvement between students and educators. One major point stated was that the first ten minutes of a lecture are the most vital because the students are most attentive. Bonwell also states that it is important to understand that students will learn better if they have a vested interest in the material. He elaborates by citing J. Thomas's "Studies in Adult Education," which states "students learn what they care about and remember what they understand." This quote explains the importance of stimulating students' involvement and interest (Bonwell, 2000).

Dr. Bonwell elaborates on how to effectively stimulate interest in material through the use of a few simple methods. He advised the use of short courses, small class sizes, concrete concepts, humor, and strong course structure. Additionally, he stressed the importance of student-to-student and student-to-teacher interactions during a class period. These interactions allow students to feel involved in the educational material, leading to improved material retention and increased interest in the material. Dr. Bonwell also acknowledges the flaws of this educational model, stating that students may be resistant to non-traditional styles, and educators may see difficulties adapting to this system due to the amount of preparation required. In response to these differences, Dr. Bonwell suggested two course styles: one that focuses on the teacher-to-student interactions and one that focuses on student-to-student interactions. In the first model, educators balance traditional lecturing styles with interactive materials. This model is considered the low risk alternative because it allows for an easier transition from traditional to active teaching methods. The second model proposed a high risk alternative, which suggested that teachers act as mediators in student-to-student discussions. Through the high risk model, educators could see high educational payouts through increased interactions or, alternatively, very low educational payouts because of the radical course design. Both course designs propose an increase in educational retention through interactivity and can be used in conjunction with educational campaign materials to build successful educational models. (Bonwell, 2000; University of Minnesota, 2008)

2.10 Behavioral Psychology

2.10.1 Social Dilemma

Changes in behavior are often related to social situations. A social dilemma situation encompasses two aspects, where an individual benefit is weighed against a social deficit (Dawes, 1980). The social dilemma is perpetuated by the human instinct of self-preservation in which a person would often focus on his or her personal gain. The effects of the individual's action are perceived by the individual as negligible to the community as a whole. The irony of social dilemma revolves around the fact that, through small personal sacrifice, the overall detriment to the community can be avoided (Dawes, 1980). One example of social dilemma is a socioeconomic issue currently present in India. Women in India are often unable to work, and will most likely outlive their husbands. Due to this probability, elderly women will rely on their male children as primary sources of income. Women will achieve the highest personal benefits by having as many children as possible. In contrast, a gross overpopulation occurs and prohibits the possible implementation of social programs such as social security. If each woman were to personally sacrifice by having fewer children, the entire community would benefit through government funded social security programs. (Dawes, 1980)

The most famous example of social dilemma is a scientific study known as "The Tragedy of the Commons" by Garrett Hardin (Hardin, 2009). In this model, a common pasture is used by multiple shepherds. Each shepherd has a personal motivation to add animals to his herd. The individual benefit is great, and the cost of that additional animal in the herd on the common pasture in respect to that shepherd's needs is negligible. This simple cost-benefit analysis by a single shepherd drives the incentive to add animals to the herd. Adversely, all shepherds have the identical mentality, resulting in the overgrazing of the common pastures (Hardin, 2009). This anecdote can be applied to a myriad of social situations in which the individual benefit is great, while the perceived effect of that individual action on the entire community is insignificant. However, if all individuals hold the same mentality, the effect of each individual action is greatly compounded and deleteriously affects the community as a whole.

These concepts can be related to the benthic communities in Puerto Rico. These areas are considered to be common ground for boating, and thus can suffer a fate similar to the "Tragedy of the Commons." Because no *one* individual has specific property rights to the benthic communities, each may disregard the health of these areas and only consider their personal happiness. For example, if a family took a boat to a local coral reef to observe the fish, the boat operator would want to park a boat in close proximity to the coral reefs. To secure the boat, the operator may use an anchor, which could cause damage to the surrounding coral and seagrass. In this scenario, the boat operator neglects the health of the coral reef in place of personal happiness. If multiple boaters perpetuate this same mentality, an act such as anchoring could heavily degrade benthic community health.

2.10.2 Groupthink

Individualistic decision making processes can be altered psychologically in a group or community environment. Irving Janis was the most prominent researcher in this area and published “Victims of Groupthink” in 1972, which was edited and republished in 1982 as “Groupthink: Psychological Studies of Policy Decisions and Fiascoes.” His literature states that when decisions are made in a closed group setting, individuals are more concerned with the cohesive nature of the group and unrealistically assess the topic in question (Janis, Esser, Timmons, & Mihal, 1983). Groupthink ideology excludes all outside sources of information and opinion and increases the support of beliefs created inside the group, disregarding possible shortcomings. Members of the group conceal their own views in order to conform to the group dynamic and appear a “loyal” member of the group. Any different ideas are viewed as “disloyalty” to the group and its beliefs. Janis states that contrasting ideas and viewpoints were excluded from sectors of military and government, resulting in a lack of overall intelligence and rational decision making capabilities. (Janis et al., 1983)

Groupthink consequences can be applied in much smaller scale scenarios as well. If a large congregation of boaters ignores laws and regulations pertaining to mooring buoy use and anchor restriction, one boater may inherently feel hesitant to stand out and present a contrasting idea to the group.

While difficult to alter, general groupthink situations have been overcome using outside leadership. The traditional methods for correcting the groupthink mentality involve the use of outside personnel to act as leaders and devil’s advocates’ in order to present alternative views to the group. (Das Behl, 2012)

2.10.3 Psychological Projection

Psychological projection is a defense mechanism unconsciously imposing negative, personal attributes or behaviors onto an outside force. In other words, it is blaming the outside world for personal, unacceptable actions. This behavior stems from survival instincts alleviating the anxiety from performing disobedient or regretful actions. A tendency with psychological projection is to present false allegations and information to display oneself in a better light. (Freud, 1900)

An example of psychological projection is when a person receives a parking ticket. Excuses for the ticket could be that the “no-parking” sign was either inefficient or concealed. Contrary to their excuses, though, the sign was most likely in clear sight. Parking in the “no-parking” zone would be the unacceptable behavior, and the excuse would be the psychological projection. The individual wants to deflect his or her own negative action onto the city’s ineffective parking ticket signage (Tavris & Wade, 1997). Boaters may apply this same mentality to justify their incorrect boating habits.

3.0 Methodology

This project provides the Department of Natural and Environmental Resources (DNER) of Puerto Rico with an evaluation of the usage of the mooring buoy system, and then a collection of recommendations to alter any harmful boating behaviors. If these goals are accomplished, Puerto Rico's benthic communities will sustain less damage and will promote recovery. To accomplish these goals, the team conducted interviews with DNER staff to gain information about the mooring buoy system as well as past and current educational efforts. Furthermore, the team analyzed boating behaviors using three major methods of data gathering. We assessed a collection of historical, aerial photographs from 1994 to 2012 of four small islands, called keys, in the La Parguera region and one key in the Guánica region. We also conducted onsite observations in the four photographed keys in La Parguera. In addition, we created and administered a survey to evaluate the nautical community's awareness and opinions on the mooring buoy system and the benthic communities in these mooring buoy areas. We designed separate databases for all gathered data, allowing us to analyze boater's behavioral tendencies in regards to mooring buoy use in the five examined keys, and for future data gathering and analysis by the DNER.

3.1 Interviews with DNER Personnel and Maritime Rangers

Our first step was to conduct interviews and gain insight from those who have previous experience with the mooring buoy system and the corresponding benthic habitats. A conference call interview was scheduled with Aileen Velazco, our project liaison at the DNER, to refine the scope of our project. This interview confirmed the focus of the original problem statement centering on improper mooring buoy use and the resulting damage to coral reefs and seagrasses. We gained information on previous work relating to mooring buoys and educational efforts, as well as general knowledge specific to the island, such as the condition of the benthic areas. The minutes from the interview are included in Appendix A.

Interviews were also conducted with DNER personnel directly working on the mooring buoy system. The team interviewed Carlos Matos Rodriguez and Edwin Rodríguez, DNER staff who have worked with the mooring buoy system, in order to gain deeper insight into the system and patterns they have noticed since the buoy implementation in 1999. Erasto Nieves, the DNER's director of a boating access project in the La Parguera region, was also interviewed to find overlaps with his work and our own. Alternate ideas such as our own suggestion of the possible use of "no-anchoring" signage buoys in regulated areas were discussed (reviewed further in Recommendations). Two DNER Maritime Rangers, one patrolman and one higher ranking sergeant, were interviewed to determine their priorities while patrolling the keys. The two rangers spoke in Spanish, so Aileen Velazco acted as translator. They were asked questions about actions taken regarding violations of laws on mooring buoy and anchor usage. Interviews were conducted at the DNER office building and, with permission; all responses were typed and documented.

There are possible limitations when working with interviews. These limitations could include biases of certain DNER staff, answering based on what the interviewer might want, the tendency to lie due to lack of knowledge, or simply incorrect knowledge (Oatey, 1999). Information from interviews needs to be confirmed using outside sources. Portions of information from interviews with non-English speakers may have been misinterpreted or lost through translation.

3.2 Photographic Analysis

Interviews provided background on past and current boating tendencies, allowing us to better conduct and analyze other data gathering methods. For 20 years, the DNER has been conducting aerial photographic examinations of Puerto Rico's coastal areas and the 290 mooring buoys under the F-27 "Evaluation of Recreational Boating Anchor Damage on Coral Reefs and Seagrass Beds" project (McNally et al., 2009). These photographs were used for our photographic assessment. Our focus areas were the keys of Caracoles, Collado, Enrique, and Mata la Gata in the La Parguera region, and one key in the

Guánica region named Guánica key. The photographic collection consisted of hardcopy photographs from 1994 - 1999, and digital photographs from 2000 - 2012.

To begin, Carlos Matos Rodriguez instructed the team on proper techniques for analyzing photographs using a similar key in a different region in Puerto Rico as an example. This preliminary practice was done to train our team to recognize the size classification of vessels, how each vessel was secured, and occurrences of rafting. Rafting is when multiple vessels tie together hull to hull, creating a line of vessels. After the preliminary practice was completed, we conducted a single-blind study utilizing a chosen subset of 85 photographs of the five keys. The subset was identified by the non-evaluating team members, removing photographs that displayed the least amount of information from each flyover. Photographs chosen for the subset focused on large boating populations and useful photographic angles. The two photograph-evaluators were blind to the location and time of each photograph during assessment. The blind evaluative method removed the potential for any bias that the evaluators might interject. The two non-evaluating team members marked each photograph with a number corresponding to a list of dates and locations specific to each photograph.

The two evaluators began recording the data obtained from the photographs of the four keys in La Parguera, as well as the one key in Guánica. The number, size (class 1 – class 6), and behavior of each boat (mooring, anchoring, tying to mangroves, other) were documented. Boat sizes are estimated using reference points in the photograph, such as a boat of recognizable size (e.g., kayaks, jet skis, or boats with cloth canopies that are generally between 22-30 feet). Boat class sizes are categorized as follows: class 1 (up to 16 feet), class 2 (16-22 feet), class 3 (22-30 feet), class 4(30-48), class 5 (48-65 feet), and class 6 (greater than 65 feet). Boats chosen to be reference points in the photograph were categorized by class and measured using a ruler to create a scale length. This scale length was then compared to all other boats in the photograph in order to determine their relative lengths (class sizes). Stationary boats in the close vicinity of a mooring buoy were categorized as “moored,” stationary boats not in the vicinity of a mooring buoy were categorized as “anchored,” boats stationary along a wooded coast were categorized as “tied to mangrove,” and any other behavior was categorized as “other” (e.g. in motion). An example photo shows how to correctly classify boats and their corresponding behaviors in Figure 14.

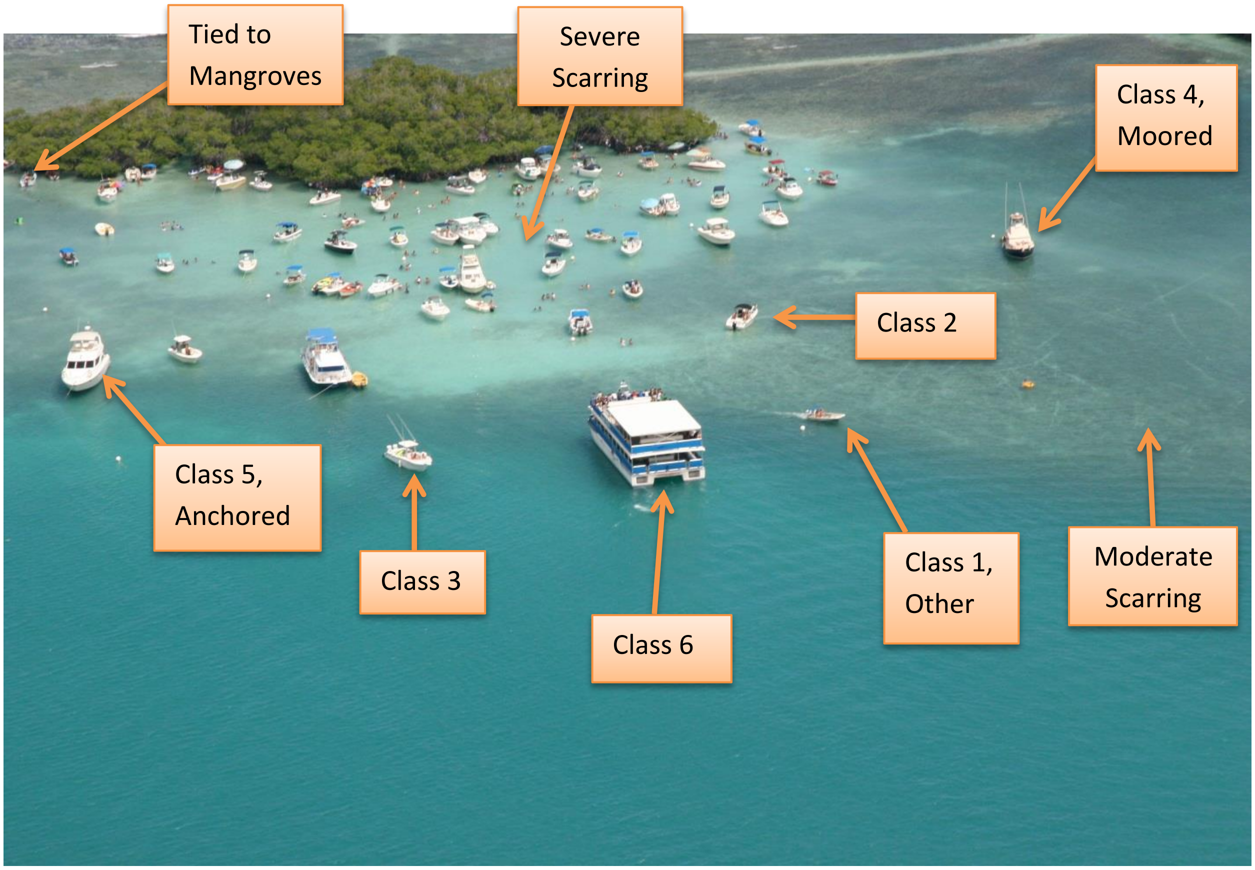


Figure 14 Classification of boating classes and their corresponding behavior

The evaluators also made note of the scarring of seagrass based on a preexisting scale used in a Florida seagrass case study (Sargent, Leary, Crewz, & Kruer, 1995). Scarring was classified as a 1, 2 or 3, (light, moderate, severe) as designated and can be applied specifically to areas shown in Figure 15. Evaluators visually created scarring polygons shown in Figure 15 and recorded the highest level of scarring in each photograph.

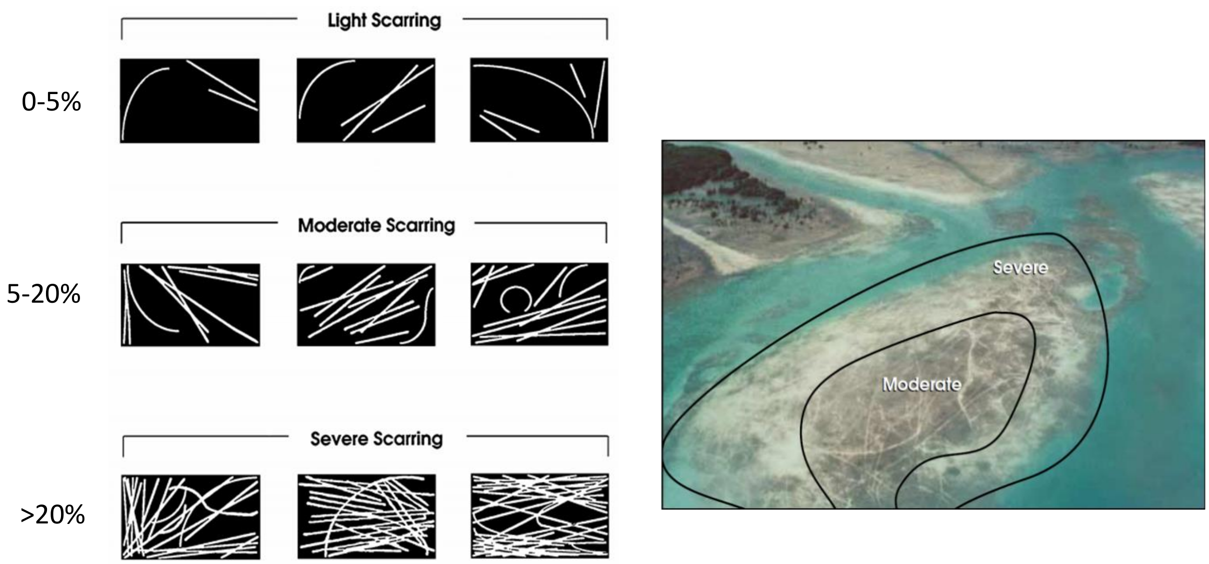


Figure 15 - Seagrass scarring scale and polygon application to a photograph (Sargent, Leary, Crewz, & Kruer, 1995a)

Figures 16 and 17 are examples of photographs depicting congregations of boats in determined sensitive areas that were analyzed and that resulted in scarring. Additional photographs are shown in Appendix C.

Figure 16 - Congregation of local boaters in Caracoles Key in La Parguera Natural Reserve (DNER, 2011-2012)

Figure 17 - Scarring in seagrass beds in Caracoles Cay in La Parguera Natural Reserve (DNER, 2011-2012)

The team designed an Excel database in which to enter observed data from each photograph organized by geographic location, and then by year. The two non-evaluating team members decoded, collated, and entered the data into the database. We created a template for the assessment to facilitate reproducibility by DNER personnel. The template of the photographic assessment tool is shown in Figure 18 as well as Appendix D. A technical document explaining how to take the most useful photographs possible while conducting a photographic flyover and enter the data into the Excel database is shown in Appendix E.

Location:		Date:		Group	I.D.#
Class of Vessel	Moored	Anchored	Tied to Mangrove	Other	Totals
Class 1	_____	_____	_____	_____	_____
Class 2	_____	_____	_____	_____	_____
Class 3	_____	_____	_____	_____	_____
Class 4	_____	_____	_____	_____	_____
Class 5	_____	_____	_____	_____	_____
Class 6	_____	_____	_____	_____	_____
Jetski	_____	_____	_____	_____	_____
Casabotas	_____	_____	_____	_____	_____
Totals	_____	_____	_____	_____	

Severity of Scaring
_____
Total Mooring Buoys
_____
Unused Mooring Buoys
_____
Number of Boats Present
_____

Figure 18 - Excel database for photographic assessment

The aerial photographs presented certain limitations. The photographs were taken from a combination of angles and distances from the boats. The angle sometimes concealed mooring buoys behind boats or concealed boats behind mangrove patches. The air to ocean distance also presented a clarity problem, making it difficult to discern whether or not a boat was anchored as well as moored, or difficult to determine the difference in boat class size. For certain years there were no photographs, leaving gaps in the data. There was no consistency in dates or times of the aerial photographic flyovers, making accurate comparison between years difficult. To alleviate these concerns and verify what was seen in the photographs, we completed onsite observations.

3.3 Onsite Observations of Mooring Buoys in La Parguera

Using the photographs and previous experience, the DNER identified two sections of the island as high priority hotspots. The keys of La Parguera and Guánica have shown heavy activity in photographic assessment and in previous field research done by the DNER. We decided it would be beneficial to observe firsthand the boating behaviors and health of the benthic communities in La Parguera (due to traveling restrictions, Guánica was not observed). To record specific boating information we created an observational assessment tool template found in Appendix F, similar to the photographic assessment tool. As with the photographic assessment tool, a technical document explaining how to utilize the observational assessment tool can be found in Appendix G. All other applicable locations around the island can be assessed by the DNER using this technical document and observational tool.

We chose Good Friday of Holy Week (part of the Christian celebration of Easter) as the primary day to conduct field research and observation because of the popularity of recreational boating on that day. DNER Rangers escorted the team by boat to each of the specific keys under study in La Parguera. For the analysis of the various keys, we took the following steps to ensure continuity and consistency when comparing results.

1. To assess each key, the team was split into pairs of two to obtain two individual data sets.
2. One team member completed assessment by orally counting all vessels, mooring buoys, and each boat's method securing (anchored, moored, moored and anchored, tied to mangroves) while the other team member recorded the data in the onsite observational assessment tool.
3. Occurrences of rafting, and the numbers and types of vessels rafted (class 1 – class 6) in each rafting occurrence were recorded.

4. Photographs were taken of each site to further evaluate all recorded observations.
5. The team took underwater photographs and videos capturing the health of the benthic communities in the area.

The proximity of our observations allowed the team to count when mooring and anchoring occurred in tandem, which was not recorded in the photographic assessment tool. However, our vantage point hindered our ability to count the number of boats. We also had a limited amount of time in each area due to the ranger's strict schedule. These limitations were overcome by taking multiple photographs from many angles at each key to ensure all the data that were missed in primary assessment could be later reviewed. In reviewing onsite photographs, the close proximity to the boats made behaviors very clear and more accurate numbers could be recorded because there was no limit in time; although, the onsite vantage point remained an issue in blocking boats from view behind others. The onsite vantage point, though, allowed us to determine the relative lengths of boats reasonably precisely.

3.4 Surveying

Using interviews as preliminary guidance and after testing survey drafts with DNER personnel, the team refined the survey to ensure questions were clear, concise and could accurately gauge the selected knowledge of the nautical community. The team designed this survey in order to assess community awareness of benthic habitat importance, mooring buoy importance and usage, and boater behaviors. Common boating behaviors included dropping anchor, boating through sensitive waters, tying to mangroves, and mooring. Boating behaviors are cognitive; therefore, questions were geared towards how boaters perceive their surroundings. Attitudes towards the environment, regulations, mooring buoys, and even other boaters were examined in order to determine reasons behind observed behaviors. It was also important to understand the boater's opinions on any changes to future regulation on boating habits, such as the potential of "no-anchoring zones." Questions also considered if locals wanted additional mooring buoys, or if they thought the number was already sufficient or too high. In order to measure information retention, we also included questions based on existing educational materials.

Question responses were Likert scale, multiple-choice, and free response. This style of questioning is easily answered, permitting more questions to be asked while still allowing for a quickly completed survey. The five-point Likert scale eliminates qualitative responses, which are more difficult to analyze. The survey was edited by our advisors and then translated into Spanish by Carlos Matos Rodriguez and Aileen Velazco. The survey is included in Appendix H.

To assess knowledge and awareness, the team surveyed local boat operators utilizing a purposive sampling method to confirm the survey takers have relevant knowledge (Chambliss & Schutt, 2013). The surveys were conducted at the DNER registration office, marinas in San Juan and Fajardo, and specific mooring buoy locations in La Parguera to comply with the purposive sampling technique. All survey responses were then collated and entered into the survey response Excel database. A technical document explaining how to properly enter survey results into the Excel database can be found in Appendix I. Once in the database, results were analyzed according to our research questions. Statistical tests (McNemar, t-test and correlation) were performed specific to each result in order to prove significance or connection.

There are multiple limitations involved with the survey data. We surveyed 100 members of the nautical community, but a larger sample size would have allowed us to draw more representative results from the data. Our limited transportation restricted us from surveying more areas around the island. Given transportation, we would have included more regions in our sample size for a more geographically diverse data set. The survey was printed in both English and Spanish creating the possibility for information to be lost or misinterpreted during the translation. The translation could have altered the meanings of the questions and have caused a discrepancy between the English and Spanish results. The latter issue was not a problem due to the majority of the surveys being administered in Spanish; however, open response results may have been affected. Overall, the variety of data gathering methods should minimalize the effect of each method's limitation on the final results.

4.0 Results & Discussion

Using the data gathered from all of the discussed methods, we were able to gain insights regarding our two research questions of mooring buoy and educational effectiveness.

Fifty-three photographs from 2006 to 2012 were used to obtain these data. This range was selected because of the frequent flyovers, and subsequent photographs taken by the DNER. Photographs analyzed were of the Caracoles, Collado, Enrique, Mata La Gata and Guánica keys. The following is a table describing the analyzed photographs:

Year	Caracoles	Collado	Enrique	Guánica	Mata La Gata	Grand Total
2006	3	2	3	2	2	12
2007	1	0	1	1	1	4
2008	0	0	0	0	0	0
2009	3	3	1	3	3	13
2010	2	2	3	2	3	12
2011	0	0	2	2	1	5
2012	1	2	1	1	2	7
Totals	10	9	11	11	12	53

Table 1 - Numbers of photographs analyzed by year and location (no photographs were available for 2008)

All onsite observations took place on March 29, 2013. Observations were of all keys analyzed in photographs with the exception of Guánica. The team spent 15 minutes at each key recorded the data to complete our onsite observational tool.

All survey data are based on a sample size of 100 boaters. Of that sample size, 92% were male and 92% were over 25 years of age. Over 90% of the population had received a college/university education or higher. Of the survey population, 77% reported having a boating license, but only 37% reported having seen any DNER educational materials. The majority of surveys were administered in the

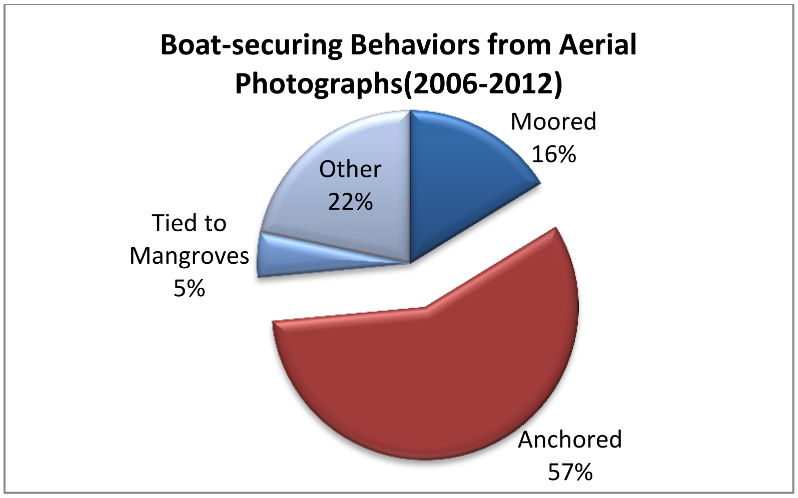
DNER boater registration office, thus this study is most representative of the boating community in the vicinity of San Juan. The following are responses of behaviorally relevant survey questions used in this section:

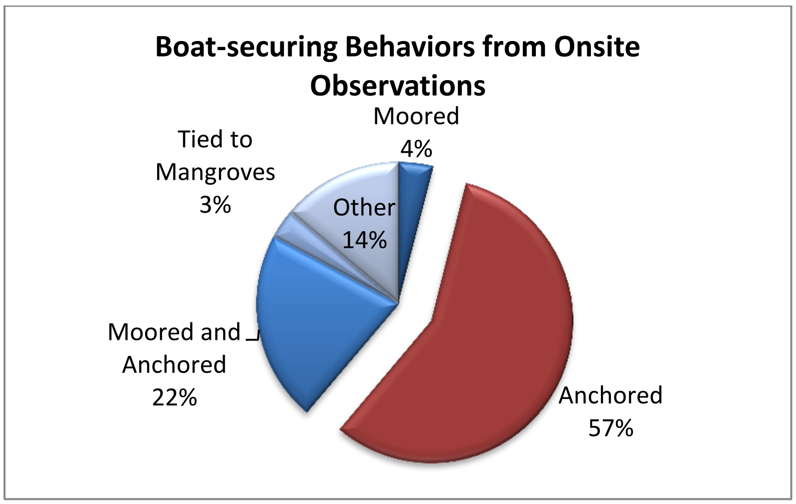
Question	**Mean** (1-5)	**Disagree, 1** (%)	**Agree, 5** (%)
1. I find the mooring buoys useful.	4.2	5	75
2. The current mooring buoys are in convenient locations.	3.7	9	52
3. I would like to see an increase in the number of mooring buoys.	4.4	6	81
4. I prefer beach areas to be covered in sand rather than seagrass.	3.7	17	55
5. I believe that anyone has the right to enjoy the ocean.	4.6	6	90
6. Everyone anchors or moors wherever they want.	2.0	73	19
7. One anchor will not harm the coral reefs or seagrass.	1.6	89	10
8. Anchoring is the best way to keep stationary boats close together.	2.8	34	23

Table 2 - Response frequencies of behaviorally relevant survey questions, omitting neutral or blank responses (n=100)

4.1 Mooring Buoy Usage

Photographic assessment, onsite observations, and survey responses were used in evaluating the effectiveness of the mooring buoy system. The results of photographic assessment and onsite observations were compared to each other, and then to specific survey responses to gain further insight into why the mooring buoys have or have not been effective. The following is a collection of results from all data gathering methods illustrating boat-securing behaviors.





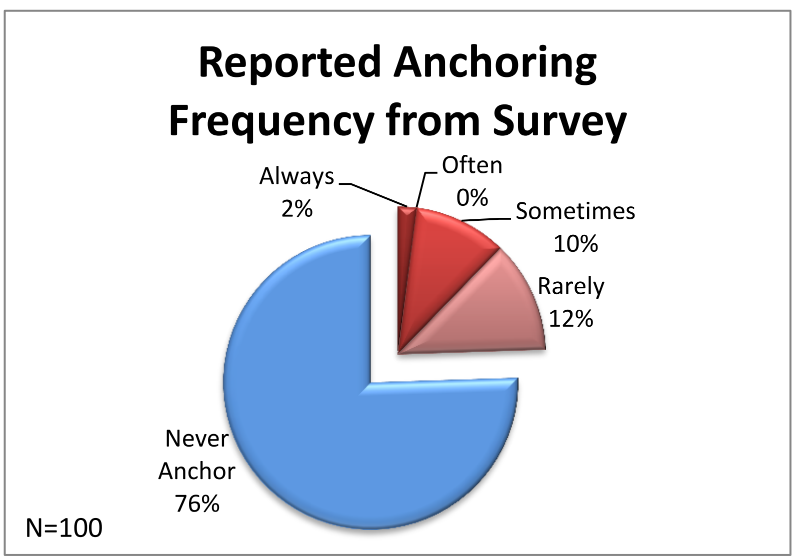


Figure 19 - Results from Aerial Photographs, Onsite Assessments and a related survey question illustrating anchoring frequencies

Figure 19 displays the results of the aerial photographic assessment and onsite observations. The results compared the amounts of boats that were observed anchoring to other boat-securing methods. Figure 19 also displays the survey results reporting frequencies of anchoring. Note the discrepancy between photographic assessment and onsite observations reporting much higher frequencies of anchoring than are indicated by survey responses.

The graph of photographic results shows that 57% of the total boats observed were anchoring, while only 16% of the boats were mooring. The overall relationship between these percentages is confirmed by the data seen from the onsite observations. While onsite in La Parguera, 57% of the observed boats were anchoring while only 4% were using a mooring buoy without also anchoring. To assess the total amount of boats that were using mooring buoys while onsite, with or without anchoring, the team combined the onsite results of mooring and anchoring with the onsite results of solely mooring. This comparison still shows only 26% of the observed boats using mooring buoys compared to 57% using anchors. These photographic and onsite results allowed us to see that the mooring buoys are not being used effectively in comparison with the observed boater population.

Photographic and onsite results may be compared to the survey results also shown in Figure 19. Results of the related survey question "How often do you ONLY anchor?" show 76% of the survey population responded that they never anchor. This survey result is compared to the 57% of boaters observed using anchors from photographic and onsite assessments. These percentages imply that individuals answered the survey differently than how they were observed in photographs and onsite.

One possible explanation of the difference between actual and reported buoy use might be that the population believes the buoys are being used more than they have been observed to be. If it is public belief that the buoys are commonly used, it might lead boaters to assume they are already taken upon arriving to a crowded key, leading them to anchor instead. Another reason might be that individuals answered the survey in accordance with what they believe should be occurring, indicating that they know what is correct but are choosing to disregard it in order to continue their activities. This discrepancy could also imply that boaters understand the consequences of anchoring, meaning either fines or environmental damage, but are unaware of the severity of those consequences. The convenience of anchoring in any chosen spot may also tempt boaters to disregard the mooring buoy system, indicating “no-anchoring” zones as another possible solution. Of the total survey population, 71% responded in support of no-anchoring zones, reinforcing the viability of this option.

Of the ten photographs analyzed for Caracoles from 2006 to 2012, 90% displayed at least one instance of rafting on a mooring buoy. This percentage coincides with instances of rafting observed in all visited keys; 20% of all observed boats were rafted. From the three photographs analyzed during photographic assessment taken in 2009, we observed roughly 40% of the total mooring buoys being rafted upon. These data do not encompass occurrences of rafting without utilizing mooring buoys.

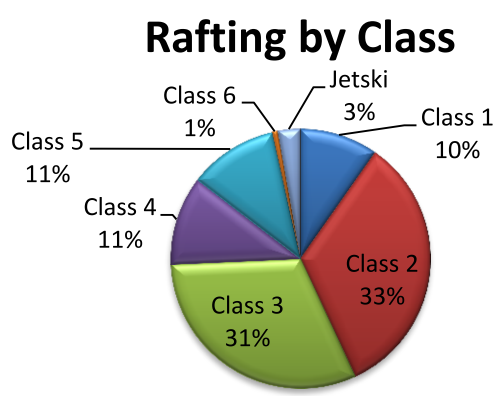


Figure 20 - Percentage of boats observed rafted by class in photographic assessment, 2006–2011

Figure 20 shows that class two and class three boats are the most commonly rafted. Boats are classified by length, ranging from class one (under 16 feet) to class six (65+ feet). A class two boat is between 16 and 22 feet in length and can weigh up to 4400 pounds. Class three boats are 22 to 30 feet in length and can weigh up to 10,800 pounds. The average number of boats rafted to one buoy was four.

From the data on common rafting numbers, boat sizes and the type of buoy (discussed in section 2.5.2), the team was able to estimate the stresses a mooring buoy would sustain during an average occurrence of rafting (Appendix J).

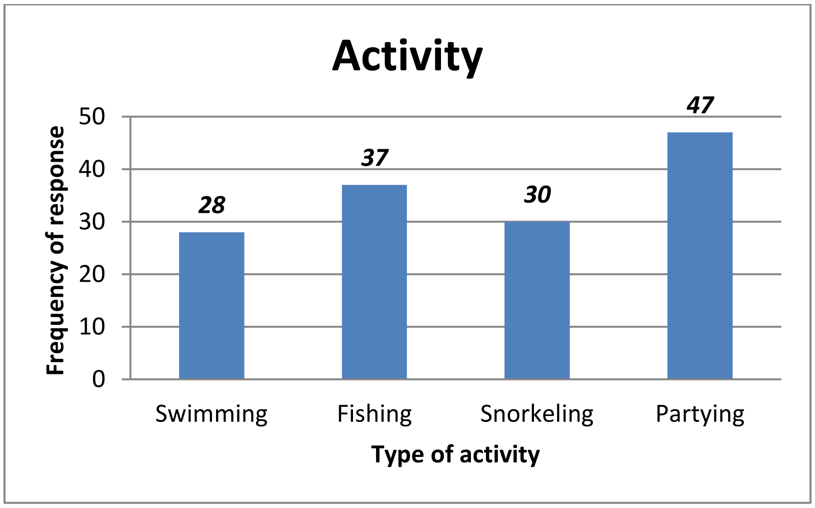


Figure 21 - The frequencies of activities reported on the survey

Rafting is a behavior that stems from the type of activity in which boaters are participating. Figure 21 shows the frequency of responses to the survey question “When you go boating, in which of the following activities do you participate?” From Figure 19 we see that partying is the most frequently reported activity. This figure supports the onsite observation that 100% of boaters were engaging in recreational activities, the most common being partying. Partying is one such activity that requires individuals to be in close proximity with one another. The prevalence of partying, then, provides an insight as to why rafting is common and the current mooring buoy system is not always effective for this population and their behaviors.

Year	**Caracoles**	**Collado**	**Enrique**	**Guánica**	**Mata la Gata** (no mooring buoys)
2006	87.09	46.67	88.46	25.64	0
2007	76.92	N/A	N/A	85.71	0
2008	N/A	N/A	N/A	N/A	N/A
2009	73.68	59.09	16.67	30.95	0
2010	71.875	68.75	55.17	32.14	0
2011	N/A	N/A	16.67	32.15	0
2012	100	31.25	100	50	0
Average	81.913	51.44	55.394	42.765	0

Table 3 – Average percentage of mooring buoy usage observed in photographs from 2006-2012 (N/A = no photographs)

The team also used photographs and observations to assess the percentage of boats moored in relation to the total boats present (shown in Table 3). Additionally, we assessed the percentage of mooring buoy usage in relation to the number of mooring buoys present. We determined Caracoles had the highest percentage of mooring buoy usage over the six year period, at 82%, as compared to 55% in Enrique, 51% in Collado and 42% in Guánica. While an 82% usage of mooring buoys might seem high, this usage only represents 12.9% of the total population of boats visiting Caracoles. The average number of boats observed in a photograph of Caracoles is 150. Our data do not explain any causes of changes in percent buoy usage over years. This percentage is consistent with survey responses indicating that 84% of boaters would like to see an increase in the number of mooring buoys, suggesting that more boaters might use the buoys if they are made available.

As a result of the buoys not being effectively available for the boating population, the benthic communities have suffered. The purpose of mooring buoys is to curb boating damage to benthic habitats; however, all keys were categorized with severe scarring during photographic assessment. This severity of benthic damage shows that the mooring buoys have been insufficiently effective thus far.

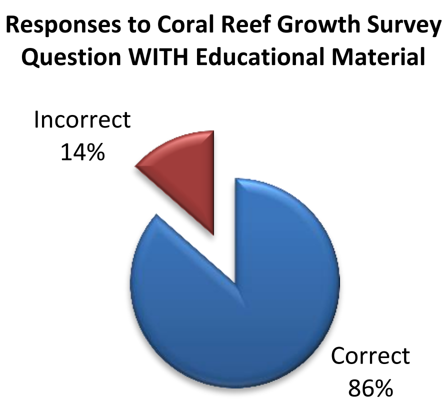
4.2 Educational Effectiveness

The team assessed the effectiveness of DNER education on the boating community using the results of the photographic assessment, onsite observations and the survey responses. The difference between observed behaviors and survey responses may be associated with education, meaning those with education and those without tend to respond differently. Psychology, though, leads to certain responses and may explain the causes behind behaviors.

4.2.1 Retention of Specific Information

The survey included questions asking for specific information about the growth rate of coral and the cost of a fine for not obeying mooring buoy regulations. With these questions we assessed whether the boating community has retained important material taught by the DNER.

Survey Question:	Possible responses:	
How much does coral tend to grow per year?	*a. 0.5 to 5 mm (0.02 to .2 in)*	a. CORRECT
	b. 0.5 to 5 cm (0.2 to 2 in)	b. CORRECT
	c. *0.5 to 5 m(20 to 200 in)*	c. INCORRECT
	No response	INCORRECT



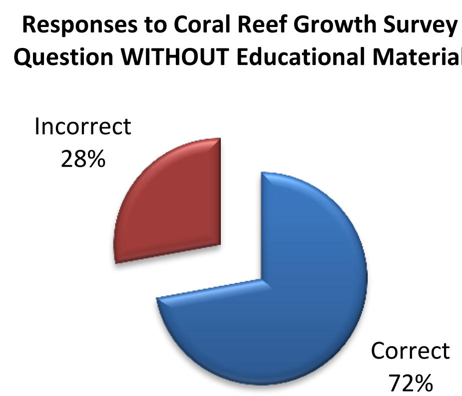


Figure 22 - Responses of the population who reported seeing educational materials to responses about the growth rate of coral , and responses of those who reported NOT having seen educational materials to responses about the growth rate of coral (n=37, n=61 respectively)

Figure 22 shows that 86% of the surveyed population who reported having seen DNER educational materials knew how much coral tends to grow. On the other hand, only 72% of the population who did not see educational materials knew how much coral tends to grow. We conducted a McNemar test and based on our results these proportions differed significantly (chi-square = 29.5, p<0.001). To conduct this test, we grouped correct responses (*a* and *b)* and incorrect responses (*c* and *no response)*. Individuals who saw educational materials responded incorrectly 14% less often than those who have not seen educational materials.

Survey Question:	**Possible responses:**	
What is the largest fine for anchoring in mooring buoy areas?	*a. Up to $100*	a. INCORRECT
	b. Up to $1,000	b. INCORRECT
	c. *Up to $10,000*	c. CORRECT
	No response	INCORRECT

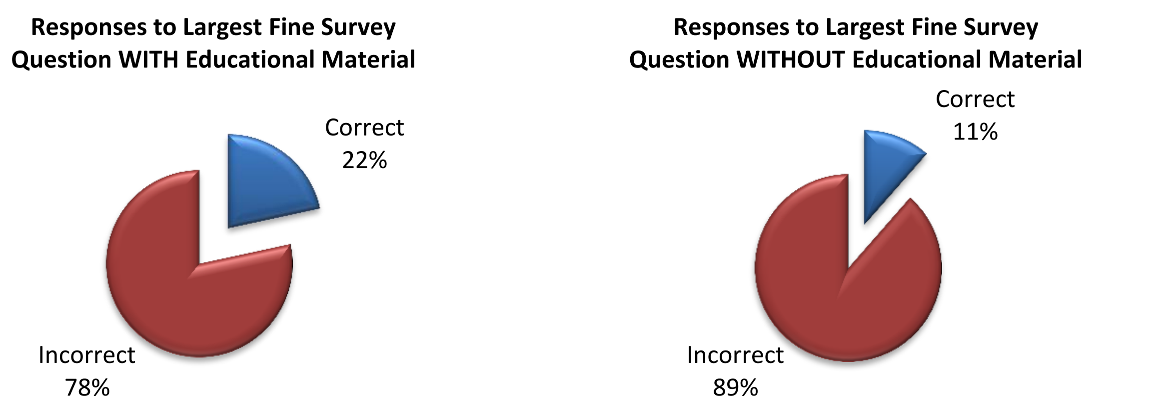


Figure 23 - Responses of the population who reported seeing educational materials to responses about largest fine for not following mooring buoy laws, and responses of those who reported NOT having seen educational materials to the responses about the largest fine (n=37, n=61 respectively)

Figure 23 shows that 22% of people who reported seeing educational materials knew the maximum fine for not following mooring buoy laws compared to only 11% of people who reported not having seen educational materials. We conducted a McNemar test and based on our results these proportions did not differ significantly. To conduct this test, we used the correct response (*c)* and grouped incorrect responses (*a, b* and *no response)*. Although those who saw educational materials tended to respond more correctly than those who had not, the population's responses were still largely incorrect.

There is a statistically significant difference between the responses regarding coral growth of those having and having not seen educational materials. The increased correct responses of those who had seen DNER educational materials can likely be attributed to the effectiveness of those materials in that subject area. We can see, though, that responses for the question on coral growth are predominately correct overall. The overwhelming percentage of correct responses may indicate that the population is also generally aware of the growth rate of coral, possibly somewhat lessening the apparent difference due to education. Figure 21 was not proven to have statistical significance, implying that there is no significance between education and responses regarding fines. This lack of significance is important because education *should* be effectively improving responses on this topic, meaning that if the education was effective there would be a statistical significance. From the dominating percentage of incorrect responses and lack of statistical significance, it may be inferred that fines are an area that may not have been effectively learned from educational materials. By revealing that education has not improved responses regarding fines, we may identify this as an area in education that potentially needs improvement. The survey population who had seen educational materials had slightly more correct responses compared to those who had not, but whether or not this difference is due to education is unclear. Using the support of information from interviews with DNER Rangers (shown in Appendix B), an explanation of these incorrect responses aside from education might be that the fines are not commonly issued. Interviews with DNER Rangers confirmed that the fines are not commonly issued due to uncertainty regarding costs of fines and the circumstances under which they should be issued. Assuming based on survey responses that boaters are unaware of the fines, more frequently issuing the fines could inform, or educate, those who are unaware. Additionally, the increase in fines issued could inform other boaters through social contact. According to survey responses, 65% of boaters believe that an increase in issued fines would effectively encourage mooring buoy use. Boaters appear to be aware of certain aspects of the environment, such as coral, but remain unaware of the penalties for damaging them.

The responses of the population that reported having a boating license show the same overall tendencies in relation to the same two questions (coral growth and maximum fine) in that they responded largely correct regarding coral growth and incorrect regarding fines. Those who reported having licenses, though, more often responded incorrectly than those without. Boaters with licenses might be expected to know more information than those without due to the one-time educational course required in order for them to receive their license. The boating license educational course, though, was not required for those born before July of 1972. This survey population may have been largely born before that date, therefore never having received the course. The increase in incorrect responses for those who reported having licenses may be specific to this survey population, 92% of whom were over 25 years of age. Another explanation might be that individuals with boating licenses are generally older, making it longer since they were required to learn the information.

Given these patterns and survey data, it would appear that the focus of further education may need to be altered to concentrate more on boating rules and regulations and less on the importance or biology of benthic habitats. If the boating population becomes more informed of the law and its penalties regarding mooring, it could potentially prompt a corresponding change in destructive boating behaviors.

Survey Question:
Are you aware of when coral reefs and seagrasses are below you?

Possible responses:

Never	*Rarely*	*Sometimes*	*Often*	*Always*
☐	☐	☐	☐	☐

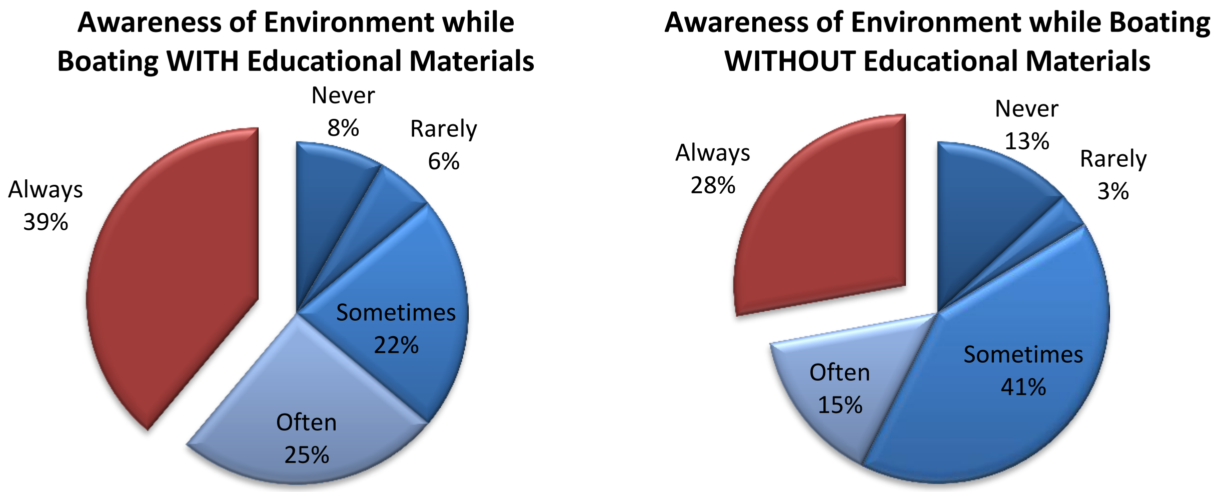


Figure 24 - Responses of the population who reported seeing educational materials to responses about awareness of benthic environments while boating, and responses of those who reported NOT having seen educational materials to the responses about awareness of benthic environments while boating (n=36, n=61 respectively)

Figure 24 illustrates the differences in survey responses regarding awareness of surrounding benthic habitats of those who did and those who did not see DNER educational materials. We conducted a McNemar test and based on our results the proportion of boaters who were aware of the environment below them had seen more education, and is significantly different than boaters who had seen less education (chi-square = 11.3, p = 0.001). This test was conducted omitting neutral “sometimes” responses and grouping the responses “often” and “always”, and the responses “rarely” and “never”. By omitting the neutral responses, we limited the sample size to 66. Individuals who reported seeing educational materials also reported “often” and “always” being aware 10% and 11% more, respectively. These data say that the population who did see educational materials is more largely aware of the environment than those who did not.

This difference in environmental awareness may be related to the DNER’s educational materials. Local environments may be an area that is covered effectively in the materials, thereby increasing the population's frequency of awareness. The responses of those reporting not having seen educational materials are different, most often reporting being "sometimes" aware. If the majority of the boating population who has not already seen educational materials is already "sometimes" aware of the environment, education might be the solution that pushes them towards the next step, being "often" or "always" aware. Combined with other education on the importance of benthic environments and how boating behaviors such as mooring or anchoring can affect them, improved environmental awareness while boating has the potential to lead to better boating practices (e.g. mooring).

4.2.2 Educational Impact on Mooring and Anchoring

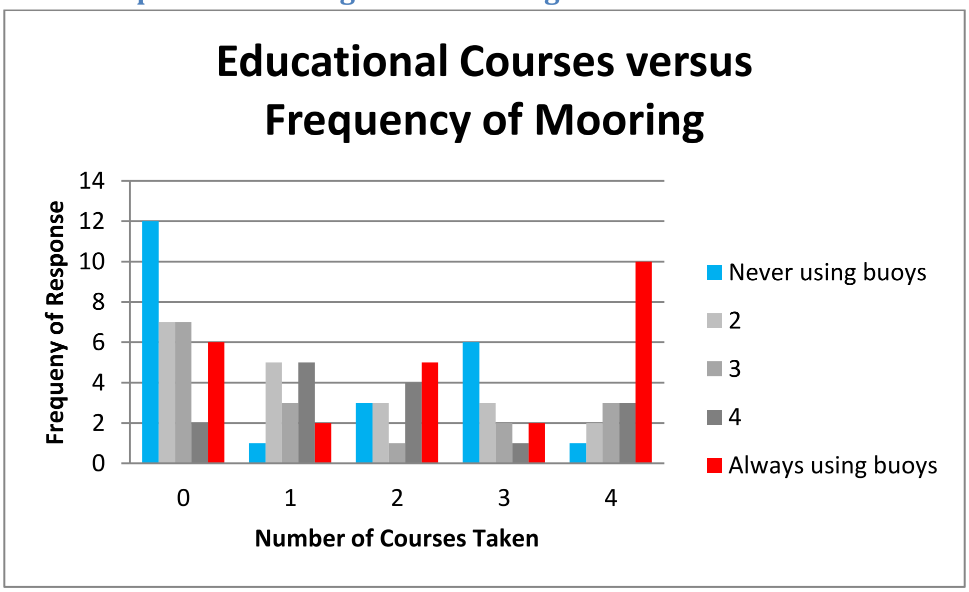


Figure 25 - Comparison of the number of courses taken to how often mooring buoys are used (n=99)

Figure 25 compares the number of educational courses on mooring buoys participants reported taking versus their responses regarding frequency of mooring. We conducted a single-tailed t-test and based on the results, we concluded there is a statistical significance between the relationship of mooring buoy usage and education received ($t=2.358$, $p=0.01$). To conduct this test we used two groups: those who have taken no educational courses and those who have. The mean usage response of those who had education was 3.25, while only 2.51 for those without education. We also conducted and proved a positive correlation between mooring buoy usage and the number of received educational courses ($R=0.259$, $p=0.009$). The plot shows that 53% of those who reported taking four educational courses on mooring buoys most often reported always using the buoys. Conversely, 35% of those who reported never taking any courses most often reported never using the buoys. This percentage is low due to the larger number of individuals who reported taking no courses.

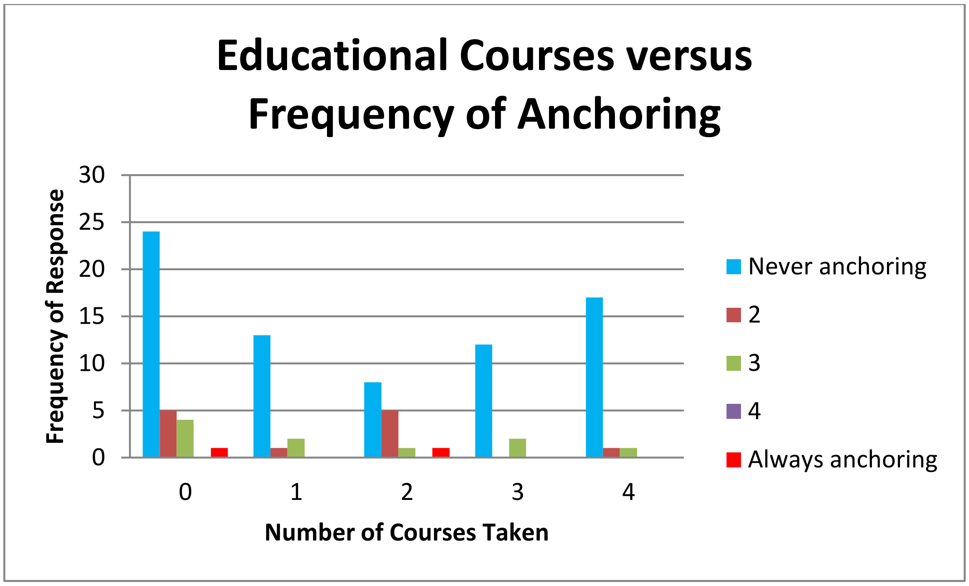


Figure 26 - Number of courses taken compared to how often mooring buoys are used (n=98)

Figure 26 compares the number of educational courses the survey population reported taking to their response on frequency of anchoring. The data show no apparent pattern. Figures 23 and 24 illustrate how the number of educational courses an individual has taken relates to frequencies of mooring and anchoring. Results shown in Figure 23 indicate that, without education, the population does not use the buoys as frequently, but with educational courses on mooring buoys their use effectively increases. This result points towards a necessity for more education about the mooring buoys if they are to be used by a larger population. Figure 24 is the counterpart, reporting frequencies of anchoring. The results shows no observable pattern and the data do not lead to significant conclusions.

A possible explanation for such varied results could be that such a large portion of the boating population anchors due to an insufficient number of mooring buoys.

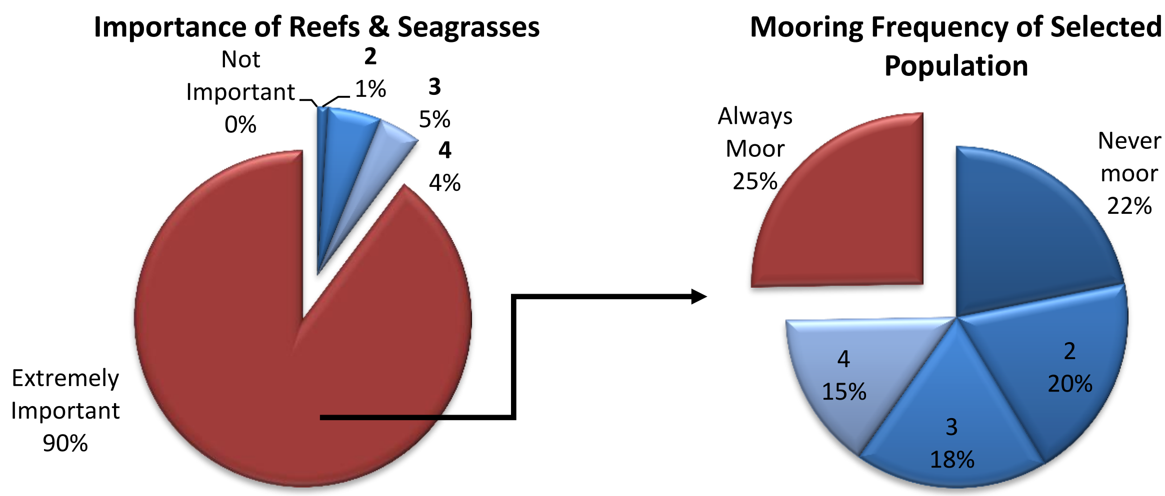


Figure 27 –Survey responses on the importance of reefs and seagrasses, and then the mooring frequency of the population who responded that those environments are extremely important (n=98, n=87)

Figure 27 reveals that the survey population is in almost complete agreement that coral reefs and seagrasses are extremely important, 90% reporting so; however, of that 90% only 25% reported always mooring. From Figure 27 we can see that the population is aware that these benthic environments are important, but their actions do not reflect that knowledge. If the boating community is largely in agreement that these benthic communities are important, then perhaps that is an area in which they have been effectively educated. The lack of action to support that knowledge, though, could indicate a gap in which the population was not sufficiently educated on how their actions effect these environments. This gap might be identified using the previously stated correlation between amount of education and mooring frequency, showing that this low percentage of mooring could increase with increased education. In open-ended survey questions, about 20% of boaters responded that they would like to see an increase in education and information about mooring buoys. Due to the many DNER materials that contain mooring buoy information, though, these responses asking for education may be caused by psychological projection in which individuals are blaming their negative behavior on others, in this case the DNER. This psychological projection could be a defense in which the survey participants are justifying their answers and their actions to themselves.

Education seems to have a positive impact on boating behaviors, but there is a lot of opportunity for improvement. For instance, while onsite our team observed that much of the DNER's educational materials do not command significant attention. Certain areas such as the biology of coral seem to be known, but information on fines and locations of benthic communities are lacking. To fill the knowledge gap may require increased education geared specifically towards what actions boaters can take to help preserve what they already know are important areas.

4.2.3 Concluding Explanations on Reviewed Behaviors

We have discussed boating behaviors and how they relate to education, and the causes of those behaviors may be explained using survey responses. Specific data was chosen from Table 2 to offer potential explanations to support previously proposed hypotheses; however, these are not the only possible explanations that might be drawn from these data.

Results from questions one and two illustrate that 75% and 52% of individuals agree that mooring buoys are useful and convenient, respectively. Despite these results, we have already seen that the buoys are not used by the majority of boaters. Question three, then, shows us that 81% of the surveyed population would like to see an increase in the number of buoys, possibly indicating that there are not enough buoys for the population that wants to use them. Lack of buoys often leads to anchoring rather than leaving the populated area because, as shown in question five, boaters believe that anyone has the right to enjoy the ocean. This could suggest that boaters may have knowledge on the buoys, possibly from educational efforts, but the insufficient number of buoys might be causing boaters to anchor.

When the results are put together, questions five, six and seven offer another potential explanation. Boaters appear to be in agreement that anyone has the right to enjoy the ocean, but 76% disagreed with the statement that everyone moors or anchors wherever they want. What these data may indicate is that, despite feeling free to enjoy the areas, there is an awareness of regulations. Awareness, however, will not likely translate to concern if boaters commonly notice unenforced regulations. We observed this lack of concern in both photographic and onsite observations. If we apply groupthink theory, without an external force it is unlikely that boaters will begin abiding by the laws while the vast majority does not.

Question eight offers another argument, showing that the survey population did not very strongly agree or disagree to anchoring being the best method of securing a boat. Due to the lack of strong preference, it may be inferred that boaters are anchoring because it is useful to the activity in which they are participating (e.g. partying, previously discussed). This passiveness towards anchoring also indicates that the boaters may be open to an alternative method of securing given that it is useful, allowing education the opportunity to direct them towards mooring. These behaviors can be changed, and our team has created a list of suggestions to facilitate that change.

5.0 Conclusions and Recommendations

Through background research, interviews with DNER personnel and Maritime Rangers, photographic assessment, onsite observations, and analysis of survey responses, our team has developed a collection of recommendations to encourage mooring buoy utilization and refine educational efforts. Photographic and onsite results indicated that the mooring buoy system has not been sufficiently effective, possibly due to the activities in which this population of boaters is participating or insufficient numbers of buoys. Survey responses, combined with background research and our other data collection methods, suggested possible causes of boater behaviors, such as the application of groupthink theory. Using this information, we were able to present the DNER with multiple recommendations to aid the current preservation of benthic habitats. The following recommendations are organized according to the research question they most directly address: Mooring Buoy System Effectiveness, Educational Effort Effectiveness, Further Recommendations, and Future WPI Interactive Qualifying Projects.

5.1 Mooring Buoy Effectiveness

5.1.1 Rafting Mooring Buoy Design

We recommend that the DNER implement the team's rafting mooring buoy design, shown in Appendix J. Rafting is a common occurrence among boaters that frequent the observed keys. Rafting is frequently exhibited while boaters are "partying," which from onsite observations and survey responses we determined is the most commonly seen and reported activity. The rafting mooring design allows a specified number of vessels to engage in rafting behavior, without the necessity to drop anchor in order to remain stationary.

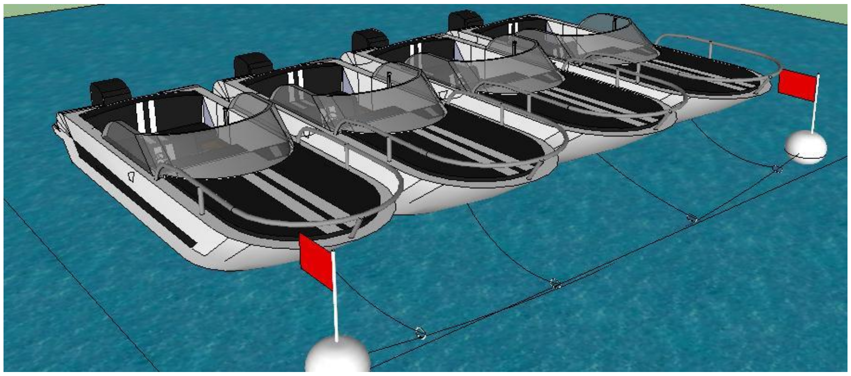


Figure 28 - Alternative mooring buoy design

The system displayed in Figure 28 involves two Manta Ray type mooring buoys set at a designated distance apart and connected by a galvanized steel cable. Each vessel will individually attach to the cable using rope from a mounting point on its bow. Vessels will then connect to each other by tying together corresponding cleats. Individually tying to the connecting cable and linking the vessels together restricts the rotation of the whole raft, eliminating the necessity for anchoring. The number of vessels per raft will be controlled by the length of the connecting cable and the distance between the two mooring buoys. Due to limitations of the Manta Ray mooring buoy, our design allows for four class 2 vessels (16 - 22 feet) or four class 3 vessels (22 – 30 feet) to raft safely without any risk of damaging the mooring buoy. The distance between the two mooring buoys will be adjusted to only accommodate the width of four class 2 or four class 3 vessels.

This design is intended to curb the negative environmental effects of the rafting behavior by eliminating the need for anchoring. Changing rafting behavior would be a much more difficult and long-term endeavor than providing a safe method of continuing the behavior. Behl Das explains altering groupthink ideology is a tasking and involved process. Rafting and anchoring behaviors are prevalent in the photographs and in the onsite assessment. In this case, the design would supply the boaters with an equally convenient way to raft without anchoring, while protecting benthic communities. (Das Behl, 2012)

5.1.2 Additional Mooring Buoys

We recommend that the DNER increase the number of mooring buoys around Caracoles key. We determined that Caracoles would benefit the most from additional mooring buoys because of its large amount of boater activity. From onsite observation, we witnessed all current 19 mooring buoys in Caracoles being used, but this portion of boats is only a fraction of the total boats that were in the area during the observation. Photographic assessment of the years 2006 - 2012 shows higher numbers of vessels in the area with 150 per photograph on average. Utilization of mooring buoys in Caracoles has been higher on average than the other four keys studied. This may be because of the amount of vessels that congregate in this small key. As more vessels visit the key, the likelihood that a vessel will use a mooring buoy increases. From photographic and onsite results, this key appears to be too full to host any additional boats to those we have observed. If Caracoles is going to continue hosting an average of 150 boats, additional mooring buoys would allow more boats present to moor without a significant increase in total boat traffic. The mooring buoys in Caracoles are being utilized and if that behavior continues, adding more will further reduce the amount of boats anchoring in the key. Data from the photographic and onsite methods show that the remaining four observed keys might not benefit as greatly from additional mooring buoys. Mata la Gata has a large dock on the key, so the majority of the vessels utilize the dock rather than the mooring buoys. Increasing the number of mooring buoys in those locations at this time would seem less efficient. Survey responses reveal that 84% of the total participants agree with the statement that there should be an increase in the number of mooring buoys. While these responses were not specific to Caracoles key, we assume that they are an accurate representation of the boating population.

5.1.3 Fine Enforcement

We recommend that the DNER increase the number of fines issued for violations of Law 147 ("Law for the Protection, Conservation, and Management of Coral Reefs in Puerto Rico") through the DNER Maritime Ranger Corps. This law was enacted in 1999 and prohibits anchoring or any method of securing or stopping a vessel, other than using mooring buoys, in areas where mooring buoys are present. After interviewing with two DNER Rangers, we uncovered that there is a discrepancy among law enforcement and what the law states. In order to effectively enforce the law and its penalties, clarification and a consensus is necessary on the specifics of the law regarding the costs of fines and under what circumstances they are expected to be issued. Through our photographic assessment, we have seen consistent violations of Law 147 in all of the observed years. Onsite observations verified the consistency of violations. In 2012, no fines were issued for violations of this law. Background research describes methods of overcoming groupthink, which might be occurring when the majority of boaters are anchoring. The most established method is to incorporate an outside and contrasting opinion. The DNER Ranger Corps will act as this external source, leading a contrasting idea. Issuing fines for violations of this law injects the idea that the current behaviors are incorrect. Groupthink can be combated by supplying the DNER Ranger Corps as an opposing stance to the boater's current behavior. In order to change boating behaviors from a less punitive perspective, other recommendations to improve the mooring buoy effectiveness are addressed from an educational standpoint.

5.2 Educational Effort Effectiveness

5.2.1 Educational Refresher Course

We recommend that the DNER implement an educational refresher course. There have been extensive educational efforts by the DNER; however, they have not been optimized for the specific needs of the boating audience. The refresher course can be integrated either biennially upon boater registration renewal or as a necessary requirement for boat operators who were issued fines in violation of Law 147 or other maritime-related laws. The course will include two sections: benthic habitat and proper mooring buoy use, and current DNER preservation projects. Survey data displays a positive correlation between mooring buoy usage and the number of educational courses received. Participants also agreed that most would like to see more buoy related education. The refresher course would utilize active learning, a specific method of educating proven by Dr. Bonwell to be effective. Dr. Bonwell states that information retention is greatly reduced after ten minutes, so the informational sections of the course should be no longer without the inclusion of a method of active learning. An example of active learning is short multiple choice quizzes during the education session to encourage student involvement. Active learning has been identified as an effective tool in educating older audiences, coinciding with survey results that most of the current nautical community is over 25 years of age (Bonwell Ph.D., 2000). The other aspect of the course will attempt to stimulate the nautical community's interest and involvement through government agency transparency. This section will describe any current DNER preservation projects, and how individuals can assist in their success. If the course can involve individuals of the nautical community in the preservation efforts, those individuals might in turn act as leaders with opposing ideas to combat groupthink ideology (Das Behl, 2012).

5.2.2 Video Presentation

We recommend that the DNER create a ten minute video presentation for viewing in the boater registration office. Survey responses indicate 90% of the participants believe the benthic communities surrounding mooring buoy areas are important. Of that 90%, only one-fourth answered that they always use mooring buoys in these areas. The DNER boater registration office has a flat screen TV in the waiting room that is an underutilized resource, currently looping tourist videos and cable television channels. This can be better used to advertise preservation projects, public service announcements (PSA), and to advise the community on how they can participate and aid the DNER in accomplishing their environmental goals. One of the PSAs should be an instructional and educational video establishing the connection between proper mooring buoy use and its benefits to the benthic community. Repetition and limiting material to ten minutes are effective methods regarding information retention (Bonwell Ph.D., 2000). Video presentations are an engaging method of education that would supplement the refresher course. Survey analysis suggested that an increase in mooring buoy usage was associated with more educational courses received. In open-response questions, survey participants also suggested that more education would improve the usage of mooring buoys. Information displayed in the registration office television would target the boating audience that the DNER is attempting to reach.

5.2.3 Additional Informational Signage

We recommend that the DNER increase the amount of informational signage about benthic communities and mooring buoys at point of access locations and in the water denoting sensitive benthic areas. Visiting marinas in the large port city of Fajardo showed that the majority of DNER educational materials are located within marina offices, where from onsite visits we found they do not command significant attention. Again, repetition of information is important for increasing retention rates (Bonwell Ph.D., 2000). Placing large signs at docks instructing proper mooring buoy use and outlining the fines associated with not complying with the regulations will remind the boaters. Case studies on the Great Barrier Reef showed significant community support for signage over coral reef areas designating “no-anchoring” zones, which survey responses indicate 71% of boaters would support. It is recommended that the DNER adopt this idea and place buoys warning boaters of the benthic communities below and reminding them that it is a no-anchoring zone. Only one-third of survey participants answered that they always knew what kind of benthic community was below them. In-water signage was also suggested in the open-ended survey responses. The Great Barrier Marine Park Authority suggests another constant reminder to the boaters may further deter them from anchoring in these areas (Great Barrier Marine Park Authority, 2011).

5.3 Further Recommendations

5.3.1 Restricting Key Access

We recommend that the DNER close off important keys for restoration purposes and encourage a shift in boater activity to a different designated key to give damaged areas a chance to

recover. In order to more effectively save large amounts of benthic habitats, the DNER may have to shift efforts and try to preserve keys individually rather than trying to moderate damage in all keys at once. To determine the keys from which to shift, the DNER must determine which keys have benthic communities that are not damaged past the point of a possible recovery. These areas can be selected through one project at a time and closed off with signage directing boaters to the preferred key locations. Keys that have benthic communities that are deemed unsalvageable will be yielded and used to host the boaters from the preserved keys. In speaking with our sponsors, we have learned that some areas are already believed to be unrecoverable, and this approach will determine these areas. This approach will protect benthic communities in desired keys from all outside contact, allowing for a more natural and accelerated recovery. Through photographic assessment we could see that the mooring buoys, which attempt to alleviate portions of damage in scattered areas, have not been sufficiently successful; severe scarring was observed in every analyzed key. Selecting individual keys to completely close off to boater activity may preserve more benthic habitats than attempting to only slightly alleviate damage in all areas. (Velazco, 2013)

5.3.2 Commercial Sponsor

We recommend that the DNER seek a commercial sponsor to further influence the changes sought after in boating behavior. Recreational behaviors were the most recorded activities in onsite observations, and survey participants most frequently responded that "partying" was a reason they visited the keys. This suggests that the DNER may not be able to reach this audience with the intended level of success. A commercial sponsor that better connects with this demographic of people might be a more influential figurehead than a government agency. Information promoting mooring buoy use from a seemingly unaffiliated sponsor may also disrupt the groupthink ideology boaters may possess about using anchors. Inserting contrasting ideas about anchoring will aid in overcoming groupthink and promote mooring buoy usage though multiple avenues (Das Behl, 2012). A company that is involved with some aspect of the "partying" atmosphere could be a more relatable leader than the DNER to change the anchoring behavior. Energy drink corporations, for instance, may be one viable option relating to this demographic.

5.4 Future WPI Interactive Qualifying Projects

5.4.1 Rafting Mooring Buoy Design Testing

We recommend that a future WPI IQP team test the viability and performance capabilities of our Rafting Mooring Buoy Design. The DNER believes this design idea shows potential in allowing rafting behavior while eliminating anchoring. Before the DNER can proceed with implementing rafting mooring buoys, the preliminary calculations and proof of concept for the design must be further verified. A WPI team could design the system in CAD modeling software and conduct stress analysis simulations with varying:

- Number of vessels
- Size (class) of vessels
- Wind speeds
- Other factors that the team decides may alter stress conditions

The stress analysis simulations will further refine the limitations of the system in regards to the capacity and types of vessels it can safely secure. The team can then construct the system and conduct experimental testing assessing stress analysis with the same varying factors tested in simulations. Unforeseen complications will be discovered, and the team can resolve them with adjustments in the initial design. Long-term tests will also need to be conducted with the maximum acceptable weight of vessels to evaluate if the system will withstand fatigue stress. Experimental testing will inform the DNER if the rafting mooring buoy design is a sound and feasible option to permit rafting and eliminate anchoring.

5.4.2 Revaluating the Carrying Capacity of Each Key

We recommend a future WPI IQP project team reevaluate the determining factors of the "carrying capacity" of a key. The number of mooring buoys present at a key is representative of the estimated amount of boating activity the residing benthic habitats can withstand. Mooring buoys were installed around the island in 1999, suggesting this carrying capacity evaluation may be outdated. Both of the interviewed DNER Maritime Rangers asked for the specific carrying capacities of each key so they can enforce regulations and limit the number of vessels in each area. A future project team should study the factors determining the carrying capacity of a key, and assess if those factors need to be reevaluated. Factors may need to be altered given current benthic habitat damage, boating behaviors (mooring buoy use, anchoring, both), and current visitation of the key. If mooring buoys are being used properly, no anchoring will occur. If anchoring is eliminated, then the key can host more vessels without increasing the risk to benthic habitat damage. The project team should then reexamine the carrying capacity of each key in Puerto Rico (or a selection of keys), and develop recommendations to increase or decrease the amount of mooring buoys present. Updated carrying capacity data may lead to installation of more mooring buoys, thereby decreasing anchoring. DNER Maritime Rangers can use this information to enforce limitations on the numbers of vessels at each key according to their specific carrying capacity.

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7.0 Appendices

Appendix A: Preliminary Sponsor Interview

Conference call minutes

Attendees:

- Group members: Tyler Bouchard, Mark Shooter
- Sponsor: Aileen T. Velazco from the DNER

Notes:

- Photographic analysis
    - All photographs related to surveyed areas with mooring buoys
    - Span over 20 years
    - Photographs are in digital and hard copy form
        - Scanner available
    - Edwin and his team
        - F-27 project has analyzed many photographs already
        - Accompany them around to field activity
    - Two types of photographs (substantial information from photographs)
        - Aerial photographs from various sites (F-27 buoy project with mooring buoy program)
            - Count number of boats, types of vessels, moored or anchored, one or more boats moored to one buoy
        - Underwater photographs at mooring locations verified damage from aerial photographs
- Over 60,000 registered boats
- 30,000 boats are active
- First analysis of the photographs
    - Decide if the mooring buoy system has been successful
        - Pinpoint what works and what does not work
        - Based of those findings design educational outreach program
- Benthic community (coral reef, seagrass and mangrove areas) showing damage
    - Hot spots for congregation of boats
    - Mooring buoys attracting more boats, leading to more damage
- Buoys are for recreational use, one boat to one buoy (not all boat sizes are suitable for every mooring buoy)
- Focus on importance to community
    - Leads to healthier environment
    - Helpful to community
    - Eliminate tying boats to mangroves (endangered species)
- Next DNER proposal

    - Implementation of additional mooring buoy areas, no anchoring allowed in coral reefs, seagrasses and mangroves
        - Set basis of the difference of a sand, barren area vs. coral sea grass area
        - Emphasize to nautical community that the benthic community translates into their own health
        - The more the nautical community complies the better health for their recreational areas
- Regulations
    - No anchoring is allowed in coral reefs, seagrasses, and mangroves
        - Proof of vessel causing damage there is a fine (hard to prove this underwater)
    - Two coral reef species are under threatened status, seven more will be listed endangered in the coming month
    - Jet skis unaware of the damage caused by their vessels
- Discussed idea that tourists go to a place and they want to take something with them
    - Truckload of pieces of coral confiscated at airport
        - Only a small fraction of the extent of this behavior
    - One winter (high tourist season) can kill an entire coral community with people taking a piece of coral with them
- Observations have been conducted by Dr. Tom Webler
    - Behavior of people, congregate and jump in, modify those behaviors
    - Another study by local graduate students found most people are not ignorant of the sensitivity of coral reefs and choose to disregard consequences of harming them
- Economic value study done only on eastern coast by the DNER
    - Manufacturing produced the most GDP in Puerto Rico
    - Puerto Rico is trying to boost tourism
- Caribbean first recognized the appearance of bleaching and it’s devastating effects
- Whatever we can do to reduce the pressure and the non-environmental stressors on corals to help recover
    - Pollution reduction
        - Sedimentation
        - Land based or on sea
    - Help improve reef resiliency
- Surveying
    - How much can we do in terms of preliminary work
    - Able to facilitate and distribute surveys
        - Boat registration located at DNER office
        - Go to docks early in the morning or later when they come back
    - Holy week , Thursday Friday Saturday and Sunday festival
        - Huge boating week, observation opportunity

Appendix B: On-site Sponsor Interviews

Interview with: Alieen Velazco and Carlos Matos

Date: 3/19/2013 1:41 PM

1.) What have you noticed in your time working at the DNER?

Continued degradation of coral reef, seagrass and mangrove areas

- Pollution, coastal development, coastal runoff has stressed the areas
- Additionally increased human contact has further damaged the areas
- The delicate organisms have been killed by the increase in sediment and human contact
- Human interaction is the most manageable of all of the stressors and thus is why the DNER is focused on the regulation

2.) Have you noticed a change in the overall health of the coral reefs?

a. Occurrences and types of diseases
    - Yes, during her time in the field there has been a steady decline in condition due to the factors listed above

3.) Have you see significant change in behaviors before/after the installation of the mooring buoy system?

a. From time in the field has anything really changed?

b. Has this change decreased the amount of damage to these areas?
    - Reference to Edwin

4.) What is the environmental consequence of tying to mangroves, anchoring in coral reef/seagrass areas?

a. Which is most harmful to the overall ecosystem?
    - Consequences of tying to mangroves
        - Breaking of roots
        - Removal of sediment
        - Disruption of marine life within the root systems
        - Disruption of mangrove seeds
        - Disruption of juvenile fish species
    - Anchoring in seagrass/coral areas
        - Breaking of coral structures
        - Scaring of seagrass meadows
        - Death of species of marine life
    - All of the actions are harmful but in their own manner

5.) Which areas have seen the most damage due to boating?

a. Is there an area that has been completely destroyed as a result of boating?
    - There is a large port on the eastern side of the island that has seen the most significant damage due to long term use, both commercially and for military

6.) Has there been an increase in boating traffic in areas with mooring buoys or a general increase in all areas?

- Buoys are specifically placed in areas where there is a high amount of traffic. The buoys will often attract more boats to the areas

7.) **What is the cost of the placement of a single mooring buoy?** Edwin
   a. What is the total number of mooring buoys? 270 buoys currently
   b. What is the maintenance cost? Edwin
   c. Is the DNER willing to plant more moorings?
   d. What is the algorithm for figuring out what is the number of moorings a location could sustain?
      - $3400/per mooring buoy to install including the personnel. $1200 for the physical parts. $4000 total to maintain the buoy system
      - There is no specific formula that is accurate for carrying capacity. For the DNER it is based on surveys of the area, assessment of the boats in the area. Over time this study will allow them to determine the appropriate number
      - Currently in the process of installing more mooring buoys.

8.) What educational campaigns have been administered?
   a. Which were effective or received positive public response, which did not?
   b. Has there been assessment as to the effectiveness of the educational campaign before?
   c. Where have these materials been implemented
      - No analysis has been done to date as to the effectiveness of the educational materials

9.) What are there additionally related problems related to the project that could be investigated or solved?
   a. Database and photographic organization
   b. Educational campaign materials
   c. Additional?
      - Has there been a shift in any of the numbers of people visiting areas and can new buoys be placed in any areas.
      - A way to link the photographs to the GPS software that was used by the 2009 group.
      - Discriminated between the regular recreational boats versus the charter boats for companies and tailoring some educational materials for specific groups.

10.)Number of boat registrations
   a. Annually and total?
   b. Annual increase of mooring buoys? Edwin's reports
   c. Cost of a Registration

- Contacting the registration office to get numbers

Interview with: Erasto Nieves

(32 years with DNER)

Date: 3/27/2013

What specific work does the project entail?

- Developing boating access points around the island
- 10 sites have been created
- Dealing with environmental issues behind the development of these areas
- Working with NOAA, Fish and wildlife to address issues/questions regarding the species in the area
- Next month the permit will be issued for La Parguera Project which is the current project the team is working on
- Creating navigational paths throughout the La Parguera area

What are the major areas of focus for the project?

- Create an access point within the La Parguera area which is a boating hotspot on the island
- Staring in Holy Week, La Parguera comes very busy and continues throughout the summer months
- One of the signs will include a map that will show all of the channels and markers within the area.

What markers are currently in place and what markers will be added?

- Speed buoys, manatee buoys, navigational aids but more will be added to supplement

How many navigational aids are in place?

- Many are currently in place in Parguera

What types of navigational aids are being used?

- Speed buoys, manatee buoys, navigational aids

What is the cost of these navigational aids?

- Unknown cost

When were the navigational aids put in place?

- There are currently some in place, channel markers etc.?

Have they been effective at directing traffic or are they generally ignored?

- They are effective at preventing damage to the boats and generally do a good job at redirecting traffic in the area. They are having a positive impact but they also rely on enforcement by local officials to ensure

What was taken into consideration when placing these navigational aids, were there specific areas that are protected by these or just traffic guides?

- People will use the path currently. That path becomes the centerline and markers act as markers for the sides of the path to allow for people to have natural paths. Within the coral reefs, the structures grow in such a way that they create paths within the reef
- Working on knowing an area very well and marking the paths that are already currently in use

How can our project benefit yours? Will our project assist yours in the future?

- The plan is to create a sign for the boat ramp instructing on how to use the mooring buoys
- There is not a plan to include signs on the water to signify no anchoring areas
- It would be better to increase the number of mooring buoys rather than use signs that restrict anchoring

Is there a use of signage in addition to the navigational aids and is there interest in adding additional signage?

- Signage at the boat launch but none on the water due to coast guard regulations

  Would it be possible to place signs that say ”No Anchoring” as a part of the project?

- Using the no anchoring buoys as a deterrent for boaters on the water. This will be a consideration for their project. There can be issues due to coast guard regulations of mooring buoys as well as their colors and shapes.
- 8-9 agencies to seek approval from due to the number of issues with endangered species

Interview with: Carlos Matos and Edwin Rodriguez

DNER-Staff

Date: 3/27/2013

Questions regarding mooring buoy system

Currently, how many mooring buoys are placed around the island?

- There are 290 ecological mooring buoys deployed and installed around the Island.

Are there plans to expand the mooring system? By how many? In what areas?

- Yes, about 65 new mooring buoys distributed among Culebra, Guanica, Vieques, Ceiba, Mayaguez and La Parguera.

Which types of imbedded mooring are in use in each area of the island?

- Both Halas and Manta type system.

What is the holding capacity of each type of these moorings?

- 20,000 to 24,000 lbs

What is the cost of installation of a single mooring buoy?

- Depending on the anchor type: $1,500 to $1,700 for Halas Type. $1,700 to $ 2,000 for Manta.

What is the cost to maintain the entire mooring buoy system?

- Including wages, fringe benefits, insurance, deployment and maintenance equipment between $100,000.00 and $ 115,000.00

Process of analyzing the cost benefit analysis for the mooring, why was the one that was chosen the one to use? Is there a different application for each type of mooring buoy?

- Sea bottom substrate characteristics determine which anchor system will be used. These are economical and well proven systems with historical documented success in helping to protect and restore marine resources

What is the process for determining the holding capacity of an area (determining the number of mooring buoys that a benthic community can support?)

- The correct word is carrying capacity and this varies for each case as factors like aerial surveys, ecological services, utilities, benthic characterization, use pattern and historical data are taken into consideration. It is a part subjective process.

Has your team received any feedback regarding the mooring buoys from the boaters?

- Only when surveys are performed or by articles written in nautical magazines

Interview with: Vigilante Lizardo Pagan Lopez (Ponce)

Date: 4/18/2013

Questions Regarding Patrolling Procedures and Law 147

What are your priorities when you are on patrol?

- To cover the coastal zones, marine and vessel safety, first make sure boats have safety equipment as required by law 430. The second thing is to look at conservation issues. First is to check for safety equipment, then if they are fishing they check registrations and certifications for commercial activities.

Do you know of Law 147?

  a. "Law for the Preservation, Conservation, and Management of Coral Reefs in Puerto Rico"
  b. Prohibits anchoring or other methods of stopping a vessel besides using mooring buoys in areas where mooring buoys are present

- Yes they do.

Are you allowed to issue fines or warnings for violations of Law 147?

- First they offer instruction/ orientation about how to use the mooring buoy. As a part of this the people can remove the anchor without disturbing the seagrasses or they can cut the line and leave the anchor. They do not issue fines for this action. There is a hearing tomorrow because someone was caught taking live coral from the reefs and there is a huge fine for that. The violation occurred in Ponce, and there are between 3 -5 cases per year. There are no fines issued with anchoring.

Do you think warnings or fines would be effective in increasing mooring use?

- Sometimes they will observe a person about to drop an anchor, and they approach the boat and give orientation about how to use the mooring buoys but once the anchor is dropped they proceed like above. The first time is an orientation and they understand that they have the power to issue the fine but rather use the orientation instead.
- He considers that the fines are quite high for the action. $500/piece of coral. They do not issue the fines due to the high price of the fines. (Aileen explained to him the importance of the high fines)

What would be more effective, warnings or fines, both?

- Both orientation and fines would be most effective.

Are you advised to issue warnings or fines?

- They understand they have the power to issue the fines but have been educating the people for the past few years to ensure they understand how to use the mooring buoys.

Would it be possible to issues more fines?

- It is time to go out and begin to issue fines because they have been using the orientations to educate the public for the past few years and now that these people are educated it is time to use the fines to ensure that they use the moorings .

Is there a reason they are not issued now?

- They think that they are too expensive because each broken piece of coral is $500

Do you have any ideas on how to increase use of the mooring buoys?

- More mooring buoys in the areas would give more places to secure the boats. The rangers need more guidance as to the capacity of each of the sites to better regulate these areas. Capacities, specific laws to enforce, details of the areas (bi-annual reports from the DNRA to the rangers about the capacities of these areas).

Interview with: Sgt. Julio Cesar Vargas de la Paz (Fajardo)

Date: 4/18/2013

Questions Regarding Patrolling Procedures and Law 147

What are your priorities when you are on patrol?

- The first priority is to go to the protected areas and observe what they are supposed to take care of. There are some areas where fishing is allowed and some where it is not. Cana Luiz Pena & Cordierra reef reserve. Next they go over commercial and recreational fishers to make sure they are catching the right fish. Determine who is fishing and if they are commercial/recreational. Second is to check safety equipment on board the boats in the area. Then he goes over who the people are navigating the area to make sure they are being safe and correctly navigating the area. The third thing they go over is if the boats are mooring or anchoring to determine what they are anchored over. $250 fine for anchoring in the wrong areas

Do you know of Law 147?

c. "Law for the Preservation, Conservation, and Management of Coral Reefs in Puerto Rico"
d. Prohibits anchoring or other methods of stopping a vessel besides using mooring buoys in areas where mooring buoys are present

- Yes

Are you allowed to issue fines or warnings for violations of Law 147?

- Yes, it is $250 for anchoring in the incorrect area or not using a mooring buoy. Normally one or two fines are issued for this during a week with the exception of those issued during holiday or summer weekends. It takes over 20 mins per intervention so he is only able to give out 4 or 5 fines at a time because people tend to leave the area once they see the rangers issuing fines

Do you think warnings or fines would be effective in increasing mooring use?

- There is a right to go to these areas and he cannot prohibit people from going to these areas. There are not enough moorings in these locations to supply the people with other options. There is nothing in the law that says that people cannot go to these areas if there are no moorings so he doesn't have much room to work with legally.

What would be more effective, warnings or fines, both?

- Both, orientation helps but people learn better from paying the fine

Are you advised to issue warnings or fines?

- Yes, see above

Would it be possible to issues more fines?

- Yes if there was higher manpower to do so. There are not enough vigilantes to do this currently. Internal personnel structure flexibility allowing the rangers to switch between departments depending on strengths. A coordinated strike on these areas with a high amount of rangers would allow the rangers to substitute the manpower. Law 430, law 278-fisheries, law 147-coral

Is there a reason they are not issued now?

- Not enough personnel. It takes 20min/fine. There is a lack of regulations for the law so there is no reason to implement an unfinished law. Orientation for some people makes people do the right think but many people seem to justify their actions by what others are doing.

Do you have any ideas on how to increase use of the mooring buoys?

- By running the mooring buoy system like a mooring field he thinks things could improve. There could be a person to oversee directly who tells boaters where to park their boats. He doesn't know where to look to avoid or damage rafting. This is very prevalent in this area. He says he needs a manage plan or regulation to allow him to have something to act on. He would also like to know the carrying capacity of the areas he patrols. One example there is plenty of space where there could be 100 buoys so he would like to know carrying cap.

Appendix C: F27 Document Photographs

The following are example photographs taken of coral reefs and seagrass areas around Puerto Rico duinr 2011 and 2012, provided by the DNER.

Palomino Island in Fajardo

Icacos Island in Fajardo

Playa Tortuga in Culebrita Island

Caracoles Cay in La Parguera Natural Reserve

Ensenada Dakity in Culebra Island

Matías Cay in Salinas

Barcas Cay in Salinas

Matías Cay in Salinas

Combate beach in Cabo Rojo

Barcas Cay in Salinas

Caracoles Cay in La Parguera Natural Reserve

Barcas Cay In Salinas

Boqueron Beach in Cabo Rojo

Dos Palmas in Barcas Cay in Guayama

Puerto Nuevo in Vega Baja

Barcas Cay in Guayama

Matías Cay in Salinas

Collado Cay in La Parguera

Photograph Credit: DNER F27 "Evaluation of Recreational Boating Anchor Damage on Coral Reefs and Seagrass Beds" project (DNER, 2011-2012).

Appendix D: Photographic Assessment Tool

Photographic Assessment Data Collection Template

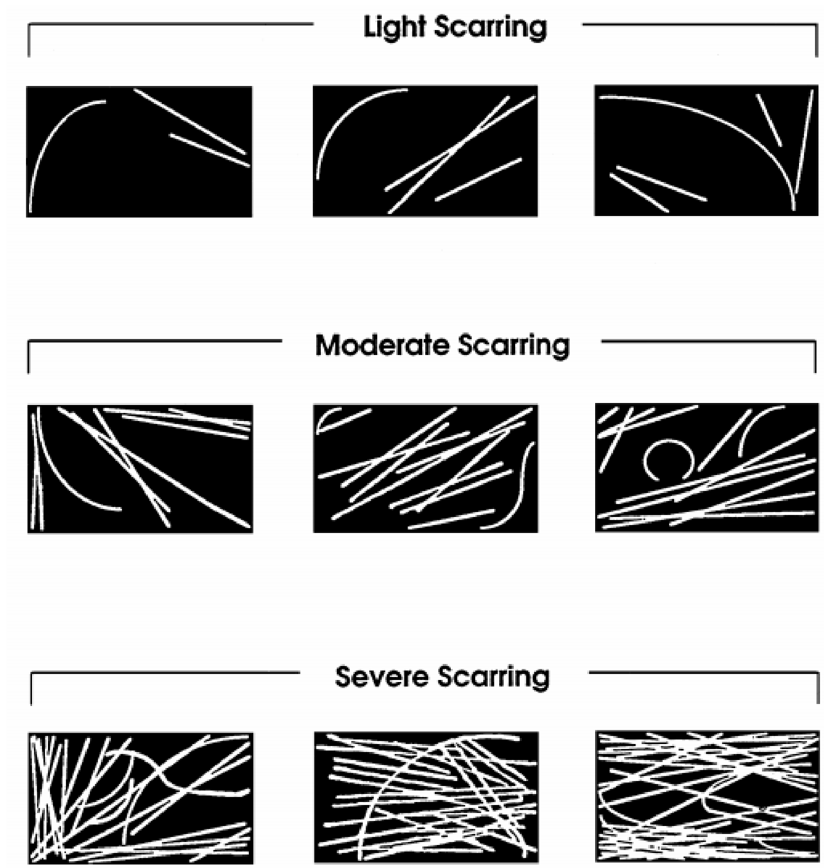
Observer:

The recorded data will be input in to the Excel database template.

Location:		Date:		Group	I.D.#	
Class of Vessel	Moored	Anchored	Tied to Mangrove	Other		Totals
Class 1	____	____	____	____		____
Class 2	____	____	____	____		____
Class 3	____	____	____	____		____
Class 4	____	____	____	____		____
Class 5	____	____	____	____		____
Class 6	____	____	____	____		____
Jetski	____	____	____	____		____
Casabotas	____	____	____	____		____
Totals	____	____	____	____		

Severity of Scaring
____
Total Mooring Buoys
____
Unused Mooring Buoys
____
Number of Boats Present
____

Severity of scarring scale (input number to left of chosen severity in to above table)



1	5%
2	5-20%
3	> 20%

Additional Notes:

Appendix E: Technical Document for Recording, Cataloging and Analyzing of Historical Photographs

Conducting an over flight:

1) When photographing, ensure that multiple photographs are taken of each area. This process will provide multiple angles and more accurate results during future analysis.
2) Record the following to ensure proper data and cataloging:
    - Date
    - Municipality
    - Key
3) Record the picture identification numbers of each series of photographs corresponding with a given key.

Uploading and cataloging photographs:

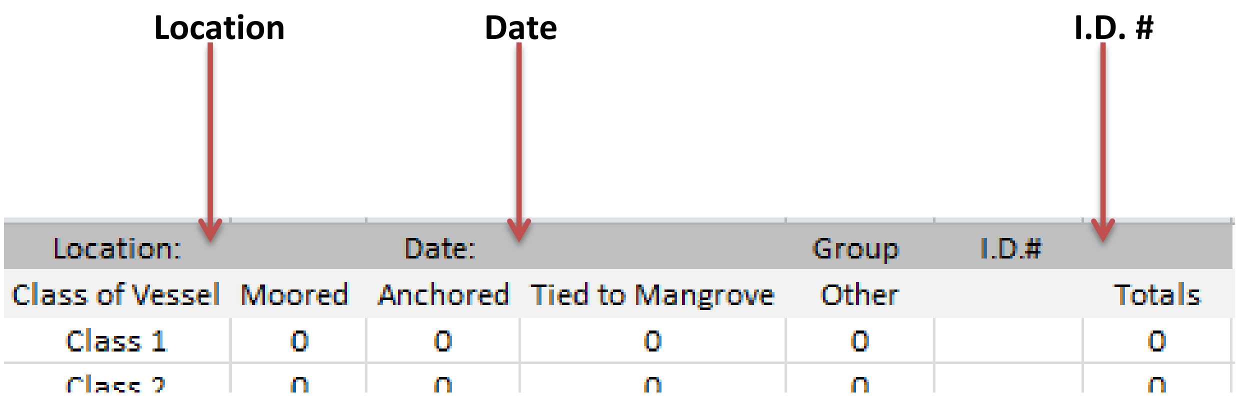
1) Reference over-flight notes to determine the proper placement for each photograph
2) The photographs should be placed in a folder by Date > Municipality> Key to ensure the photographs can easily be retrieved at a later date for analysis

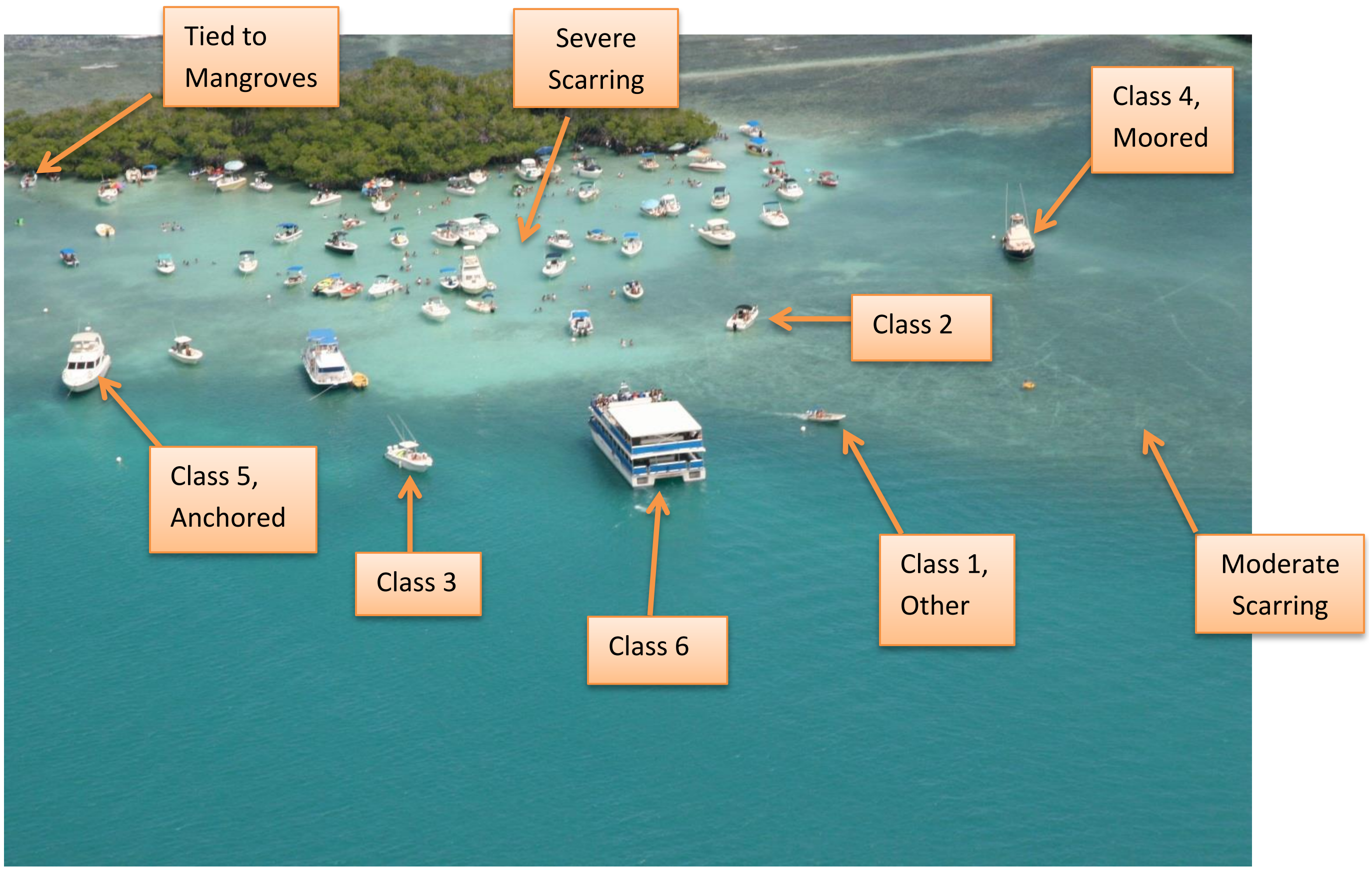
Analyzing photographs:

1) Open the Photographic Assessment Template in Microsoft Excel.
2) Open the folder containing the pictures that will be analyzed.
3) Select a photograph to analyze.
4) In the excel workbook, input the Location, Date and Photograph Identification Number in the indicated fields at the top of the table
5) In the photograph, determine a point of reference (e.g. a boat of known length) as a basis of comparison to determine the class of other boats in the area.
6) Record the specific behavior of each boat along with the number of mooring buoys present and enter the results into the appropriate table. The table will calculate the totals of each type of boat, each type of behavior, the total number of boats present and the percent usage of the existing mooring buoys in the area.
7) Each sheet in the excel workbook can be labeled as a distinct Key to further organize the gathered data.
8) When finished, save the document using the following format **Date_Municipality_Photographic Assessment.**

Location:		Date:		Group	I.D.#						
Class of Vessel	Moored	Anchored	Tied to Mangrove	Other		Totals	Severity of Scaring	Total Mooring Buoys	Unused Mooring Buoys	Number of Boats Present	Percantage of Boats Moored
Class 1	0	0	0	0		0				0	#DIV/0!
Class 2	0	0	0	0		0					
Class 3	0	0	0	0		0					
Class 4	0	0	0	0		0					
Class 5	0	0	0	0		0					
Class 6	0	0	0	0		0					
Jetski	0	0	0	0		0					
House Boats	0	0	0	0		0					
Totals	0	0	0	0							

Enter the data point in the corresponding fields below




Tied to Mangroves
Severe Scarring
Class 4, Moored
Class 2
Class 5, Anchored
Class 3
Class 6
Class 1, Other
Moderate Scarring

Appendix F: Observational Assessment Tool Template

Date and Time:
Observer:

Location:		Date:					
Class of Vessel	Moored	Anchored	Moored AND Anchored	Tied to Mangrove	Other	Rafted	Totals
Class 1	___	___	___	___	___	___	___
Class 2	___	___	___	___	___	___	___
Class 3	___	___	___	___	___	___	___
Class 4	___	___	___	___	___	___	___
Class 5	___	___	___	___	___	___	___
Class 6	___	___	___	___	___	___	___
Jetski	___	___	___	___	___	___	___
House Boats	___	___	___	___	___	___	___
Totals	___	___	___	___	___	___	

Severity of Scaring

___

Total Mooring Buoys

___

Unused Mooring Buoys

___

Number of Boats Present

___

tied per raft

___

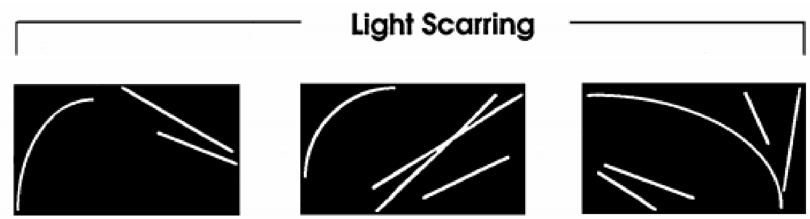
___

___

___

Severity of scarring scale (input number to left of chosen severity in to above table)

1



5%

2

5-20%

3

> 20%

Additional Notes:

Appendix G: Technical Document for: Recording, Cataloging and Analyzing of On-Site Assessments

Conducting an on-site assessment:

1) Ensure a camera and on-site assessment tools are present on the boat
2) While on the water, work in pairs of two
3) One team member must relay the following information to the other team member:
    a. Count the number of vessels
    b. Count number of mooring buoys
    c. Determine their corresponding behavior
    d. Determine the severity of scarring to the benthic communities
4) After recording the observational data, use the camera and ensure that multiple photographs are taken of each area. This will ensure multiple angles and accurate results during future analysis.
5) Visit every desired key and repeat steps 2-5
6) Return to the office and record the following to ensure proper data and cataloging:
    a. Date
    b. Municipality
    c. Key
7) Record the picture identification numbers of each series of photographs corresponding with a given key

Uploading and cataloging on-site assessment tool data and photographs:

8) The photographs should be placed in a folder by Date > Municipality> Key to ensure the photographs can easily be retrieved at a later date for analysis
9) Open the Photographic Assessment Template in Microsoft Excel
10) Extract from the camera the pictures that will be analyzed
11) Select a photograph to analyze
12) In the excel workbook, input the Location, Date and Photograph Identification Number in the indicated fields at the top of the table
13) In the photograph, determine a point of reference (e.g., a boat of known length) as a basis of comparison to determine the class of other vessels in the area.

14) Record the specific behavior of each boat along with the number of mooring buoys present and enter the results into the appropriate table. The table will calculate the totals of each type of boat, each type of behavior, the total number of vessels present and the percent usage of the existing mooring buoys in the area.
15) Each sheet in the excel workbook can be labeled as a distinct key to further organize the gathered data.
16) Combine the results from the on-site assessment tool and the photographs to extract the most accurate results
17) On a separate excel sheet, enter the final results.
18) When finished, save the document using the following format **Date_Municipality_On-Site Assessment.**

Location:		Date:		Group	I.D.#						
Class of Vessel	Moored	Anchored	Tied to Mangrove	Other		Totals	Severity of Scaring	Total Mooring Buoys	Unused Mooring Buoys	Number of Boats Present	Percantage of Boats Moored
Class 1	0	0	0	0		0				0	#DIV/0!
Class 2	0	0	0	0		0					
Class 3	0	0	0	0		0					
Class 4	0	0	0	0		0					
Class 5	0	0	0	0		0					
Class 6	0	0	0	0		0					
Jetski	0	0	0	0		0					
House Boats	0	0	0	0		0					
Totals	0	0	0	0							

Input the data point in the corresponding fields below

Location **Date** **I.D. #**

Location:		Date:		Group	I.D.#	
Class of Vessel	Moored	Anchored	Tied to Mangrove	Other		Totals
Class 1	0	0	0	0		0
Class 2	0	0	0	0		0

Survey on Use of Mooring Buoys Located Near Sensitive Benthic Communities

NOTICE: *PARTICIPATION IN THIS SURVEY IS VOLUNTARY, YOU ARE NOT REQUIRED TO ANSWER EVERY QUESTION AND MAY STOP TAKING THE SURVEY AT ANY TIME. ALL INFORMATION IS CONFIDENTIAL.*

Administered by students from Worcester Polytechnic Institute (Massachusetts) as part of a study sponsored by the Puerto Rico Department of Natural Resources (DNER) ----Tyler Bouchard, David Levien, Victor Puksta, Mark Shooter

Appendix H: Standardized Survey [English & Spanish]

Choose the answer that best represents your opinion.

Section 1

	Less than once a month	*1*	*2*	*3*	*Greater than once a month*
1. **How frequently do you boat near coral reefs and seagrasses? (times per month)**	☐	☐	☐	☐	☐

2. **Which of the following do you believe are in the immediate area when you boat? (circle all that apply)**
   - *a) Coral Reefs*
   - *b) Seagrasses*
   - *c) Trees on the shore*
   - d) *None of the above*

3. **When you go boating, in which of the following activities do you participate? (circle all that apply)**
   - *a) Swimming*
   - *b) Snorkeling*
   - c) *Partying*

Section 2

	Never	***Rarely***	***Sometimes***	***Often***	***Every time***
4. **How often do you use ONLY mooring buoys while visiting the coral reefs and seagrasses? (if present)**	☐	☐	☐	☐	☐
5. **How often do you ONLY drop anchor while visiting the coral reefs seagrasses?**	☐	☐	☐	☐	☐
6. **How often do you use mooring buoys and also drop anchor?**	☐	☐	☐	☐	☐

Section 3

	None	***1***	***2***	***3***	***More than 3***
7. **During your last outing, what was the largest number of boats you saw tied to one mooring buoy? (including boats tied together)**	☐	☐	☐	☐	☐
8. **During your last buoy use, how long did you stay (in hours)?**	☐	☐	☐	☐	☐

Section 4 - Indicate the extent to which you agree with the following statements

	Strongly Disagree	***Disagree***	***Neutral***	***Agree***	***Strongly Agree***
9. **I find the mooring buoys useful.**	☐	☐	☐	☐	☐
10. **The current mooring buoys are in convenient locations.**	☐	☐	☐	☐	☐
11. **I would like to see an increase in the number of mooring buoys.**	☐	☐	☐	☐	☐
12. **I prefer beach areas to be covered in sand rather than seagrass.**	☐	☐	☐	☐	☐
13. **I believe that anyone has the right to enjoy the ocean.**	☐	☐	☐	☐	☐
14. **Everyone anchors or moors wherever they want.**	☐	☐	☐	☐	☐
15. **One anchor will not harm the coral reefs or seagrass.**	☐	☐	☐	☐	☐
16. **Anchoring is the best way to keep stationary boats close together.**	☐	☐	☐	☐	☐

	Strongly Disagree	***Disagree***	***Neutral***	***Agree***	***Strongly Agree***
17. **I would support voluntary "no-anchoring" zones over sensitive coral reef and seagrass areas.**	☐	☐	☐	☐	☐

18. **I believe fines and other penalties would be effective in encouraging mooring buoy use.**	☐	☐	☐	☐	☐

Section 5

19. **How much educational courses have you had on mooring buoys?**	*None* ☐	*1* ☐	*2* ☐	*3* ☐	*4* ☐
20. **Are you aware of when coral reefs and seagrasses are below you?**	*Never* ☐	☐	*Sometimes* ☐	☐	*Always* ☐
21. **In your opinion, how important are coral reefs and seagrasses?**	*Not* ☐	☐	*Neutral* ☐	☐	*Extremely* ☐
22. **How harmful do you believe anchoring can be to coral reefs and seagrasses?**	*Not* ☐	☐	*Neutral* ☐	☐	*Extremely* ☐

Section 6

23. **How much does coral tend to grow per year?**
   - d. *0.5 to 5 mm (0.02 to .2 in)*
   - e. *0.5 to 5 cm (0.2 to 2 in)*
   - f. *0.5 to 5 m(20 to 200 in)*

24. **What is the largest fine for anchoring in mooring buoy areas?**
   - d. *Up to $100*
   - e. *Up to $1,000*
   - f. *Up to $10,000*

25. **Have you seen any of the educational material distributed by the Department of Natural & Environmental Resources?**
   - a. *Yes*
   - b. *No*

Section 7

26. **Gender:**
   - a. *Male*
   - b. *Female*

27. **Age:**
   - a. *Younger than 25*
   - b. *25 or older*

28. **Years of study in school:**
   - a. *K-12*
   - b. *College/University*
   - c. *Graduate Studies*

29. **In what city do you live?** ________________

30. **Do you have a boating license?**
   - a. *Yes*
   - b. *No*

31. Are there any other suggestions you have for the improvement of the mooring buoy system?

32. Do you have any general comments on mooring buoys?

33. Do you have any other ideas to increase the boater community's support of coral reef preservation?

Thank you for your time! Your participation will help in the protection of Puerto Rico's coral reef and seagrass habitats. For results please email pr13photographs@wpi.edu.

Encuesta sobre el uso de boyas de amarre localizadas cerca de arrecifes de coral

NOTA: *SU PARTICIPACION EN ESTA ENCUESTA ES COLUNTARIA. NO ESTA OBLIGADO A CONTESTAR*

TODAS LAS PREGUNTAS Y PUEDE DAR POR TERMINADA LA ENCUESTA EN CUALGUIER MOMENTO. LA INFORMACION ES CONFIDENCIAL.
Esta encuesta es administrada por estudiantes del Instituto Politecnico de Worcester(en el estado norteamericano de Massachusetts) como parte de un studio auspiciado por el Departamento de Recursos Naturales y Ambientales del Estado LIbre Asociado de Puerto Rico ----Tyler Bouchard, David Levien, Victor Puksta, Mark Shooter

Escoja la contestacion que mejor represente su opinion.

Seccion 1

	Menos de una vez al mes	*1*	*2*	*3*	*Mas de tres veces al mes*
34. **Cuan frecuente ubica su bote cerca de arrecifes de coral o de hierbas marinas?**	☐	☐	☐	☐	☐

35. **Cual de los siguientes recursos marinos cree que hay cercanos al area donde navega con su bote?(circule aquellos que entienda aplican)**
   - e) *Arrecifes de coral*
   - f) *Hierbas marinas*
   - g) *Bosques costaneros*
   - h) *Ninguno de los anteriores*

36. **Cual de las siguientes actividades practica cuando sale a pasear en su bote? (circule aquellos que entienda aplican)**
   - d) *Natacion*
   - e) *Pesca*
   - f) *Buceo con solo careta y tubo de respiracion*
   - g) *Diversion festiva*

Seccion 2

	Nunca	***Rara vez***	***A veces***	***Frecuente***	***Todo el tiempo***
37. **Cuan frecuente usa solo las boyas de amarre cuando sale a pasear con su bote?**	☐	☐	☐	☐	☐
38. **Cuan frecuente ancla sobre arrecifes de coral y hierbas marinas?**	☐	☐	☐	☐	☐
39. **Cuan frecuente usa simultaneamente tanto la boya de amarre como ancla en el lugar?**	☐	☐	☐	☐	☐

Section 3

	Ninguno	***1***	***2***	***3***	***Mas de 3***
40. **Cual fue el mayor numero de embarcaciones que ha visto amarrada a una sola boya de amarre durante su ultimo paseo en bote?**	☐	☐	☐	☐	☐
41. **Cuantas horas permanecio amarrado a una boya de amarre durante su ultimo paseo en bote?**	☐	☐	☐	☐	☐

Seccion 4. Indique la extencion de su acuerdo con los siguientes planteamientos

	Total desacuerdo	***Desacuerdo***	***Neutral***	***De acuerdo***	***Total acuerdo***
42. **Encuentro las boyas de amarre utiles.**	☐	☐	☐	☐	☐
43. **Las boyas de amarre estan convenientemente localizadas.**	☐	☐	☐	☐	☐
44. **Me gustaria ver un increment en el numero de boyas de amarre.**	☐	☐	☐	☐	☐
45. **Prefiero ver las playas cubiertas de arena en vez de hierbas marinas.**	☐	☐	☐	☐	☐
46. **Creo que todos tenemos el derecho de disfrutar del oceano.**	☐	☐	☐	☐	☐
47. **Todo el mundo deberia anclar o amarrarse dondequiera que deseen.**	☐	☐	☐	☐	☐
48. **Un ancla no lastimara ni los corales ni nlas hierbas marinas.**	☐	☐	☐	☐	☐
49. **El anclaje es la major manera de mantener los botes unos cerca de los otros.**	☐	☐	☐	☐	☐
	Total desacuerdo	***Desacuerdo***	***Neutral***	***De acuerdo***	***Total acuerdo***

50. **Apoyaria zonas de no anclaje voluntario sobre areas sensitivas con arrecifes de coral y hierbas marinas.** ☐ ☐ ☐ ☐ ☐

51. **Creo que la imposicion de multas y otra penalidades seran efectivas en estimular el uso de las boyas de amarre.** ☐ ☐ ☐ ☐ ☐

Seccion 5

52. **Cuanta educacion ha recibido sobre las boyas de amarre? (cursos)**

Ninguno	*1*	*2*	*3*	*4*
☐	☐	☐	☐	☐

53. **Tiene conocimiento de los arrecifes de coral y las praderas de hierbas submarinas que puedan estar debajo de su bote en estos momentos?**

Nunca		*A veces*		*Siempre*
☐	☐	☐	☐	☐

54. **En su opinion, que importancia tienen los arrecifes de coral y las hierbas marinas?**

Ninguno		*Neutral*		*Muy importante*
☐	☐	☐	☐	☐

55. **Cree que el anclaje puede ser prejudicial al arrecife de coral y las hierbas marinas?**

Ninguno		*Neutral*		*Muy importante*
☐	☐	☐	☐	☐

Section 6

56. **Cuanto crece el Coral en doce(12) meses?**
   - *g.* *0.02 to .2 pulgadas*
   - *h.* *0.2 to 2 pulgadas*
   - i. *20 to 200 pulgadas*

57. **Cual es la multa maxima por anclar en areas de boyas de amarre?**
   - *g.* *Hasta $100*
   - *h.* *Hasta $1,000*
   - i. *Hasta $10,000*

58. **Ha visto el material educativo que distribuye el Departamento de Recursos Naturales y Ambientales?**
   - c. *Si*
   - d. *No*

Section 7

59. **Genero:**
   - *c.* *Masculino*
   - *d.* *Femenino*

60. **Edad:**
   - *c.* *Menor de 25*
   - *d.* *25 o mayor*

61. **Escolaridad:**
   - *d.* *K-12*
   - *e.* *Colegio/ Universidad*
   - f. *Estudios Graduados*

62. **En que ciudad vive?** _________________

63. **Posee una licencia para la navegacion de embarcaciones?**
   - *c.* *Si*
   - *d.* *No*

64. Tiene sugerencias para mejorar el sistema de boyas de amarre?

65. Tiene algun comentario sobre las boyas de amarre?

66. Tiene otras ideas para acrecentar el apoyo de la comunidad nautical hacia la preservacion de los arrecifes de coral?

Muchas gracias por la cooperacion brindada. Su participacion ayudara en la proteccion de los habitats de los arrecifes de coral y hierbas marinas de Puerto Rico. Para los resultados de esta encuesta favor de enviar un email a: pr13photos@wpi.edu.

Appendix I: Technical Document for Administering Surveys & Inputting Survey Responses

<u>Administering:</u>

1) Surveys will be administered to boaters in any areas of interest
    - **Registration offices, marinas, various keys**
2) After a survey is completed, label the bottom right corner with the date and location
    - e.g. "4/3/13 R" would mean the survey was administered on April 3, 2013 in the Registration office
3) Keep surveys from same dates and locations together, it will make data entry easier later

<u>Entering responses into database:</u>

1) Should be using at least 2 people, one checking the other's work
2) Open the Excel file titled "***Database_Survey***"
3) Responses will be input numerically into the sheet labeled "*Data,*" numbers assigned to each response can be found in the sheet labeled "*Legend*"
4) Check periodically to make sure the Excel column and the survey questions are correct
5) Label the top right corner of each survey with a consecutive number as it is input (e.g. 1, 2, 3…) to prevent accidental rerecording and tie the database to the hardcopies

<u>Analyzing results:</u>

1) Results will be computed in the sheets labeled "*Results*"
2) There are a set of provided measurements of specific trends and questions that will update automatically as new data are entered (Tables can be updated with the "Refresh All" button)
3) New trends can be added using the same methods
    - **Pivot tables** are a good way of comparing the responses of specific survey questions
    - **Averages and percentages** can be used to show the trend of a single question

Individual columns for each question

	Obs #	Date	Location	Language	1 Freq	2 Environment a	2 Environment b	2 Environment
2	1	24-Mar	SJ Marina	0	0	1	0	1
3	2	24-Mar	SJ Marina	0	0	0	1	0
4	3	24-Mar	SJ Marina	0	0	1	0	0
5	4	24-Mar	SJ Marina	0	2	0	0	0
6	5	24-Mar	SJ Marina	1	4	1	1	0
7	6	25-Mar	DRNA Reg.	0	0	1	0	0
8	7	25-Mar	DRNA Reg.	0	0	0	0	0
9	8	25-Mar	DRNA Reg.	0	0	0	1	0
10	9	25-Mar	DRNA Reg.	0	2	1	0	0
11	10	25-Mar	DRNA Reg.	0	0	0	0	1
12	11	25-Mar	DRNA Reg.	0		1	0	0
13	12	25-Mar	DRNA Reg.	0	0	0	0	0
14	13	25-Mar	DRNA Reg.	0	2	1	0	0
15	14	25-Mar	DRNA Reg.	0	0	1	1	1
16	15	25-Mar	DRNA Reg.	0	0	0	1	0
17	16	25-Mar	DRNA Reg.	0	0	1	1	0
18	17	25-Mar	DRNA Reg.	0	0	0	0	0
19	18	25-Mar	DRNA Reg.	0	0	1	0	0
20	19	25-Mar	DRNA Reg.	0	0	0	0	0
21	20	25-Mar	DRNA Reg.	0	0	0	0	0
22	21	26-Mar	DRNA Reg.	0	0	1	0	0
23	22	26-Mar	DRNA Reg.	0	0	0	0	0
24	23	26-Mar	DRNA Reg.	0	0	0	0	0
25	24	26-Mar	DRNA Reg.	0	3	1	0	0
26	25	26-Mar	DRNA Reg.	0	0	0	0	1
27	26	27-Mar	DRNA Reg.	0	0	1	0	0
28	27	27-Mar	DRNA Reg.	0	0	0	0	0
29	28	27-Mar	DRNA Reg.	0	1	0	1	1
30	29	27-Mar	DRNA Reg.	0	0	0	0	0
31	30	27-Mar	DRNA Reg.	0	0	0	0	0
32	31	27-Mar	DRNA Reg.	0		0	0	0

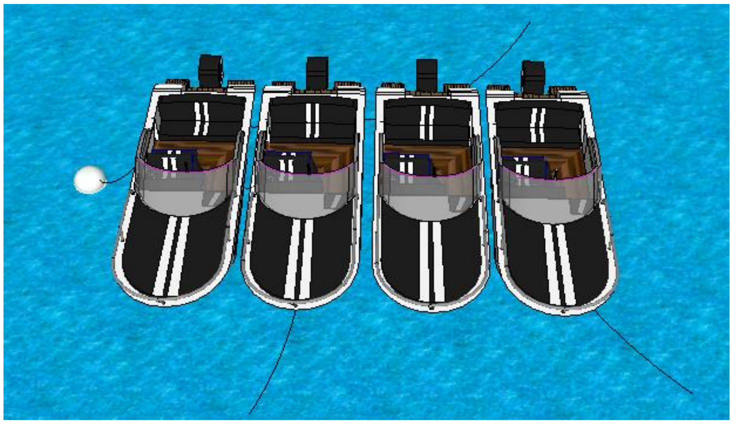
Data Legend Results Results2 Results3

Various sheets (Data, Legend, Results)

Appendix J: Proof of Concept for a Raft Mooring Buoy

Abstract:

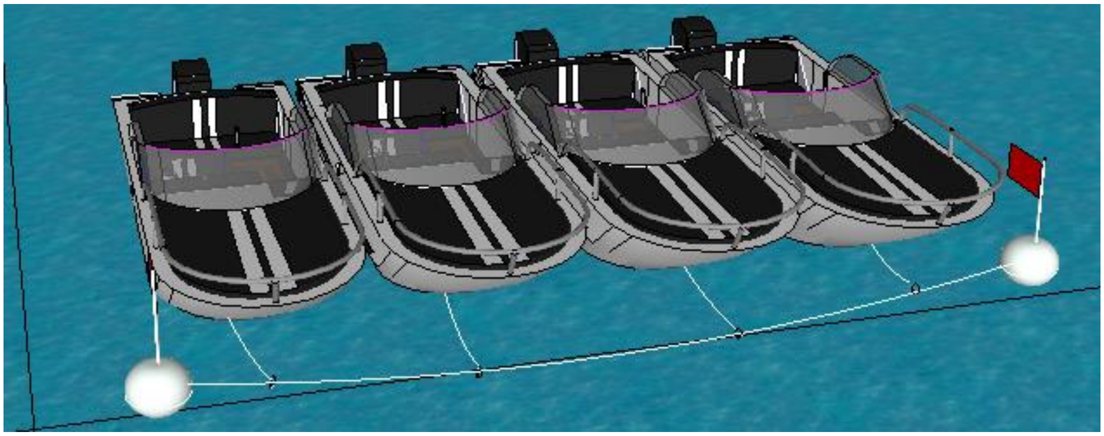
The current mooring buoy system has seen limited usage in the recent years by members of the nautical community. From the analysis of aerial photographs, one of the major behaviors exhibited by boaters is rafting (tying a number of boats together, side to side, in an effort to park in close proximity to each other). This behavior requires the boaters to anchor each of their boats to ensure that they remain stationary and not cause damage to neighboring boats. This behavior promotes anchoring, which can damage benthic communities as shown in the image below.



In this figure, four boats are tied together, hull to hull in common rafting fashion. One boat is tied to a mooring bouy and all additional boats have dropped anchors to secure the raft at multiple points. Each of the black lines represents an anchor that is dropped in this rafting scenario.

Design:

Currently there are 290 mooring buoys strategically placed throughout the waters surrounding Puerto Rico. These buoys are placed in high traffic areas to provide a viable alternative to anchoring. However, these mooring buoys are underutilized by members of the nautical community due to the convenience of anchoring. The buoy system is currently only supporting a fraction of the boats that visit the keys. Using the existing mooring system, the new raft mooring buoy design would incorporate a floating cable that would run between two mooring buoys as shown in the figure below.



This system would allow multiple boats to park in close proximity to each other with less environmental damage. The cable would act as the primary securing point for a boat. Using the eyehook found on the bow of the boat, a boater would attach from the boat to the floating cable at a designated point. The secondary connection would be made to an adjacent boat. The boaters would secure two boats of similar size, cleat to cleat to create a rafted group as is commonly seen. With this system, multiple boats would be able to park together without the use of anchors that could cause damage to the seafloor.

Calculations & Analysis:

Given:

Constant Wind speed= 15 kts= 17.262 mph (Bio-Optical Oceanography Laboratory, 2013)

Surface water current is negligible due to calm water conditions in key locations

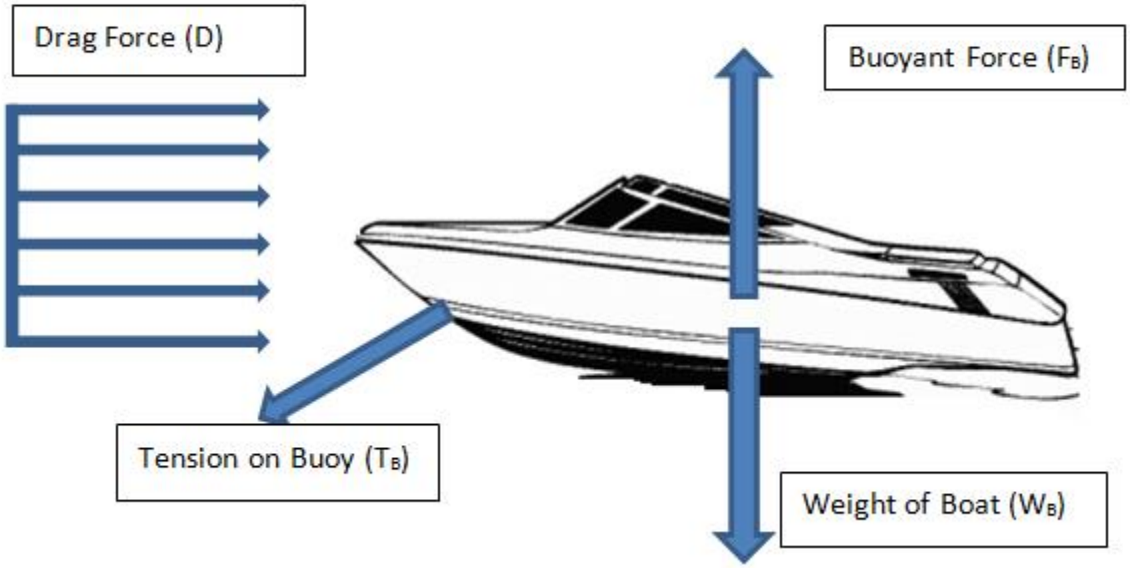
Weight of a 22 ft boat (Class 2) = 4400 lbs

Dimensions: 22*8.5*8.5 ft

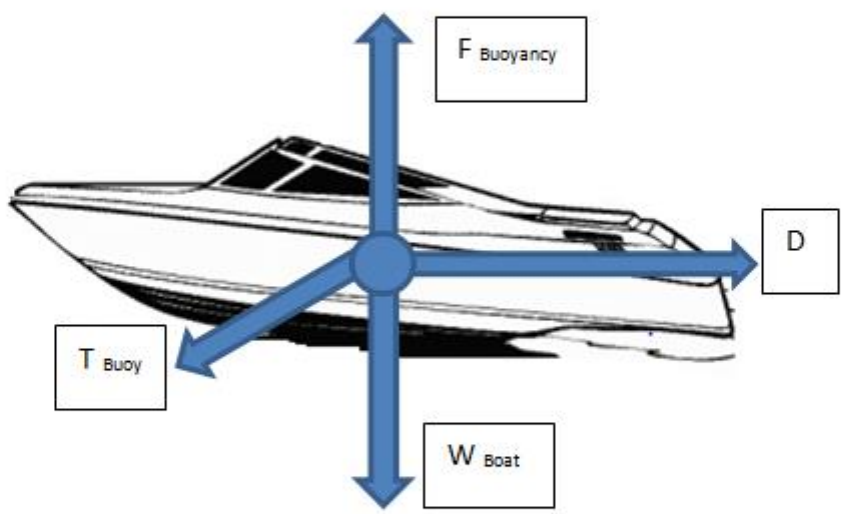
Weight of a 30 ft boat (Class 3) = 10,800 lbs

Dimensions: 30*10*10 ft

For a floating boat Buoyant Force = Weight



Actualization of Forces experienced on a moored boat



Idealization of forces experienced by a moored boat

Archimedes' principle states that we are able to neglect the weight of the boat due to buoyancy. Because the boat is floating on the water, we assume that the weight and buoyant forces are in equilibrium.

Additionally we are able to reduce the distributed load from the wind into a point load by assuming that the area in contact with the wind is a constant flat square area equal to the tallest height of the boat times the widest width of the boat, known as the beam.

This allows for the following calculation: (for a 22ft boat) from the bow:

Height: 8.5 ft

Width: 8.5 ft

Sq. Ft area in contact with the wind: A= 72.25 ft^2

Drag coefficient for a streamlined body: C_d= 0.04 (Giordano, 2012)

Wind Speed: v = 17.25 mph= 25.299 ft/s

Density of air=rho= 0.0717 lbm/ft3 (at 85F and 70% humidity)

Drag Force D= (0.5)(C_d)(rho)(v^2)(A) (Giordano, 2012)

$= (0.5)*(0.04)*(0.0717)*(72.25)*(25.299)^2$

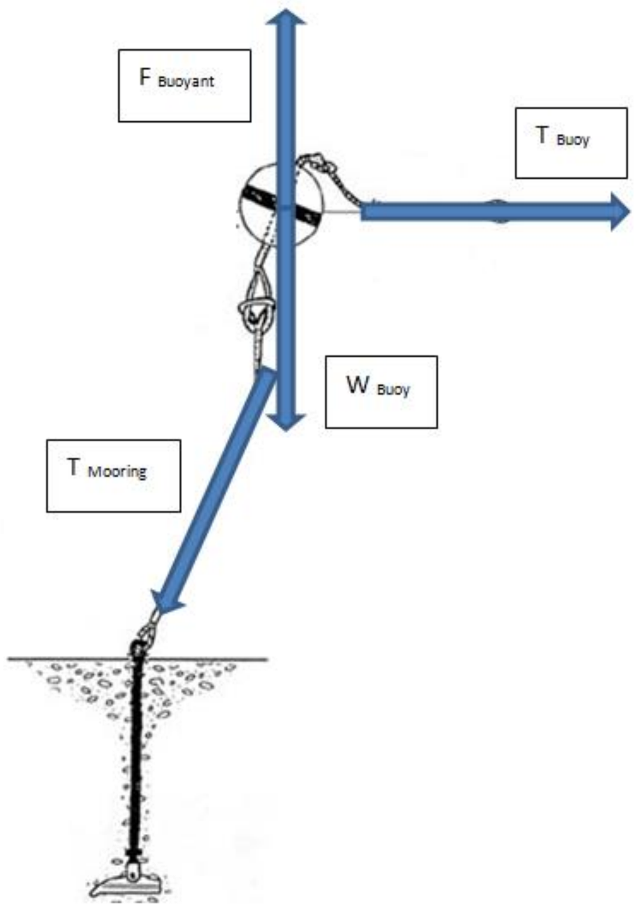
= 69.065 lbf

From this calculation we are able to see the amount of force that is applied to the rope connecting the boat to the mooring. To get the largest force that the rope will experience, we assume the angle between the wind force and the tension force is equal to 180 degrees.

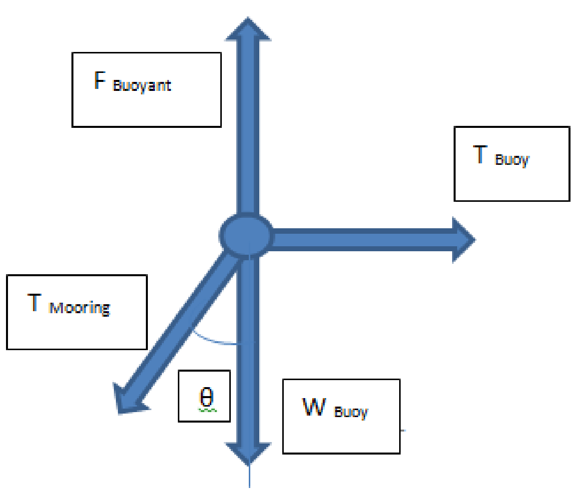
For and angle of 180 degrees:

T_{Buoy}=D= 69.065 lbf

For the Mooring Buoy:



Idealization of the Mooring Buoy:



From the idealization, we are able to understand that the maximum tension that could be put on the mooring is a result of the force caused by the wind speed on the profile of the boat such that

$T_{Mooring}*\sin(\theta) = D$

$T_{Mooring}*\cos(\theta) = F_{Buoyant} - W_{Buoy}$

For this calculation, we can assume the gravitational effect on the Buoy, W_{Buoy}, is negligible in comparison to the buoyant force working, $F_{Buoyant}$. We can also assume that the vertical force is not pertinent to the calculation of the force applied on the mooring by the boat.

To determine the angle theta we assume the length of the mooring rope to be 10ft and the depth of the water in the Paguera Keys to be approximately 4 feet in depth.

Theta= arcsin (Depth of water/length of mooring line)

$\theta = \arcsin(4/10) = 23.578$ Degrees

$T_{Mooring} = D/\sin(\theta) = 69.065/\sin(23.578)$

$= 172.664$ lbf.

Wind across the side cross section:

L=22ft

H= 8.5ft

A=187 ft^2

rho= 0.0717 lbm/ft3 (at 85F and 70% humidity)

v = 17.25 mph= 25.299 ft/s

$D = (0.5)(C_d)(rho)(v^2)(A)$

$= (0.5)*(0.04)*(0.0717)*(25.299)^2*(187)$

$= 171.632$ lbf

$D = T_{Buoy} = T_{Mooring} \sin(\theta)$

$\theta = \arcsin(4/10) = 23.578$ Degrees

$T_{Mooring}$=D/sin(θ)= 171.632 /sin(23.578)

= 429.083 lbf

From the NOAA test we know that the system can withstand a force of 7500 lbf with no sustained damage (National Oceanic and Atmospheric Administration, 1996-2005).

Additionally, these calculations were discussed with a Fluids Professor at Worcester Polytechnic Institute and deemed an acceptable approximation for the stresses on a mooring buoy.

For a rafted group of boats, the area in contact with the wind is the changing factor for the calculations. In a scenario where four boats are rafted together and the wind is in contact with the bow surface, the area becomes A_N= (Height)*(Beam Width)*(Number of Boats rafted).

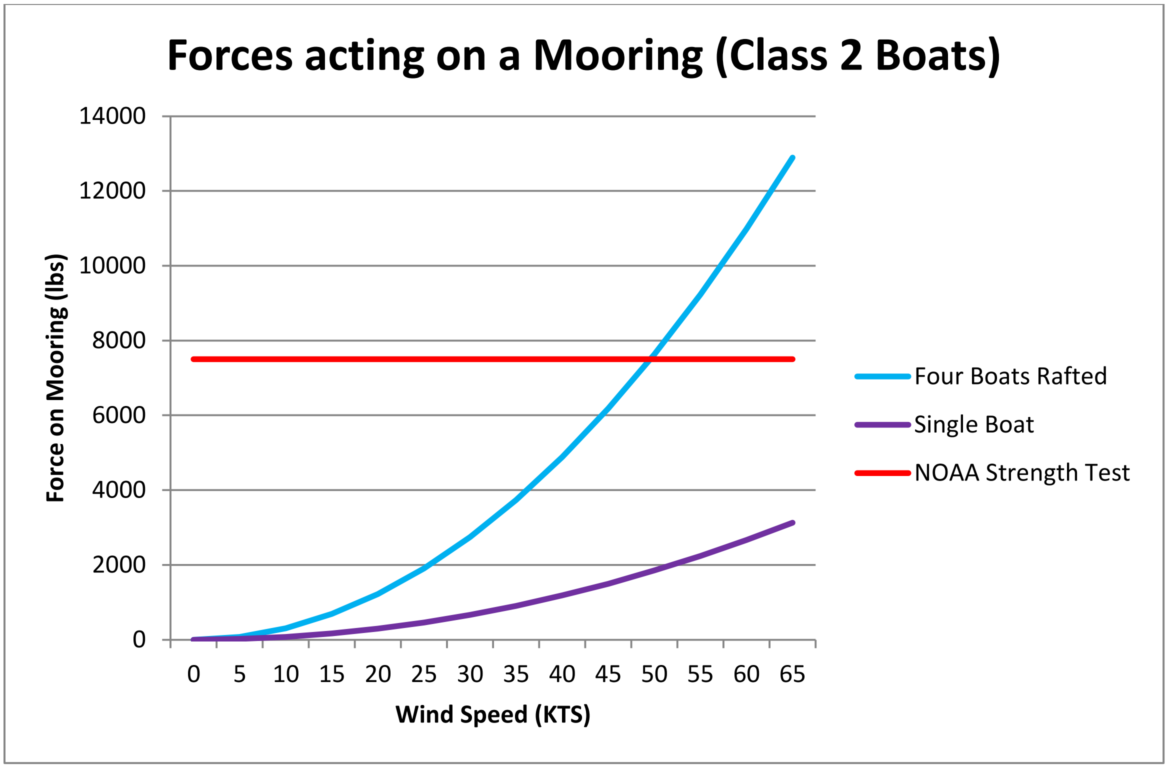
For the proposed situation, where n=4 and wind direction is across the bow

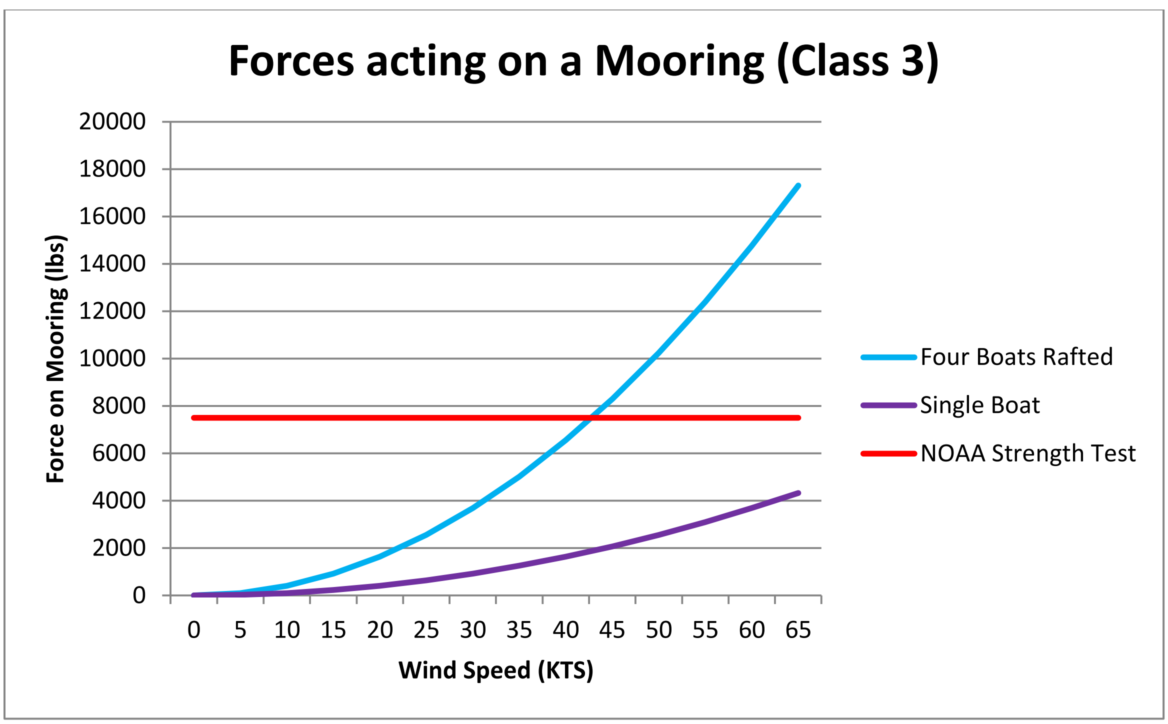
A = 289 ft^2

D = 265.25 lbf

$T_{mooring}$ = 640.62 lbf

These calculations reflect the idealization for this type of system. Due to wind direction, the total force of the boats could be applied to a single mooring. The calculations were done to determine the maximum forces that the system could experience. By doing calculations for extreme conditions we can assume that under normal operating conditions, the system would see reduced forces that those shown above. Due to the fluctuation of ocean conditions extensive testing would need to verify these calculations. The figures below show the projected forces that the system could sustain in varying wind speeds.


Forces acting on a Mooring (Class 2 Boats)
Force on Mooring (lbs)
14000
12000
10000
8000
6000
4000
2000
0
0
5
10
15
20
25
30
35
40
45
50
55
60
65
Wind Speed (KTS)
Four Boats Rafted
Single Boat
NOAA Strength Test


Forces acting on a Mooring (Class 3)
Force on Mooring (lbs)
20000
18000
16000
14000
12000
10000
8000
6000
4000
2000
0
0
5
10
15
20
25
30
35
40
45
50
55
60
65
Wind Speed (KTS)
Four Boats Rafted
Single Boat
NOAA Strength Test

In these figures it is important to note that the forces do not consider the effects of any surface water currents. These currents are negligible during periods of low wind but may cause additional stress to the mooring system during periods of high wind. It is also important to note that in the NOAA stress test, the manta ray mooring buoy was not removed or damaged at a load force of 7500 lbs. Additionally mooring buoy regulations do not permit any boating traffic on the water at wind speeds exceeding 40 nautical miles per hour (KTS). These two limiting factors would help to restrict the forces that the system would see during typical use.

In order to ensure that the system would function properly, extensive testing would have to be done. Factors such as the holding strength of the mooring as well as water currents and wind speeds and directions would all have to be considered before the system was to be implemented. A test similar to the NOAA strength test should be conducted to determine the actual strength of the system. Below are conceptualizations of the system. These drawings help to show the operation of the system while in use. It also helps to describe where and how the boats should tie together to properly use this system.