Final Proposal
Guardians of the Reef

Part 1: Problem Space

Section 1: Problem Statement

Worldwide, people are the biggest threat to corals. At the moment the most effective way to help coral reefs globally is to protect the ones that already exist. This can be done through the use of Marine Protected Areas (MPAs). The main issues with MPAs are that they are large scale areas and that they have inadequate enforcement. Specifically in the Florida Keys, where the Great Keys Reef lies, boaters, tourists, and other people in the area have been driving through the area without knowing that they are crossing into a protected area. Due to the lack of enforcement and on-water indicators locating MPAs, ignorant people are causing damage that they are not aware of. Park rangers doing reef cleanups or divers who notice the damage are currently the only information sources, unless a scientist is studying the reef. Consequently, the people who cause the coral injury are not held accountable because the damage they cause is not discovered right away, if at all. Working to prevent people from entering the areas will in turn allow for the boating accidents to be avoided. By creating a system that notifies boaters when they are approaching a MPA, coupled with increasing the public’s knowledge of coral reefs’ importance, the team will be able to better protect the coral inside of MPAs.

Section 2: Problem Significance

2.1: Problem Importance

1) Coral reefs generate a lot of money for numerous economies around the world. Worldwide, coral reefs provide $375 billion in total revenue through the goods and services it provides (National Ocean Service, 2008). Coral reefs provide a diverse array of fish that people need for food and medicine. The beautiful scenery of coral reefs causes millions of people to visit them, creating revenue for local economies. For example, US fisheries make $100 million in commercial value from coral reefs and $100 million per year in recreational fishing (National Ocean Service, 2008). The coral reefs that our group is trying to protect, the reefs in the Florida Keys, have an asset value of $8.5 billion; these reefs generate $billion dollars in local sales and $2 billion in local income (National Ocean Service, 2011). The coral reefs in Florida create over 70,400 full and part time jobs, illustrating how much the residents of the Keys truly rely on the coral reefs for a significant amount of their income.

2) Coral reefs provide protection for people on coastlines from natural disasters such as hurricanes and tsunamis by reducing the energy of the waves that hit the shore. This is important because 450 million people live within 60 kilometers of a coral reef, so they rely on the coral reef to protect their property (WWF, 2015). The coral reefs can reduce up to 75%-95% of the energy of the waves, decreasing the impact of the waves when they hit the shore (Endangered Species International Inc., 2012). As a result, billions of dollars saved in reduced insurance and reconstruction cost. For instance, the US saves $10.7 billion from damage and from building coastal defenses (Endangered Species International Inc., 2012).
3) Corals provide food and medicine for numerous people. One billion people, or one seventh of the world’s population, rely on the coral reefs to provide food for them (Carili, 2013). Thirty million people, living in developing tropical countries are completely dependent on the coral reefs for food. Therefore, a huge food supply for numerous people will be gone if the coral reefs die out; such a catastrophe would cause serious problems, such as starvation, for the people dependent on the coral reef. Furthermore, the coral reefs provide a diverse range of fish which provide medicine for humans. Many marine organisms in coral reefs are rich in chemical compounds called marine natural products. They are used by marine wildlife as protection from predators, but humans use them to make medicine. For example, the soft coral Eleutherobia spp is used to make the medicine Eleutherobin, a cancer cell inhibitor(Endangered Species International Inc., 2012). Other medical issues such as AIDS and inflammatory issues are also being treated using chemicals produced by corals and fish living in reefs. If the coral reefs die, these vital resources that could cure many of the diseases plaguing humanity will disappear.

2.2: Causes of the Problem
Coral reefs are being lost due to three primary reasons: global climate change, pollution, and unsustainable fishing practices. The increase in carbon dioxide in the atmosphere has led to a decrease in the pH of the ocean water, which in turn has led to a subsequent decrease in the rate of calcification of corals. Calcification is important to corals because without this process, corals cannot grow. As more carbon dioxide and other greenhouse gases are released into the atmosphere, the average temperature of the ocean increases, bleaching coral reefs.

In the context of this problem space, pollution is defined as movement of harmful substances from land to the oceans, particularly movement of nutrients, sediment, and other pollutants. These substances get to the oceans via runoff, surface waters, atmospheric deposition into the ocean, and groundwater seepage. When runoff of nutrients enter the ocean, algae, which thrive on such nutrients, have a population explosion. The proliferation of the algae leads to a subsequent proliferation of bacteria and archaea, both of which eat algae. The bacteria and archaea take all of the oxygen in the water, depleting oxygen supplies for fish. The fish, which are integral to coral health, die, and organisms which are harmful to coral and which are eaten by those fish, prosper, causing coral to die.

The health of coral reefs is incompatible with unsustainable fishing practices. Fishing techniques, such as dynamite fishing, bottom trawling, and boaters anchoring their vessels in reefs, directly damage corals. Large fishing vessels also sometimes catch or kill non-target species; these non-target species could be vital to reef health, depending on the species. Overfishing in general can destroy reefs if the overfishing is of critical species. Rapid human population growth only exacerbates this threat to coral health because of the increased demand for fish.

Section 3: Stakeholders

Coral reefs draw numerous tourists each year. Millions go to reefs to snorkel and dive every year. Protected coral reefs tend to be most popular because they are in best shape. The Caribbean alone was host to around 20 million tourists last year, despite the fact that around 80
percent of the coral reefs in the Caribbean are gone. People still go to the remaining reefs because they value their intrinsic beauty and biodiversity. In fact, divers value reefs so much that they would pay an annual average of $25 per diver to keep Caribbean reefs healthy. In the Keys, tourists said that they were willing to spend between $23 and $64 million in total to protect the reefs. Thus, tourists and divers do in fact want the reefs to be protected.

Several Caribbean countries get almost half of their gross national product directly from tourism, specifically from snorkelers and scuba divers seeking to see the reefs. 350 million people in Southeast Asia alone live within 50 kilometers of coral reefs. In southeastern Florida, reefs generate $2 billion in local income per year and have created over 70,000 jobs. As such, maintaining healthy coral growth is paramount in order to sustain a flourishing economy.

The pharmaceutical industry has been researching coral and marine species that depend on coral, exploring the potential use of these animals in drugs that could be used to cure cancer, arthritis, and other viruses. For example, anticancer agent Ara-C was developed from extracts of sponges in Caribbean reefs. Properties of chemicals found in Caribbean sea-whip corals include skincare, anti-inflammatory, and painkiller properties. Australian researchers have used a coral chemical with a natural sun block to develop a type of sunscreen. The limestone skeletons of coral have been tested for potential use as bone grafts. These beneficial chemicals/compounds are the direct result of the vast biodiversity of coral reefs, without which these possible cures, and the revenue from them, would go unrealized, resulting in a pharmaceutical interest in maintaining reef health.

The fishing industry depends on coral reefs for its survival. It directly employs 38 million people worldwide, and an additional 162 million indirectly. Coral reefs provide food to over 1 billion people worldwide. Of those 1 billion people, 85 percent rely on the fish from coral reefs for protein. U.S. coral reefs generate $100 million per year from fishing. Reef-based recreational fisheries in the U.S. add another $100 million annually in value. In sum, fisheries in coral reefs worldwide generate $5.7 billion. Properly managed reefs can yield 15 tons of fish per square kilometer per year. However, roughly eighty percent of the world’s shallow reefs are severely overfished, which will limit long term fish production.

Section 4: Context and Existing Solutions

4.1: Context

Protecting the coral reefs is a complex problem because there are numerous detrimental factors. A major issue to protecting reef health is the timescale surrounding potential solutions. Corals can take several thousand years to grow to maturity. For instance, today’s established reefs are 5,000 to 10,000 years old (Thomas). Damage to coral reefs, therefore, could take thousands of years to fix. Furthermore, the effects of climate change are delayed by several years. The environmental damage that humanity is causing right now will not be visible for several years from now, making it hard to predict the effects. Attempted solutions have not focused on this aspect of the problem. Creation of MPAs and removing human interaction between the reefs have been the most successful methods of protection so far. Different experiments have been done for coral growth, such as electric cages and facilitating polyp growth, but in comparison not much research has been done on methods of protection (Hanley). Clearly, coral destruction is still a problem due to the fact that very little has been done to prevent its death and destruction. One of the primary issues is that even the smallest infractions,
such as absentmindedly letting a piece of trash blow off the beach and into the ocean, or accidentally treading on reef growth, add up to result in an immense effect (Kashi). The issue has not been solved because it is much more complex than one solution, and occurs on a global scale. Parts of the issue have been controlled and solved, but an overall solution is yet to be found.

4.2: Existing Solutions

Existing solutions have included attempts to grow corals in aquariums. The most successful existing solutions have attempted to fix the problem of unsustainable fishing practices.

The best existing solution is a project in Indonesia called COREMAP. Funded by the World Bank, the project established marine protected areas (MPAs) in Indonesian waters and trained the local populace to enforce these MPAs. MPAs are special zones in which recreational activities such as fishing, swimming, or anchoring, are limited. The project educated the locals on the values of the reefs so that the locals understand why they need to enforce these MPAs. The locals have bought into the project, and they have enforced the MPAs well. As a result, the communities near the MPAs have experienced a 20 percent increase in their incomes, and the coral cover in these MPAs has increased by 25 percent. These results show that if MPAs are well enforced, they are effective.

Unfortunately, similar solutions have failed in the U.S., particularly in the Florida Keys. The Florida Keys have several thousand square kilometers of MPAs, but they only have two people enforcing these MPAs. Furthermore, if somebody were to be caught by one of the enforcers, that person would only be issued a warning because if that person were sent to court, there would only be one person enforcing the MPAs, as the other enforcer would have to be a witness in the trial/hearing.

Another solution that has been tried is assisted evolution of corals. Researchers at the University of Hawaii have started selectively breeding shallow-water coral colonies so that the colonies might become more resistant to global climate change. Such assisted evolution would involve capturing a type of microscopic algae living inside corals and artificially selecting them to modify the corals. This approach, however, is especially daunting. While this approach may be effective, the timescale for such a solution to be implemented and be effective would be enormous.

A solution that closely mirrors the group’s chosen solution is also a smart buoy from Intellicheck Mobilisa, which utilized infrared cameras and various other sensing devices to sense various vehicles under, on, and above the water, as well as environmental sensors meant to detect traces of radiation, chemicals, and biological substances. Developed for port security to assist the Coast Guard, the buoy design was bought by the U.S. Navy and has continued production under government classification. Problems associated with the buoy include cost, as the suite of sensors and communications devices were purchased from high-end commercial interests and customized to the project.

Section 5: Why This is Still a Problem

A recent study on the global strength of marine protected areas looked at five markers that determine the success of MPAs. These markers include: how well enforced fishing rules are,
the age of the MPA, the size of the MPA, how much fishing is allowed in the MPA and the location of the MPA. A good MPA should function in a well enforced prohibited fishing zone larger than 100 square km and should be isolated. Existing MPAs are not designed properly and/or not managed well and hence do not achieve their desired effect on the region surrounding them. Less than half of the current MPAs are restricted fishing zones, and those that have laws prohibiting fishing are not enforced. Most attempts to hinder fishing are not obeyed by fishing vessels due to the fact that enforcement is not present in the majority of MPAs. The MPAs are not established in localized regions, so they do not preserve the larvae dispersal and hence are not properly preserving biodiversity. In addition, many of the world’s MPAs are not properly mapped out so fishermen do not know which regions are restricted from fishing.

Part 2: Proposed Work

Section 1: Goals

The group’s goals relate to providing relevant information concerning marine traffic within MPAs (Goal One) as well as deterring any detrimental traffic from entering the protected areas (Goal Two). By the end of the project, the group, at a minimum, will have completed Goal One, providing a stepping stone for future projects meant to deter harmful marine traffic within MPAs. Goal Two will be considered complete when a system of deterrence is in place that has been analyzed to be effective. If Goal One is achieved, the group will have provided important data that currently does not exist, paving the way for future studies and efforts. If Goal Two is achieved in addition to Goal One, the group will have decreased harmful traffic in MPAs that can lead to damage to the coral reef, allowing the reef to regrow and resulting in an increase in ocean health. The group is attempting to achieve these goals through improved identification of MPA boundaries and deployment of equipment within the MPA.

Section 2: Objectives

Objective 1: Determine a viable location for implementation of the group’s solution. It is extremely important to identify a realistic location for the trial of the group’s solution, as the location, the health, and the restrictions of the MPA determine whether the group can actually trial their solution in that location. The group is looking at Florida, specifically the Florida Keys, for this location. The Florida Keys provides the most realistic and appropriate environment for the group’s solution, as it is composed of 225 MPAs, most of which have strict regulations that determine whether boats can anchor, fish, or even travel through the waters. To determine the best location, the group will research the regulations of each MPA candidate, searching for the MPAs with the strictest regulations and the lothe teamst relative health, producing a preliminary list. The group will then continue to research the chosen MPAs, specifically to determine which areas are hardest hit by activities such as illegal fishing and anchoring practices.
Research should also include talking to MOTE Marine Research Laboratory, which has expressed interest in continuing a relationship with the group and also has field experience that the group can take into consideration when determining the final location. In order to consider this objective completed successfully a suitable MPA has to be found.

**Objective 2:** Determine a corporate/commercial/non-profit entity that is willing to work with the group in the preliminary design and implementation of the group’s system. The group has already identified a potential partner that has also expressed an interest in continuing to work with the group. In order to consider this objective completed successfully the group must have identified and engaged in a relationship with a corporate/commercial/non-profit entity that can assist in any of the following: solution design/implementation, funding, guidance, and providing relative information.

**Objective 3:** Locate a faculty member or administrator willing to assist in the design, development, and manufacturing of the buoy. This step is pivotal in the successful construction of the group’s solution, a smart buoy. This objective will be considered completed when the group has contacted and confirmed a faculty member at the university that is willing to assist in the design and manufacturing aspects of the project.

**Objective 4:** Identify potential customer with a stake in the Florida Keys as well as contact them to ensure a viable market for the buoy device. The group is to conduct research into possible customers, private, commercial, or otherwise, contact them and determine a viable customer for the produced buoy device. Without suitable demand, the produced device would never be implemented. This objective will be considered complete when the group has successfully entered into a relationship with an interested customer.

**Objective 5:** Identify potential buoy(s) to re-use, cutting the cost of creating a brand new central buoy and providing a suitable platform for experimentation. This objective will be considered complete upon purchase and delivery of buoy chassis.

**Objective 6:** Determine primary hardware/software to be utilized by the buoy system, such as Arduino or some other hardware. Factors taken into account will be price, ability to connect with numerous other devices, as well as the learning curve associated with the software. This objective will be considered complete upon purchase and development of software to be used.

**Objective 7:** Determine primary method of communication between buoys. This objective will involve numerous stages of research to determine the most cost-effective and efficient method of communication, whether it be through satellite uplink, radio transmission, or a wifi network. This objective will be considered complete upon purchase and development of the method of communication.

**Objective 8:** Determine brand of thermal imaging camera and obtain sufficient knowledge to interact with the imaging system. This objective involves determining the most cost-effective and efficient camera model, as well as its ability to interact with the chosen software. This
Objective 9: The team will conduct a trial period for the prototype buoy(s). This objective involves successfully trialing a buoy to determine how it copes with factors in an uncontrolled environment. This objective will be considered complete upon temporary implementation of the buoy in a suitably trafficked body of water. Success entails correct identification of vessels, suitable collation of data, and efficient transmission of that data to a location on the shore.

Objective 10: Complete successful construction and implementation of buoy device in primary location, as well as infrastructure surrounding the collation and gathering of remote data from buoy device. This objective involves utilizing the various skills present in the group in order to successfully design and manufacture a buoy device within a manageable time frame and with reasonable material and financial resources. In order to consider this objective successfully completed, the group must have developed a prototype device that has the minimum capability of transmitting valuable data concerning marine traffic, with the possible addition of a method of deterrence.

Section 3: Research Team/Roles of Team Members

3.1: Programmer/Circuit-Master
This person will code the computer programs that the buoys will use to detect incoming boats and potentially alarm these boats that they are entering an MPA. This person will also be responsible for the setup of the communications network between the mother buoy and land as well as the communication network between the buoys, and is responsible for the electronics (wiring, batteries, etc.) as well.

3.2: PR Head
This person will be the link between the group and the group’s contacts in the Department of Natural Resources and MOTE Marine Laboratory as well as Georgia Tech professors. This person will also find a customer for the team’s final product.

3.3: Construction Team
People on this team will be responsible for the construction of the buoy. This team will determine the materials that both meet the requirements of the team’s solution while minimizing costs. The construction team will have the final say on the final design/construction of the buoy.

3.4: Testing Team
This team will determine the best location for implementing the prototype of the buoy. They will monitor the buoy for a trial period, after which they will return the data received from the trial to the construction team.

Section 4: Potential Advisers

4.1: Mark Hay
Dr. Hay is a leading expert on coral reefs and marine protected areas. His research has been very influential in proving the success of well enforced MPAs. When the team interviewed
him as part of our research, he seemed excited about our project and happy to help guide us if the
team had any questions. At this point the team have presented our general solution to him and are
waiting for a response about guidance.

4.2: Mote Employees
   The team has contacted four researchers from the Mote Marine Institute in Florida. The
team has presented a basic layout of our problem space and solution and are awaiting a response
on advisorship.

4.3: John Pennekamp
   The team has reached out to John Pennekamp Coral Reef State Park, which includes 25
miles of coastal shoreline in Key Largo, which also extends 3 miles into the Atlantic Ocean.
“These areas were established to protect and preserve a portion of the only living coral reef in the
United States” (Pennekamp). We hope to get advice from the park rangers, with the possibility of
implementing our solution in the waters of this state park.

4.4: Georgia Department of Natural Resources
   Dr. Wynens has reached out to his contact Sid Johnson, the Commissioner of Department
of Administrative Services, who will set up an interview between our group and the DNR
Commissioner. We hope to test out our buoy system in Lake Lanier, over which the Georgia
DNR has control. Through this contact the team is seeking advisorship and assistance in
implementing our experiment when it is ready.

Section 5: Timeline

- **Spring 2015**
  - *March*: Determine MPA to work on, determine method of deterrence, determine
    method of data collection
  - *April*: Locate advisor/partner, design initial buoy prototype

- **Summer 2015**
  - *June*: Obtain buoy materials, begin experimentation and programming
  - *August*: Visit Florida for contact with partners (early August), create simple
    physical buoy prototype

- **Fall 2015**
  - *September*: Have experiment for demonstration of buoy systems
  - *October*: Run experiment for systems, travel to Florida Keys for field experiments
  - *December*: Major modifications on project/buoy system (winter break)

- **Spring 2016**
  - *March*: Finalize design, presentation, visit Florida Keys for check-up

- **Summer 2016**
  - *August*: Finish construction, final implementation, visit Florida Keys
Section 6: Budget

6.1: Materials and Supplies

The materials the team requires are the components of making the buoy, infrared detector, solar panels, batteries, a cellular antenna, a CDMA modem, and computer. There are various components that can make up the buoy depending on the size and needs the team desire for the buoy, the team are going to talk John Pennekamp or the Motes research facility in the keys to get advice on how to create the buoys for the Keys and perform the functions the team desire the buoy to perform. The infrared detector will be placed on the child buoys to locate the ships that pass through the buoys or near the MPA. The solar panels will be used to power the buoys, and these solar panels will absorb 12 volts and 20 watts of power, providing the energy supply for the battery. That amount of energy will allow is enough to run the computer on the mother buoy and the cameras to work properly on the child buoys for the whole day. Cellular antennas and CDMA modem are placed in the child buoys to connect to the mother buoy where the ships are located at and send the data to the mother buoy system. The modems establish the cellular network for the buoy system. For the mother buoy, it will use the cellular data and CDMA modem to receive the information from the child buoys and then send that data to an offshore location where the coastal guards and local enforcement can retrieve the data. The computer will be on the main buoy to collect the data from the buoys and process it into information that the law enforcements can easily understand. The computer will come from AXYS technology who focuses on creating computer systems for collecting data for marine life.

6.2: Equipment

No single material costs over $1000.

6.3: Services

A manufacturing process is required to build the buoy system. We can contact AXYS Technology to help install the computer, antennas, and cameras on our buoys. They have field technicians who are skilled in deploying and implementing buoys. Also if we have time they provide a training service where they can teach the group how to implement the buoy systems ourselves. The Florida Keys National Marine Sanctuary has a program to build their own buoys, so we can ask them for assistance as well. First, the team will look for consultants from professors here at Tech to help give the team advice on building the system; if the team sees that is too difficult to build, the team will look for a source outside of Tech. Final service cost would correlate to keeping maintenance of the buoys year around. Buoys can have issues occur to them where tourists and small boats could damage them, so the team would need a service to go observe and fix its buoys if needed.

6.4: Travel

Yes, travel is involved for the team’s solution. The team will travel to the Florida Keys to implement its solution. The team needs to go down there to talk to the MOTE Research Facility
to get advice on how to implement the buoy system as well as give the team the best advice on where to place its buoy. Then the team would build the buoy in the Florida Keys. We will return in four to six months to see how effective the buoy is and see what improvements we need to make on the buoy system. The main method of transportation we will use is plane, and car once in the Florida Keys. Travel costs (based off past trip) will be likely be $70 food + $100 hotel room + ~$315 roundtrip flight per person. Driving would result in lower costs for travel, especially if numerous people are traveling. The price will be dependent on gas costs and gas mileage of the vehicle. The total driving distance is 1,642 miles.

**Part 3: Expected Outcomes and Future Direction**

The group expects to create a smart buoy system that tracks the amount of boats that enter a coral reef as well as deter them from entering the MPA. We hope that our system gives the data that the law enforcement need to optimize their time on what regions of the coral reef they should patrol. As a result, the team’s buoy system will over time see less boats coming into the MPA, and eventually the team hopes that no boats enter the region in 5-10 years. After year 2, the team hopes to implement a prototype in Lake Lanier which is located in Georgia to test out how the team will collect data and connect the buoys together. From its small experiment, the team will see what changes will need to be made to improve on its buoy system. The team will continue to experiment our buoy system until the team find the best version of our buoy system. Hopefully by second semester of its fourth year, the team can build the buoy system and bring them to a MPA in the coral reefs to implement them.

To be successful, we will need to work with a number of partners. One of the main partners will be the MOTE marine laboratory with whom the team met in Sarasota and received contact information for their lab in the Florida Keys. They have a lot of knowledge on the MPAs in the area and where it would be best to target our solution. Additionally, they have relationships on the policy front that have allowed them to grow MPAs and install buoys of their own. It would be perfect for us to be able to tap into those relationships because the team does not have those connections and they can give the team advice on how to design the buoy system. The team’s other contact would need to be the Georgia Department of Natural Resource because they patrol Lake Lanier. The team wants to build a close relationship with them, so they can allow us to perform our experiment on Lake Lanier. The team wants to see if it can effectively communicate valuable data to the Department of Natural Resources obtained through the buoys. It would also be in the team’s best interest to develop a relationship with a manufacturer. The manufacturer could advise the team on the most effective practices and also work with it in relation to larger scale production of its solution.
Part 4: References


Carili, J. (2013, June 17). *Why are Coral Reefs Important*. Retrieved April 12, 2015, from Saltwater Science:  
http://www.nature.com/scitable/blog/saltwater-science/why_are_coral_reefs_important

hhttp://oceanservice.noaa.gov/education/kits/corals/coral07_importance.html

Retrieved March 15, 2015, from  
http://www.kaleo.org/news/uh-researcher-looks-at-assisted-evolution-to-save-corals/article_1b49fd70-8e59-11e4-9868-eb175f4a4b5.html


Endagered Species: http://www.endangeredspeciesinternational.org/coralreefs5.html


It Takes Villages to Conserve Indonesia's Precious Coral Reefs. (2014, June 6). Retrieved February 3, 2015, from  

http://ocean.nationalgeographic.com/ocean/critical-issues-marine-pollution


Retrieved April 12, 2015, from Florida Keys National Marine Sanctuary:  
http://floridakeys.noaa.gov/corals/economy.html

http://oceanservice.noaa.gov/education/kits/corals/coral07_importance.html

http://celebrating200years.noaa.gov/foundations/coral/side.html


<http://coralreef.noaa.gov/aboutcorals/val MPAs>

WWF. (2015). Fast facts: why coral reefs are important to people. Retrieved April 12, 2015, from Coral reefs:

http://wwf.panda.org/about_our_earth/blue_planet/coasts/coral_reefs/coral_facts/