The Assessment and Educational Outreach of Lighting Practices for Coastal Light Pollution Impacting Sea Turtle Ecosystems

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Abstract

This proposal, prepared for the Junta de Calidad Ambiental (Environmental Quality Board) in Puerto Rico, will describe the assessment and modification for different types of light fixtures to reduce the light pollution which is impacting coastal ecosystems. From the literature and research, we will describe what light pollution is, the regulation that is active in Puerto Rico, different types of lighting guidelines, and how light pollution is dangerous to ecosystems and the environment. We will determine a percentage of light fixtures which can be easily modified or replaced to reduce the light trespass on the beach as well as create an educational guide about light pollution and modification ideas to educate the public.

Executive Summary

As the world and society continue to grow, the amenities, benefits, and consequences that go along with it grow as well. Every day, artificial light continues to be a problem by polluting the environment and damaging aspects of life that may never be recovered. This is referred to as light pollution and there are multiple components which are covered by this term. Skyglow, light trespass, glare, and clutter are the four main components and are described as brightening of the night sky over inhabited areas, light falling where it is not intended or needed, excessive brightness that causes visual discomfort, and bright, confusing, and excessive groupings of light sources respectively ("Light Pollution," 2016). Skyglow and trespass are the two components that have the greatest impact on the environment because they permeate the ecosystems of many different species.

Light pollution is defined by the International Dark Sky Association (IDA) as "the inappropriate or excessive use of artificial light which has a disruptive effect on natural cycles" ("Light Pollution", 2016). Sea turtles use the natural light from the moon and stars to find their way back to the ocean from beaches. Without artificial light, the moon reflecting off the ocean ends up being the brightest area seen from the coast. However, on many of the coastal locations in Puerto Rico, there are high levels of artificial light and the turtles therefore instinctively stray away from the ocean. Nesting female sea turtles look for the darkest and quietest locations to lay their eggs. If there is too much artificial light on the beach, they feel unsafe and will look for other beaches even though they may be less than optimal. This can result in fewer, if any, eggs hatching. Light pollution also greatly affects hatchlings because when they emerge from their nests, they look for the brightest point which is naturally the moon and stars reflecting off the ocean. However, if there are many sources of artificial light, this can confuse the hatchlings.

They can end up going towards the lights and risk dying from dehydration, exhaustion, terrestrial predation, and cars. Although we primarily focused on the effects that light pollution has on sea turtles because they are an endangered species, light pollution also affects other forms of wildlife such as frogs, birds, and moths.

With the growing amount of pollution, agencies have begun to implement laws, rules, regulations, and restrictions to reduce light pollution and its adverse effects. In Puerto Rico, light pollution is a concern because of its negative impacts on coastal ecosystems including sea turtles and marine life. With the specific limitations from the Puerto Rican government, there should be no light pollution impacting the coastal environment. Two organizations in Puerto Rico, the Junta de Calidad Ambiental (Environmental Quality Board) and the Departamento de Recursos Naturales y Ambientales (Department of Natural and Environmental Resources), are responsible for enforcing and regulating the specifics about the law and regulations. The law (No. 218) was passed in 2008 and a transitional period was established as 10 years for private lighting and 20 years for public lighting. During this time, the government is not allowed to force owners to replace noncompliant light fixtures but instead they can demand the modification of fixtures. One major problem that government agencies have encountered is that people cannot afford to modify their lighting. These regulations and issues are the purpose behind our project and efforts.

Methodology and Results

The goal of our project was to evaluate lighting practices and modifications to reduce light pollution and provide educational outreach in an effort to protect sea turtle nests on the coasts of Puerto Rico. To accomplish this, we broke our project into three main parts: data and

inventory collection, distribution of a survey, and creating an educational brochure and guide as deliverables.

We evaluated lighting practices in Isla Verde by measuring light levels using a photometer and a sky quality meter (SQM). The photometer was used to measure the intensity of a light and its units were in foot candles (fc). The higher the reading, the brighter the light and the greater the light pollution. The average maximum reading per property was 2.34 fc. Compared to the allowable level as required by the regulation of 0.05 fc, the majority of the lights were not in compliance. The sky quality meter was used in phase 1 in Isla Verde to measure the illuminance of the sky. The units were magnitudes per square arcsecond (mpsas) and the lower the reading, the more illuminance there was in the area. The average SQM reading from 19 locations in phase 1 was 17.76 mpsas. Compared to the 2014 IQP team with an average reading of 18.33 mpsas, the SQM readings at Isla Verde have decreased significantly. This indicates that light pollution has increased over the past two years.

While collecting data at night, we also performed an inventory evaluation of the light fixtures in Isla Verde and Patillas. We performed a thorough inventory collection of lights from every building that faced the beach or was close in proximity to the beach. At each building we took two pictures of every type of light fixture that was visible; one picture close up and another farther out. The lights were organized on a chart with the following categories: light identification number, quantity of lights on the property, location, photos of the light, type of light, light application, light color, whether the angle exceeded 70 degrees, shielding, number rating of compliance, average photometer readings, and recommendations.

In Isla Verde, 843 lights were assessed and from the results, a majority of the light fixtures were found to not be in compliance with the law. In terms of the color of the light bulb,

12% of the lights were compliant for light bulb color, 28% had a noncompliant light bulb color, and 60% of the lights were not able to be assessed for color. In terms of shielding, 2% had a compliant shield, 82% needed a shield added or painting of an existing shield, 13% needed a shield added and the angle of the light to be changed, and 3% needed the fixture to be removed. In Patillas, we were not able to conduct an inventory evaluation as thorough as in Isla Verde due to time constraints, however we were able to determine if light fixtures were not in compliance by shielding and the angle of the light. Of the 130 lights assessed, 25% were determined to be possibly compliant and 75% were noncompliant. We ultimately determined that most of the lights found in both communities were noncompliant with the law and needed to be modified.

After we edited our survey questions, the survey was translated into Spanish with the help of our sponsors at the Junta de Calidad Ambiental. Our final survey gathered information about the age groups of the respondents, their role in the community, their level of knowledge about the light regulation, the willingness of the community members to modify their own exterior light fixtures, and the amount of money that they were willing to spend on these modifications. The survey was distributed through a direct link on a piece of paper as well as physical hard copies of the survey on a clipboard. We walked around the community of Isla Verde and tried to get responses from different age groups and community members so that we would have a variety of answers.

Once we had all the survey responses, we formed conclusions regarding the level of knowledge the public had about the light regulations, the modifications we needed to design, and the information to include in our educational material for the community. We concluded that about half of the respondents did not know about or understand the light regulations. Many of the respondents were willing to modify their lighting fixtures, and the most popular modifications

were angling the light downwards and away from the property line, changing the bulb color and intensity, and using an automatic timer to turn the lights off when they were not in use. The main factors that persuaded community members to consider modifying their exterior lighting were to avoid receiving a fine, help protect an endangered species, and to save money on energy costs.

After the inventory was created and the survey responses were analyzed, we were able to construct our educational brochure and guide. The brochure was a double sided tri-fold which included information about the light regulations that pertain to the beach areas that sea turtles are found on, as well as an explanation about how sea turtles are affected by light pollution. The brochure also included before and after pictures of modifications that we created on the four most common light fixtures that were found. The pictures were followed by the materials that were used to create the modifications along with the average cost. The educational guide is a little longer than the brochure because it goes into more depth about the negative effects of light pollution on the sea turtles, step by step instructions on how to create modifications, and resources that community members can use to learn more about light pollution, sea turtles, and the steps they can individually take to help reduce light pollution.

Recommendations

It is evident from our investigations in Isla Verde and Patillas that the vast majority of light fixtures do not meet the requirements defined by the law and regulation in effect. There are many factors that contribute to this lack of compliance and awareness including general awareness of the law and monetary implications on owners. Therefore, the following recommendations are geared toward taking steps to resolve these issues.

1. *We recommend targeting the lighting suppliers to push for more compliant lighting fixtures and modification options.* Based on our findings, we have determined that there are significantly more noncompliant light fixtures available contrary to compliant ones. Modification pieces available for purchase are sparse. If the market was influenced toward the production of more compliant options, then it would be much easier and simpler for people to abide by the requirements of the law. This is a world-wide initiative and we realize that major transitions would need to take place. Therefore, we propose a preliminary step in an effort to make people more aware of the regulation by making informational pamphlets available throughout lighting aisles in hardware stores. We attended a local hardware store to purchase test lights and could not find any information on compliant lighting or even International Dark Sky information. By targeting the source where community members seek the product, we believe the awareness of the lighting problems will drastically increase.
2. *We recommend community outreach through kiosks and educational programs implemented in the schooling system.* Similar to the informational hut that exists in phase 1 of Isla Verde, other locations could benefit from the utilization of booths where associates and/or volunteers could distribute brochures and guides alike the ones we developed. Many residents do not have the means to purchase brand new lighting fixtures that are compliant, so it is important for people to be aware that there are affordable, do-it-yourself options. Another outlet for information is schools. Kids are already there for the purpose of learning so it is a justified location to inform people about the regulation. We believe all ages can understand the implications of the law and the positive effects it

has on the environment. For this reason, we intend that programs can be implemented in elementary through high school levels.

Authorship

The distribution of work is described as follows but our entire team of four worked through all of the proofreading/editing as a group. The organization of the paper and set up was agreed upon and executed as a team. The abstract, executive summary, authorship, acknowledgements, and “Introduction” were written by Liam, all four of us collectively, Liam, blank, and RiAnna respectively.

Regarding the background, “Light Pollution”, “Sky Glow”, “Light Trespass”, and “Legislation Regarding Light Pollution” were primarily written by RiAnna. “Impacts of Light Pollution”, “Ecological Effects On Species”, “Sea Turtles”, and all of the subsections within “Sea Turtles” were primarily written by Liam. The introduction to the background, “The Communities” and “Increasing Community Awareness” were primarily written by Celeste. “Light Pollution Initiatives”, “International Efforts”, “Related Projects”, and “Junta de Calidad Ambiental” were primarily written by Maria.

Regarding the methodology, both RiAnna and Celeste wrote the introduction to the chapter. “Measuring Light Levels” was primarily written by RiAnna. “Inventory Evaluation” and “Modifying Light Fixtures” were primarily written by Liam. “Final Deliverables” was primarily written by Celeste. “Survey Logistics” and “Survey Questions” were primarily written by Maria.

Regarding the results and analysis, “Inventory” was primarily written by RiAnna. “Simple Modifications” was primarily written by Liam. The introduction to the results and analysis chapter as well as “Brochure, Guide, and Presentation” were primarily written by Celeste. “SQM Light Levels” was primarily written by Maria. “Survey” was written by Maria, Liam, and Celeste collectively. “Conclusions and Recommendations” was also primarily written by RiAnna.

Regarding other various work, RiAnna was primarily responsible for most of the inventory data as well as the entire analysis of the inventory. Liam was primarily responsible for creating diagrams and visuals, translating the survey, and major edits made to the background and methodology chapters. Celeste was primarily responsible for creating the brochure and guide as well as major edits made to the methodology chapter. Maria was primarily responsible for taking the photos of the light fixtures and buildings. The team as a whole distributed the surveys.

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1.0 Introduction

As the global population increases, so does the use of artificial light. While artificial light is common globally, very few people consider the effect of light on the environment. Light pollution is defined as “the inappropriate or excessive use of artificial light which has a disruptive effect on natural cycles” (“Light Pollution”, 2016). One glaring disruption of a natural cycle occurs in Puerto Rico where light pollution is essentially causing the deaths of many newly hatched sea turtles due to their false sense of the direction of the ocean (Klinkenborg, 2008). Not only does light pollution have negative effects on ecosystems, but it also negatively impacts human health. Light pollution contributes to many health complications and defects including the suppression of melatonin production which is the main hormone that regulates the sleep cycle (“Human Health”, 2014).

There are many organizations that are taking steps to control and reduce light pollution which involves educating communities. For instance, the International Dark Sky (IDA) has compiled a set of regulations and if these regulations were followed then sea turtles would not be misguided to the safety of the ocean. However, Puerto Rico's light pollution is still in the process of becoming compliant after a law was passed in 2008 which outlines many of the same regulations as the IDA (No. 218, 2008). This project specifically looks at the light pollution in Puerto Rico and the government’s actions to create and implement a protocol for controlling and modifying coastal light fixtures.

It is important to understand the monetary impact of implementing a lighting protocol. The Junta de Calidad Ambiental (JCA), an environmentally focused agency, has found that although a law was passed regarding the regulation of light fixtures, people do not have the

necessary funds to modify their private and/or public lighting (Alicea Pou, personal communication, September, 12, 2016). In previous years, Worcester Polytechnic Institute project teams assessed the light levels on the coast of a Puerto Rican beach called Isla Verde. From their findings, it was concluded that there were some lighting fixtures that could not be modified because security lighting was necessary in some public areas (Gabriel, Greenbaum, Holmes & Ouellette, 2014). Therefore, it is crucial to take into consideration the purpose of the lighting when assessing lights within compliance and to assure people that the modifications are having a positive impact on their community and environment.

The main goal of this project is to evaluate existing exterior lighting practices in properties adjacent to different coastal sea turtle habitats and to recommend modifying options to reduce light pollution at those locations. Also, we will provide educational outreach to the communities near the affected ecosystems in an effort to help protect the sea turtle arrivals and departures during their nesting on the coasts of Puerto Rico. Because of time constraints, the entire Puerto Rican coast cannot be evaluated so Isla Verde will serve as our main focus area for data collection with a subsidiary location in Patillas. We have outlined four key objectives to be executed. The first objective is to create an inventory of light fixtures visible from the coast including contributing factors such as color, angle, and shielding. The second objective is to provide the JCA with recommendations to improve lighting practices and possible modifications that can be implemented. The next objective is to survey the community to gauge their knowledge of the light regulation and their willingness to modify existing lighting fixtures. The final objective is to create an educational guide on current light pollution issues affecting sea turtles and simple modifications of light fixtures than can help decrease light pollution levels. The Junta de Calidad Ambiental (JCA) and the Departamento de Recursos Naturales y

Ambientales (DRNA) can distribute this guide to the community to aid in the transition to acceptable light fixtures to improve ecosystems and human health.

2.0 Background

This chapter outlines how light pollution is measured as well as light pollution legislation in Puerto Rico. This includes what kinds of guidelines are used to quantify light and what kinds of fixtures can be added to lights to reduce unnecessary emissions. The chapter also examines the impacts of light pollution on the environment with special attention to sea turtles. Specifically, the negative impacts of light pollution can encompass migration patterns, orientation disruption, and interactions with other species. The chapter also discusses the best practices on educating and raising awareness in communities. Lastly, the chapter provides an overview of the project's connection with the community of Isla Verde and Patillas.

2.1 Light Pollution

The International Dark-Sky Association (IDA) categorizes light pollution into the following four categories: glare, skyglow, light trespass, and clutter (See Glossary for definitions) ("Light Pollution," 2016). All four categories are the result of artificial lighting practices during the nighttime. Skyglow is the most overarching of the categories referenced in discussion about light pollution. It results from the upward illumination of artificial light sources such as car headlights, billboards, and street lamps. Light trespass is also known as spill light which means that the light exceeds and spills past necessary boundaries of a given light source.

2.1.1 Skyglow

Puerto Rico has higher levels of skyglow compared to surrounding islands in the Caribbean Ocean as depicted in Figure 1 below (Falchi et al., 2016). Skyglow is easily measured

(via satellites) and has the most negative effects such as limiting sky and star exploration by astronomers and disrupting mammal day-night cycles.

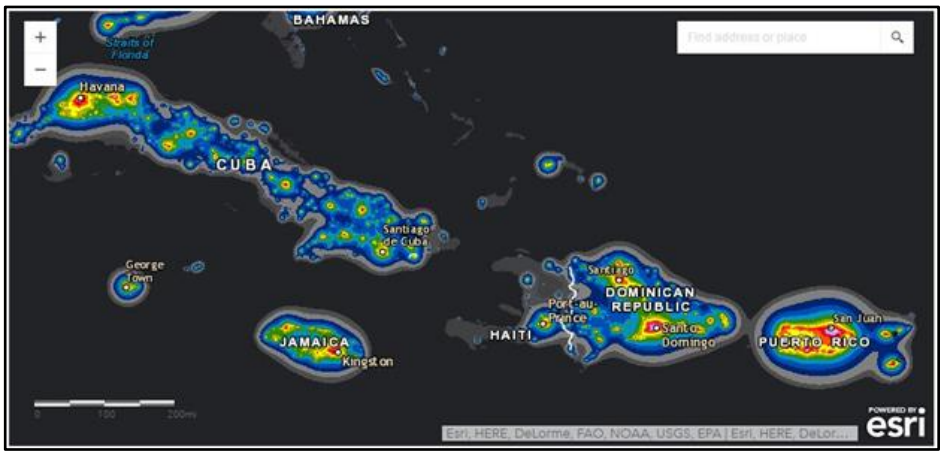


Figure 1: Light Pollution in the Caribbean

Red, yellow, and blue areas are considered to have high, moderate, and low levels of light pollutions respectively. Puerto Rico has the highest levels of the main Caribbean islands.

(Source: Falchi et al., 2016)

In heavily populated areas, skyglow is inevitable for basic living and security reasons. Therefore, the IDA proposes five lighting zones ranging from "No Ambient Lighting" to "High Ambient Lighting" (See Glossary for definitions) to differentiate guidelines that take into consideration populous areas. Within these five zones, there are allowable levels of backlight, uplight, and glare, which the Illuminating Engineering Society (IES) has simplified to BUG. The IES is an organization that conducts research and investigations to provide communities with information and recommendations about lighting practices. Uplight is the main focus of the BUG system because this light is emitted directly up into the sky and it is the greatest contributor to skyglow. Small amounts of uplight are only allowed in highly populated areas which are classified as moderately high and high ambient lighting zones. The other three zones allow no uplight ("Model Lighting Ordinance," 2011). While the IDA zones are not regulated by law, many governments and organizations are adopting this model in an effort to reduce light

pollution. In Figure 2 below, the left side depicts a high amount of skyglow and the right side depicts very little to no sky glow. For more visual examples of skyglow, see Figure 3 and Figure 4 in Appendix A.

Figure 2: Skyglow Before and During a Power Outage
Without the effects of artificial lighting, stars are much more visible and sky quality is improved.
(Source: "Light Pollution", 2016)

2.1.2 Light Trespass

The current lighting practices from residences and commercial businesses near the shores in Puerto Rico need to be reduced to preserve the natural darkness of those ecosystems. Light trespass is the main contributor to unnecessary coastal lighting that invades naturally dark habitats. In some cases, lights that illuminate in excess of their necessary boundaries cannot be eliminated but can be modified to lower light brightness or redirect the light toward the intended area. Figure 5 below gives examples of acceptable and unacceptable light fixtures as defined by the IDA ("Outdoor Lighting Basics," 2016).

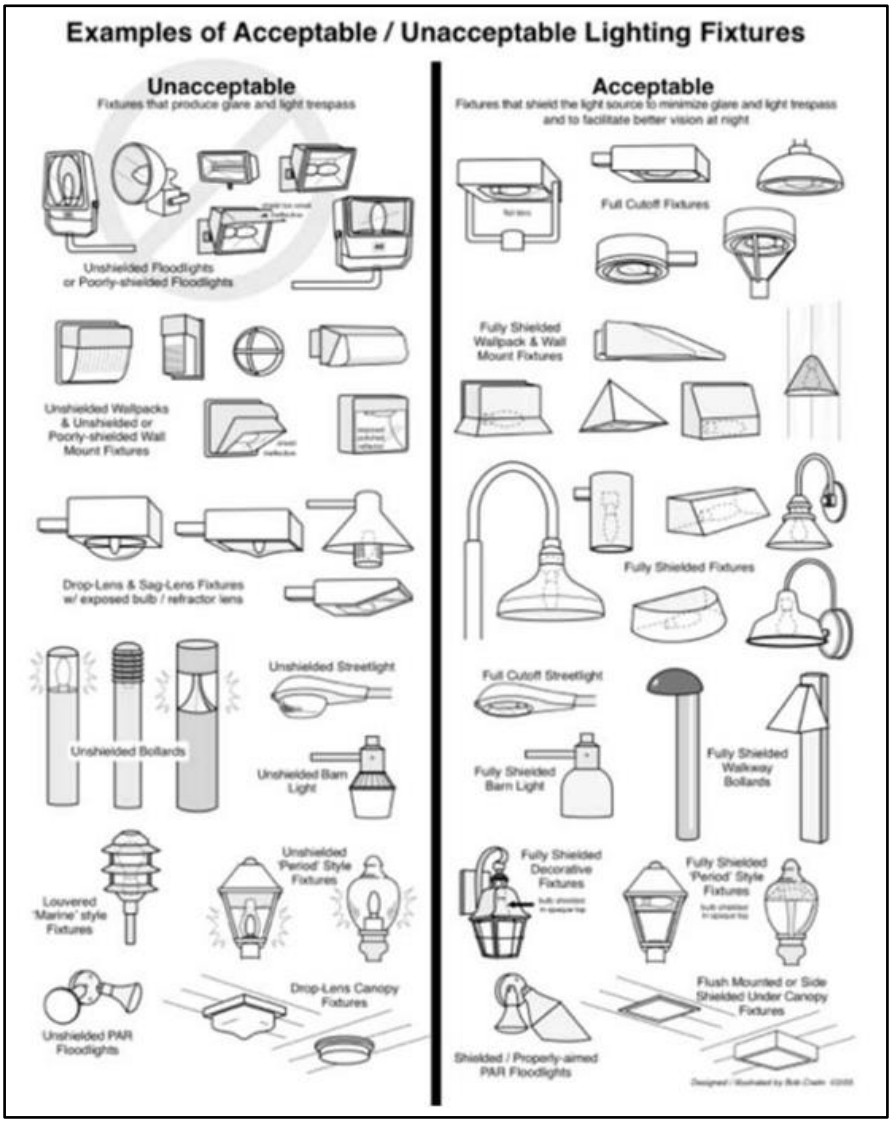


Figure 5: Acceptable and Unacceptable Lighting Fixture Examples
(Source: "Outdoor Lighting Basics," 2016)

The common element of the acceptable light fixtures is that the light is focused by some sort of shade or cover that directs the light downward to a confined area. The direction of the light is important as well as the hue of the light. Blue tones of light are the worst contributors of light pollution. Orange and red tones are the more preferred hues on the color spectrum because they have a longer wavelength which means the light does not spill past boundaries as far. LED and metal halides have the bluest tones and are the least desirable in terms of light pollution.

However, LEDs are long lasting and energy efficient which make them desirable to consumers because they reduce cost ("Lighting Choices to Save You Money," 2012). Color, size, and direction of light all matter when evaluating contributors of light trespass. While certain types of light bulbs are more desirable than others, shades or covers that can be placed over lights to concentrate light on the ground are less expensive than replacing the light completely and reduce light trespass as well. The reduction of light trespass in turn decreases the intrusion on ecosystems (Alicea Pou, personal communication, September 12, 2016). Figure 6 below shows an example of how light trespass of a lighting fixture affects its surroundings. For more visual examples of light trespass, see Figure 7 and Figure 8 in Appendix A.

Figure 6: Light Trespass in a Residential Area

The illumination from the street light intrudes into unintended areas such as the patio of the nearby home and potentially through windows.

(Source: "My Neighbor's Lighting," 2015)

2.2 Impacts of Light Pollution

Light is a way for humans to have better vision at night but improper and excessive lighting fixtures are damaging to the environment. Typically for humans, the sunrise and sunset mark the start and end of the day but for some species the sunset is their “alarm” to begin their typical day. Each organism on Earth has developed a day-night illumination schedule during which necessary biological activities are completed but this complies with natural lighting. Light pollution can disrupt these functionalities, altering and interfering with their circadian clock (Department of Physics, Florida Atlantic University).

The word pollution has such a negative connotation that positive effects are rarely considered, however this is not always the case. From a study done in Scotland summarized by Aldred (2012), the artificial light at night can aid birds with finding food. Typically, birds will locate food by sight during the day and by touch during the night. However with artificial lighting, birds have the capability to use sight at night to locate food, allowing them to stock up on more food for their spring flight. Especially during the winter, the birds must use daylight productively to find enough food but with artificial lighting from the oil refineries and power stations, birds are able to feed more efficiently at night (Aldred, 2012).

Although it has had some positive effects for birds, they are also one of the victims of light pollution along with frogs, moths, and sea turtles (Department of Physics, Florida Atlantic University). Using the moon and stars as a navigational tool, birds migrate at night biannually but become disoriented around brightly lit areas. When birds are lost in the light, they may collide into towers or buildings or drop out of the sky due to the exhaustive circling (Guynup, 2003). Frogs deter from calling mates while in the presence of bright artificial lights (Wise,

2007). Since moths are attracted to the artificial lights, they become disoriented, exhausted, and lose their defensive behaviors leading them to be killed by predators (DeVries, 2003). Female sea turtles will refrain from nesting in brightly lit areas, resorting to less than optimal nest conditions ("Information about sea turtles: Threats from artificial lighting", 2015).

Just like with some species of animals, trees, cactuses, and others types of plants use the sunlight as their biological clock to either start or stop their daily processes. For trees, sunlight triggers their photosynthesis cycle, which is when trees convert the wavelengths from the sun to a chemical form in sugars that trees use as food (Chaney, 2002). Although many trees are not drastically affected by the intensity of night lighting, some trees can be affected if they are sensitive to day length. The extended day length from night lighting can influence flowering patterns and disrupts the seasonal cycle of trees ("Outdoor Lighting Basics", 2016). The continued growth throughout the seasons will prevent trees from developing dormancy, which allows the trees to survive the winter weather. In addition, continuous lighting as opposed to lighting that is turned on and off can be more dangerous. The trees grown in continuous lighting may have a large foliage but they are more susceptible to air pollution due to a larger surface area of their leaves (Chaney, 2002).

Light pollution also affects the coastal ecosystems for sea turtles. Sea turtles use the natural light from the moon and stars to find their way back to the ocean from beaches. Without artificial light, the ocean ends being the brightest area seen from the coast. However, on many of the coastal locations in Puerto Rico there are high levels of artificial light. Therefore, the turtles end up going towards the brighter lights (Diez, personal communication, November 3, 2016).

2.3 Ecological Effects on Species

When species experience orientation disruption from artificial lighting, their visual cues that help with navigation can be influenced and cause confusion rather than clarity. For example, as sea turtles hatch, they are instinctively attracted to the moonlight that is reflecting off of the water (Alicea Pou, personal communication, September 27, 2016). Their visual cues come from the darkness and shadows created by the grasses and bushes from inland and the hatchlings move away from the dark and towards the ocean. Because of the artificial lighting, the shadows and darkness are not created and the hatchlings become disoriented (Depledge, 2010). When females arrive on shore to nest, they will often deter from areas that are lit and nest in areas which are dark. Since the overall temperature of the sand determines the sex of the turtles, having continuous light shining on areas of the sand could disrupt the distribution of sexes (Howell, 2013).

Creating an ecological trap for moths, light pollution has a negative impact on the interaction between species. Because moths are attracted to sites with high levels of light pollution, they become vulnerable to their predators (Grenis, 2016). While circling the light, moths will tire themselves out and may fall to their death. But while in the light, they expose themselves to bats, owls, and some birds. Also suggested by Grenis, “light pollution induces direct consequences for larvae and indirect negative effects on larvae mediated through changes to host plant quality induced by light pollution” (Grenis, 2016). Essentially Grenis is saying that because of light pollution, moths and larvae are directly affected in a negative way, therefore the population is being affected.

Frogs and salamanders are also affected by light pollution because artificial night lighting deters frogs from being selective and cause salamanders to reveal themselves, giving them less time to mate. When light levels are increased, female frogs will choose a mate quickly and be less selective because they want to avoid the increased chance of coming across a predator. The less selective process can cause a less than optimal mate leading to less diversity in frogs. Salamanders also want to avoid predators, so light pollution gives them less time to mate to increase their survival (Walker, 2008).

2.4 Sea Turtles

As one of Earth's most ancient species, sea turtles have existed for about 110 million years. Different from other turtles, sea turtles do not have the ability to retract their legs and head into their shells. Varying from greenish-yellow to black depending on the species, the shell of sea turtles is streamlined which allows them to swim through the water. Sea turtles can be found worldwide in warm and temperate waters, migrating hundreds of miles between nesting and feeding grounds. Because sea turtles live predominantly in solidarity, the only interaction with others is when it comes time to mate (Defenders of Wildlife, 2016).

The reproductive behavior of many animals has been influenced by artificial lighting but it has especially impacted sea turtles. Male and female turtles will court either on the surface or underneath the water and the female sea turtle will then come to the shore. Females will often avoid well-lit areas and nest on dark areas of the beach (Information about sea turtles: General behavior, 2015). As summarized by Howell, the "night lights estimated with satellite-based imagery can be used to explain sea turtle nesting activity over a large-scale area" (Howell, 2013). The images depict areas with high levels of light and turtles have refrained from nesting in those

areas (Howell, 2013). The female then proceeds through a process of digging the nest by carefully constructing it in a dry area of the beach. After 80-120 eggs are laid in the nest, she will fill it in with sand, disguising the nest by throwing sand in all different directions ("Information About Sea Turtles: General Behavior," 2015).

As an instinct, the hatchlings will move toward the reflective sea horizon but when they hatch in brightly lit beaches, they often find themselves confused due to the artificial lighting (Klinkenborg, 2008). The hatchlings that head inland to the artificial lights either die from predation, dehydration, wandering into traffic, or by drowning in swimming pools ("Information About Sea Turtles: Threats From Artificial Lighting," 2015).

All species of sea turtles are affected by artificial light. For example, nesting adult green turtles and hawksbill turtles prefer darker beaches because they are more susceptible to movements and shadows in the environment. However, when it comes to returning back to the ocean, all species are affected by artificial lights (Diez, personal communication, November 3, 2016).

2.4.1 Types of Sea Turtles in Puerto Rico

Worldwide, there are seven different species of sea turtles but the Isla Verde and Patillas coastal areas of Puerto Rico are habitat to three. The most common species found along these beaches are leatherback sea turtles but green and hawksbill sea turtles are found as well. In other areas of Puerto Rico, the green and hawksbill sea turtles are just as common as the leatherback sea turtles (Diez, personal communication, November 3, 2016).

In the uninhabited areas with little or no disturbances from humans, the inland side is dark and the hatchlings are able to find the reflection of the moon off of the water. In general, sea

turtles are the motivator to reduce light pollution because of the noticeable effects that it has on the nesting and hatchlings (Diez, personal communication, November 3, 2016). As described previously, sea turtles can suffer from the negative impacts of light pollution from artificial lighting. The following sections include the discussion of natural habitats, nesting habits, population threats, and conservation efforts for the leatherback, green, and hawksbill sea turtles.

2.4.2 Leatherback Sea Turtles

The leatherback sea turtle (see Figure 9 below) is the largest-sized species of turtles in the world with some adults reaching up to 2000 pounds (900 kg). Leatherbacks are typically found in open waters but also forage in some coastal waters. With a high oil content and large body size, they are able to migrate into colder waters, some as north as Newfoundland. For the duration of their nesting season, females will lay clutches of approximately 100 eggs at about 8 to 12 day intervals, migrating back to their respective nesting areas every two or three years.

Figure 9: Leatherback Sea Turtle
(Source: https://upload.wikimedia.org/wikipedia/commons/f/fc/Leatherback_sea_turtle_Tinglar,_USVI_(5839996547).jpg)

As for most turtles, incidental capture in fishing gear is a major threat as well as the harvest of the eggs, hatchlings, and adults. Additional threats include environmental contamination, degradation of nesting habitats, and artificial lighting. Due to the wide migratory behavior, leatherbacks are protected worldwide through the prohibition of international trade, regulatory efforts with their critical habitat, and the regulation of fishing equipment ("Leatherback Turtle (dermochelys coriacea)," 2016). Figure 10 in Appendix A depicts an entire fact sheet about leatherback sea turtles.

2.4.3 Green Sea Turtles

The green sea turtle (see Figure 11 below) has a small head compared to its large, hard shell and is the only sea turtle whose diet is strictly composed of plants. Green turtles are primarily found along beaches for nesting, the convergence zones in the open ocean, and the coastal areas for feeding. Females will return to their natal beaches every two to four years for nesting, typically between June and September. With an average of 135 eggs per clutch, the female nests about five times throughout the nesting season.

Figure 11: Green Sea Turtle
(Source: https://c2.staticflickr.com/4/3745/10424741433_a3af5be28d_b.jpg)

In addition to the common threats to sea turtles as previously described, green turtles also have the danger of catching fibropapillomatosis which is a disease characterized by tumorous growths interfering with feeding and essential behaviors. After being enlisted as an endangered species in 1978, green turtles are protected by national and state laws which include efforts to modify oceanic gear, changes to fishing practices, and closing beaches during certain times and areas ("Green Turtles (chelonia mydas)," 2016). Figure 12 in Appendix A depicts an entire fact sheet about green sea turtles.

2.4.4 Hawksbill Sea Turtles

Unlike the leatherback and green sea turtles, the hawksbill turtle (see Figure 13 below) is one of the smaller sized sea turtles species weighing in between 100 and 150 pounds. Although they move through different habitats in their life, they can mostly be found in healthy coral reefs. Like the green turtles, hawksbill females will return to their natal nesting grounds, every two to three years at night and will lay a clutch about every 14 to 16 days.

Figure 13: Hawksbill Sea Turtle
(Source: https://c2.staticflickr.com/4/3554/5840602412_40488f3f8f_b.jpg)

In addition to threats described previously, the hawksbill turtles are also threatened by the loss of coral reef communities and the increase in recreational and commercial use of their nesting grounds. Regarding conservation efforts, the modifications of oceanic gear and concerns about their habitat listed above are also used for hawksbill sea turtles ("Hawksbill turtle (eretmochelys imbricate)," 2014). Figure 14 in Appendix A depicts an entire fact sheet about hawksbill sea turtles.

2.4.5 Sea Turtles and the Ecosystems

As with all animals, sea turtles are important to the ecosystem of marine life because some species feed on the grasses and other organisms like jellyfish and sponges, which keep the ecosystem in balance (Diez, personal communication, November 3, 2016). Sea turtles graze on seagrass and keep the grass short which helps maintain the health of the seagrass beds. These beds are important because they are grounds for many breeding and developmental sites of fish, shellfish, and crustaceans. Without these seagrass beds, the marine species would be disrupted along with lower levels in the food chain. Sea turtles also play a role in the sand and dunes ecosystem because the nutrients in the sand along nesting communities come from turtles. The unhatched eggs, trapped hatchlings, and decoy eggs all provide nutrients to the sand and help strengthen the roots of the grass. This ecosystem is also healthier and with the roots, less erosion will occur ("Information about sea turtles: Why care?", 2015).

Sea turtles are not the only concern about light pollution's effects but are rather just one beneficiary. Reducing or eliminating the light pollution in the coastal areas would also be beneficial to frogs, moths, and birds. These dark time coastal ecosystems and others are majorly affected by light pollution because it could be changing the composition of marine invertebrate

communities. Because the larvae of marine invertebrates are guided by the light as they search for suitable habitats for growth and reproduction, artificial nighttime lighting both suppresses and encourages colonization. This could cause several species in unwanted places and it could also alter their abundance ("Coastal light pollution disturbs marine animals, new study shows", 2015).

2.5 The Communities

Isla Verde is a small island north of Punta El Medio and to the east of San Juan and is just one representative area of Puerto Rican beaches and coastal areas as a whole (See Figure 15 below). Resorts, high-rise apartments, guesthouses, restaurants, nightclubs, mansions, and even an airport are all located in the Isla Verde beach area. There are many tourist attractions in and around the area, and it is often filled with people and crowded on weekends. It is important to know how populated the area is because when the population data, or the density of people in the community, is paired with light scattering models, a more accurate account of lighting at night can be created (Albers, Duriscoe). This data can be used to indicate which locations of Isla Verde are emitting the highest levels of light pollution.

Figure 15: Google Map of Isla Verde

The actual island of Isla Verde was not assessed as part of the project. The adjacent beach areas extending from either side of Punta El Medio were a test site.

(Source: https://www.google.com/maps/@18.4449457,-66.016243,17z)

Patillas is also another representation of a different type of coastal community of Puerto Rico but it is fairly different from Isla Verde. The coast of interest (Figure 16 in Appendix A) primarily has one-story residences with minimal restaurants and hotels whereas Isla Verde has many high storied hotels and is very densely populated. The actual "sand area" in Patillas is visibly less than that of Isla Verde and there are many more rocks in the water as well as trees and vegetation along the beach. All of these attributes contribute to the differences between Patillas and Isla Verde. Figure 17 below shows the relationship in location between Patillas and Isla Verde.

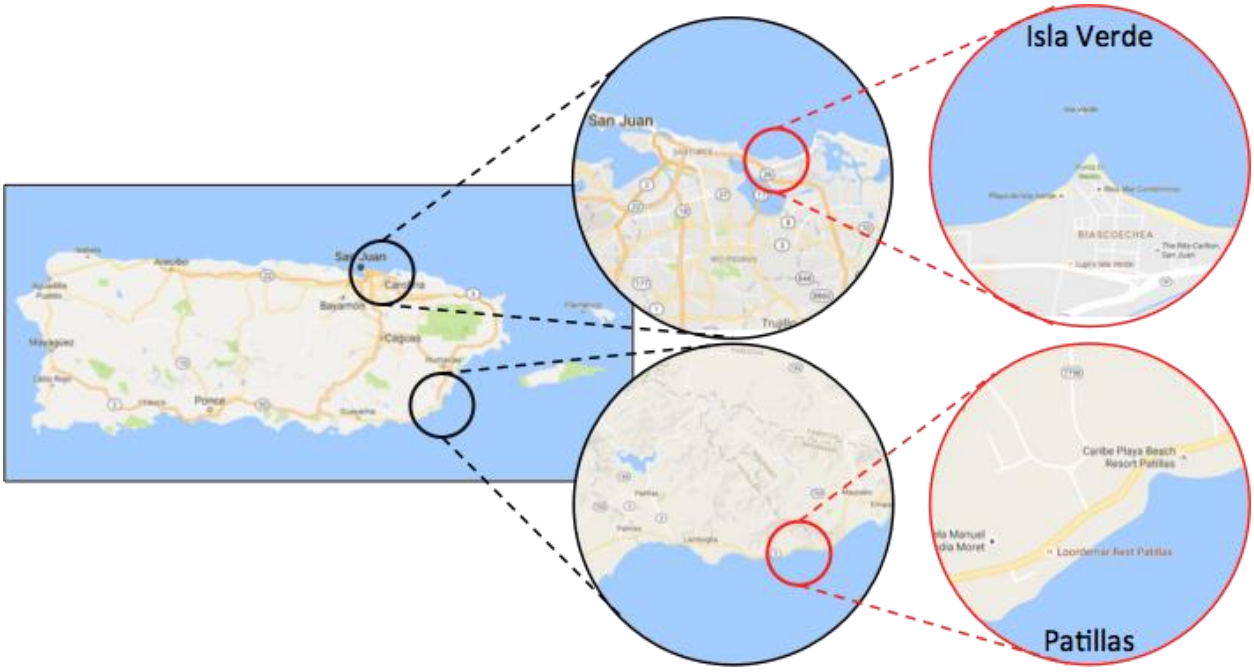


Figure 17: Isla Verde and Patillas in Relation to Puerto Rico
(Source: Adapted from Google Maps)

2.5.1 Increasing Community Awareness

There are many different methods to increasing the awareness of light pollution and its effect on the environment. For example, a 2014 WPI project team made an informational brochure to provide personalized data to the community and to, hopefully, make the reader more aware of how they could contribute to regulating light pollution. The 2014 team decided that the easiest way to condense the information was to divide the brochure into three sections: “Lighting Practices in [Region]”, “Light Pollution in [Region]”, and “Changing our Habits”. These basic categories could be implemented in any coastal region, not just for Isla Verde in Puerto Rico (Gabriel, Greenbaum, Holmes & Ouellette, 2014).

The first section of the brochure, “Impacts on Ecosystem”, described the particular impacts caused by light pollution in the specific region to the ecosystem (Figure 18a in Appendix A). On the title page, “Lighting Practices in Isla Verde”, there was an explanation of the program

that measured light levels in a certain area and identified whether or not that area met lighting standards (Figure 18a in Appendix A). The second page of the brochure, seen in Figure 18b in Appendix A, described what light pollution is and the kinds of regulations La Junta de Calidad Ambiental (JCA) created for the location. The next section of the brochure, "Lighting Practices in [Region]", used inventory data to describe the region's current lighting habits. This section also included data about the lighting practices, such as classification types, levels of shielding, bulb types, and automatic shut-off (Gabriel et. al. 2014). However, this brochure was distributed to very few individuals, and most of them were tourists.

The 2014 WPI Team also suggested creating a stargazing tour for the community. It included two components: an educational information session and a night sky tour. The tour would attract community members to participate in the program. The information session focused on the effects of light pollution specific to the location. In addition, it taught the community practices that they could implement to reduce light pollution while also making it appealing to all ages (Gabriel et al., 2014).

There are many factors that influence the magnitude of outdoor lighting. These factors include the growth rate of the population, the evolution of zoning practices and the suburban sprawl rate, the popularity of public transportation, changes in lighting technology, and esthetic and protective policies that governments might adopt which will have some bearing on light pollution (Reigle, K. 1973). These factors are applicable to many different environments and locations and they are the fundamental components for lighting ordinances. The International Dark-Sky Association (IDA) has been collecting lighting ordinances from all the U.S. states, as well as from many countries. There is also a Directory of Lighting Ordinances by state and country on their website. The IDA plans to use all of this information to create one large Model

Lighting Ordinance. From this master lighting ordinance, the vision is that the states would be able to start regulating the illumination from cities which would allow the municipal governments to determine how to meet those limits (Berg, R. 2009). For example, the governments in Bangor, Maine and Plano, Texas have implemented similar lighting ordinances. Both locations require that the owners of large properties must prove that illumination from their lights do not go past their property lines. There are also limits on duration of lighting and requirements of full horizontal shielding (Berg, R. 2009).

2.6 Light Pollution Initiatives

All over the world there have been different initiatives, organizations, and government agencies whom have been working hard to reduce light pollution where possible. From simply modifying current lighting fixtures to replacing the lighting fixtures to removing the lighting fixtures, everything has been conducted in effort to reduce the light pollution. These past projects have contributed to a greater understanding of light pollution and how it can be reduced.

2.6.1 International Efforts

There have been some initiatives outside of the United States to try to educate the global population about light pollution and encourage them to become more involved in the observation of light levels around them. One successful initiative is Globe at Night, an international citizen scientist project, whose goal is to increase awareness about light pollution to the general public. This campaign allows anyone to collect data by measuring their night sky brightness and then electronically submit their results (Globe at Night, 2016). Users measure night sky brightness in their location around 8pm-10pm and then match their observations to one of the seven magnitude

charts found on the Globe at Night website. Besides measuring night sky brightness, cloud cover, location, date and time at a specific location can also be recorded on the website. As of August 2016, there have been over 155,000 measurements from 139 countries recorded each month since 2006 (Globe at Night, 2016). Measurements of light pollution were used to create an interactive map, which anyone can access, showing the light pollution levels worldwide. The levels are measured using a limiting magnitude scale from zero to seven. A zero represents the greatest levels of light pollution in an area and a seven represents the lowest levels of light pollution in an area (Globe at Night, 2016). A seven is represented as a dark, dark red and a zero is represented as a light, light yellow. The readings are then displayed on the website on their virtual map and appear as colored dots to indicate the light level in the specific location (see Figure 19a and 19b below).

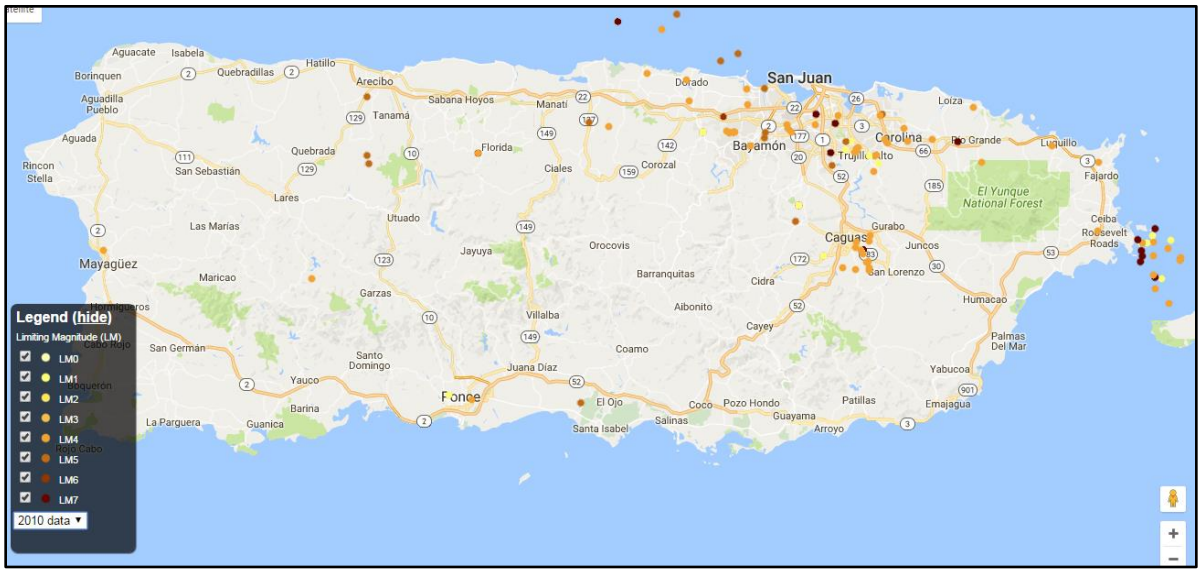


Figure 19a: Map of Puerto Rico showing a decrease in light levels in 2010

The dots displayed on the map signify locations where light pollution measurements were taken. The light yellow dots indicate high levels of light pollution and red dots indicate low levels.

(Source: http://www.globeatnight.org/map/)

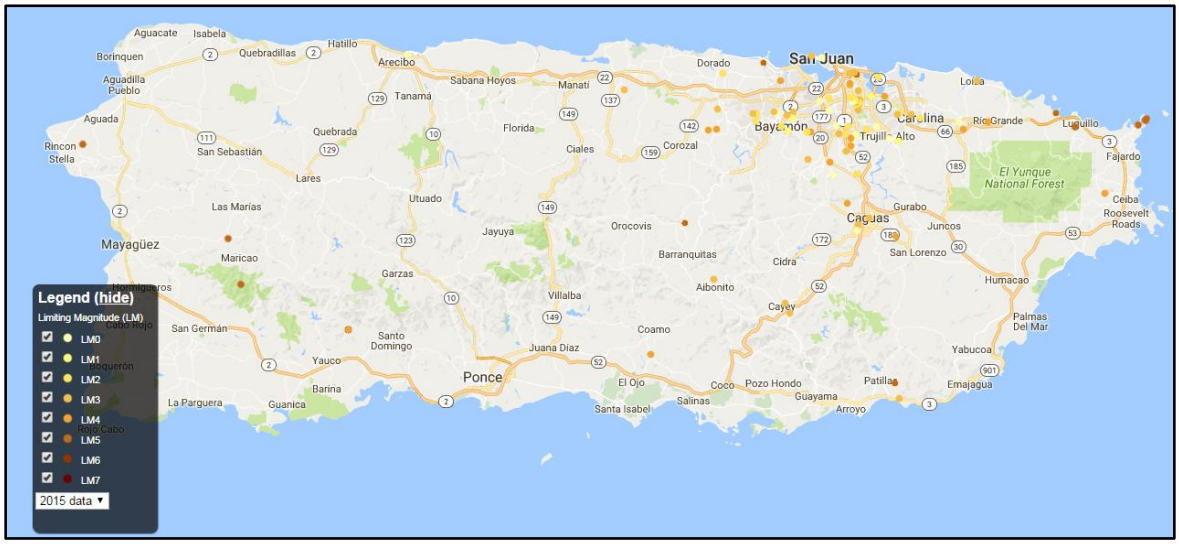


Figure 19b: Map of Puerto Rico showing light levels in 2015

There are hardly any red dots observed in the map which indicates that there are fewer areas of good sky quality.

(Source: http://www.globeatnight.org/map/)

The campaign that Globe at Night started has been successful due to its emphasis on trying to get everyone around the world to be active and aware about light pollution, through encouragement of actively reporting data and observing light levels.

Another international outreach effort is a collaboration between the IDA and the International Astronomical Union (IAU) Commission 50. These two groups came together in the early 2000s to work on a better way to educate the public on the effects of light pollution, with a focus on educating students all over the world. They created a program that encouraged a focus of educating students through teaching them about physics, astronomy, technology and the environment (Metaxa, 2013). To implement this program, the IDA and IAU Commission 50 went to schools to all over the world, noting in particular Greece and Chile, to educate teachers and students about light pollution and related fields. In Greece, the program was first tested from 1997-1999 (Metaxa, 2013). The initial test program led to the revision of the main goals which include: focusing more on training teachers the material needed to educate students on light

pollution, interacting with the IAU to connect with other teachers around the world, connecting teachers to projects focusing on light pollution and related subjects, and have the IDA continuing to help outline ways for teachers to incorporate teaching about light pollution in their curriculum (Metaxa, 2013).

As a result of reaching these goals, Chile and other countries around the world were noted to have some of the best outcomes from the program. In Chile, students were taught about light pollution in conjunction with astronomy to foster an appreciation in students for the nighttime sky. The program was extended to educate the general public to lead to the preservation of skies in national forests (Metaxa, 2013). Through the initial program to educate students and teachers about light pollution, the IDA and IAU helped set the early stages about educating and bringing awareness to the world about light pollution.

2.6.2 Related Projects

Multiple projects have been conducted in the United States, including at Worcester Polytechnic Institute. These projects focus on combating light pollution and the methods used to solve these issues. In Bar Harbor, Maine, the effects of light pollution have been studied consistently over the past few years at Acadia National Park. The Dark-Sky Project is ongoing with the first two years devoted to obtaining raw data of sky quality at the park (Carello, Carmichael, Hedberg, & Plenefisch, 2014). In 2015, the project team conducted an audit on the lighting fixtures in the park and started to keep record of what type of light fixtures were used in the area (Alsoby, Muntz, Ogren, & Sinkler, 2015). Then in 2016, the project continued to build off of "Dark Sky 2015" by collecting more data and making improvements to the light fixtures inside the park (Diamond, Jacobson, Reuter, & Shira, 2016). The findings from the groups

particularly noted that the best times to capture accurate data of light was to do it within two days before and two days after the new moon. Their findings also stressed the importance of replacing bulbs and, if needed, whole light fixtures to become compliant with local laws (Diamond, et.al, 2016).

There have also been projects conducted in Puerto Rico on the effects of light pollution in the area. Two prior projects were conducted with the JCA in 2013 and 2014. The 2013 project group was based in Old San Juan and followed a similar pattern to what was done in the Dark-Sky group with the use of Sky Quality Meter (SQM-L) devices to capture light and to collect data during nighttime (DeVries, Haring, Giambrone, & Penrose, 2013). The group had issues with collecting enough accurate data due to there being so few clear nights. They also emphasized the importance of collecting data on specific property lines to properly determine exact measurements of light trespass (DeVries, et.al, 2013). The 2014 project group continued on what the group of 2013 started, but with a focus on obtaining data from the beaches instead of inside San Juan. The group also shifted its focus towards how light pollution affected the behavior of animals like sea turtles, and how it disrupted other aspects of the beaches (Gabriel, Greenbaum, Holmes, & Ouellette, 2014). Contrasting the prior group, they made a brochure to hand out about light pollution and set up an online survey through Survey Monkey. They also had similar problems with the weather affecting their data collection and with obtaining more responses on their survey (Gabriel, et.al, 2014).

2.7 Junta de Calidad Ambiental

The Junta de Calidad Ambiental (JCA) is a governmental organization which is at the forefront of protecting the environment of Puerto Rico through means such as reducing light and

noise pollution, controlling water and air quality, and protecting the land. These concerns have been especially noticed in recent years. Organizations like the JCA were formed after the Environmental Public Policy Act of Puerto Rico. This act was passed on June 18th, 1970 and has led to the formation of the Junta de Calidad Ambiental and other environmental agencies. These agencies help combat the pollution in Puerto Rico which has led to the JCA and The Departamento de Recursos Naturales y Ambientales (DRNA) to continue to focus on certain pollution issues ("Historia de La JCA", 2016). The JCA has been working on enforcing the new law of changing light fixtures to become more environmentally friendly. To have the correct fixtures and adaptations for appropriate light levels, cheap and simple modification or replacing the fixture entirely are two viable options (Jose Alicea Pou, Personal Communication, September 12, 2016).

2.7.1 Legislation Regarding Light Pollution

Puerto Rico's government passed a law in 2008 in an effort to reduce light pollution by creating better conditions for sky exploration, decreasing utility demand, and protecting the wildlife. The following year, the governor that heavily supported the law, Anibál Acevedo Vilá, was voted out of office. In subsequent years, the focus on reducing light pollution decreased as other pollutant problems were addressed. However, in 2013, the new JCA president directed focus back on the light pollution policies. The agency has actively been enforcing the law for the past three years. One of the main focuses of this law is to reduce the negative light affecting the nighttime coastal ecosystems and the atmospheric quality.

The JCA cannot force people to replace light fixtures, but they can force people to make modifications to the fixtures to reduce light pollutants. For example, a condominium complex in

Puerto Rico painted the beach-facing portion of clear glass light covers black so that light could not escape upward. This solution eliminated possible costs of replacing the light fixtures, but still complied with the lighting standards (Alicea Pou, personal communication, September, 12, 2016). The law implemented in Puerto Rico allows twenty years for public lighting to be addressed and ten years for private/residential lighting to reach compliance. After this transitional period, the government can then force owners to replace light fixtures contrary to modifying them (No. 218, 2008). In addition to the JCA's goal to meet the requirements of the modification of light fixtures by the determined timeframes, they are also interested in expanding their light pollution efforts through the means of working to educate the general public more about light pollution. See Appendix B an English translation of Rule 13 Letter H from Law Number 218.

3.0 Methodology

The goal of this project was to partner with the Junta de Calidad Ambiental (JCA) and the Departmento de Recursos Naturales y Ambientales (DNRA) to evaluate lighting practices and modifications that reduce light pollution as well as to provide educational outreach to the community to help protect sea turtle nests on the coasts of Puerto Rico. Although the effects of light pollution on the environment and ecosystems as a whole was the overarching concern for the project, sea turtles were just one beneficiary for reducing light pollution. To start, the project involved developing and implementing a protocol for measuring light levels, creating an inventory of current light fixtures on the beach, implementing a survey to gauge the perspectives and knowledge of community members on the lighting regulations and potential modifications, and developing an educational guide for applicable light modifications. The objectives of the project were to educate the community of Isla Verde on light pollution and its adverse effects on the local environment, as well as to provide alternative lighting practices that can be implemented to current light fixtures. The Isla Verde area was broken into three different sections and we focused on each section individually. These sections were the Natural Reserve Reef (Arracife de Isla Verde), the Isla Verde Spa (Balneario de Isla Verde) and El Alambique Beach, denoted as phases 1, 2, and 3 respectively. In this project, we only assessed phase 1 as shown in Figure 20 below.

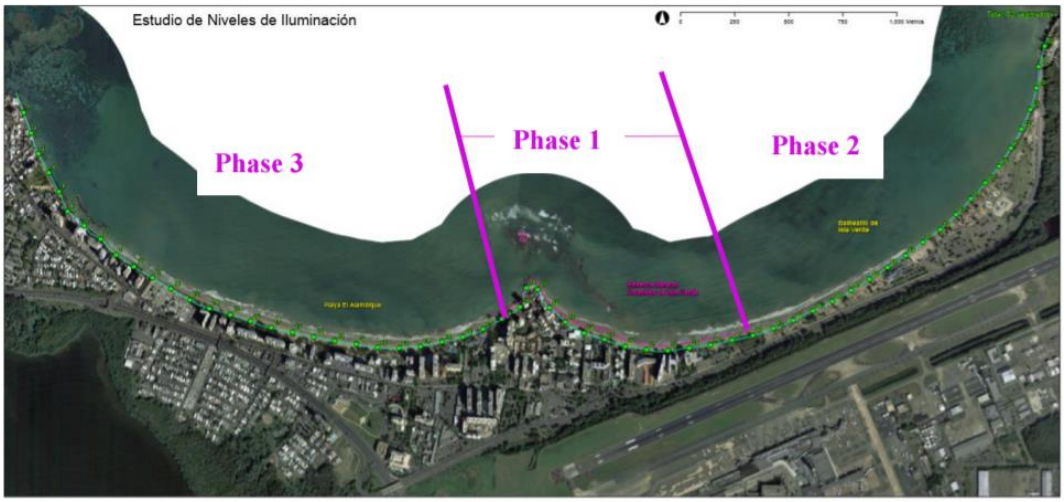


Figure 20: Three Phases of Isla Verde

The project also looked at the light fixtures on other coastal locations, such as Patillas. The initial focus of the project was the data collection, after which the data was analyzed to create the final deliverables.

3.1 Measuring Light Levels

One important piece of data we collected was the overall level of skyglow in the Isla Verde area using a Unihedron Sky Quality meter (SQM-L), depicted in Figure 21 below. The meter is user friendly and takes readings by holding the instrument up into the air and pressing a button to collect the measurement (see Figure 22 below). The units are in magnitude per square arcsecond. Because a logarithmic scale is used, only small differences in whole numbers were observed.

Figure 21: Sky Quality Meter


Figure 22: Usage of the SQM at Night

This served as a baseline that can be referenced in future years as well as a comparison to past measurements to assess whether light pollution is increasing or decreasing. Although the main data collection was not focused on measuring light levels, we collected readings along the Isla Verde coast to gather an approximate average of the light pollution.

Our protocol for measuring light was in part a modification of an existing protocol used by the JCA (Gabriel, Greenbaum, Holmes, & Ouellette, 2014), but also included additional measurements and guidelines that were not present in the existing protocol. For phase 1 we started at the westernmost point of the Natural Reef Reserve, collected a light reading, and then we walked 100 meters to collect the next reading. At each location, ten readings were taken and

averaged for the purpose of accuracy. There were approximately 20 locations for phase 1 and each location had an overall average reading.

This data collection was conducted at nighttime as artificial lights were most visible during the darkest hours. The 2014 Worcester Polytechnic Institute (WPI) IQP project team assessed 94 different points, and we analyzed their data to determine an average in units of magnitude per square arcsecond (Gabriel, Greenbaum, Holmes, & Ouellette, 2014). We then averaged our data points which presented a rough comparison in differences in light levels between the two time periods. This determined whether light pollution overall has increased or decreased in the Isla Verde area since 2014.

One problem with using an SQM was that the weather can affect the readings. Because we planned to execute this part of the data collection for phase 1 in a single night with the new moon, we took note of the current weather conditions into factor. The same protocol for using the SQM was adapted from the 2013 IQP and the 2014 project (DeVries, Haring, Giambrone, & Penrose, 2013). See Appendix C for a full explanation of the SQM protocol.

3.2 Inventory Evaluation

Our team primarily worked in the Isla Verde coastal area which is located to the east of San Juan. As previously stated, the Isla Verde coastal area was broken up into three phases and served as one representative area of Puerto Rican coasts because time did not allow us to evaluate all different coastal areas. Isla Verde is a very touristy portion of Puerto Rico with resorts, high rise apartments, guest homes, restaurants, night clubs, mansions, and an airport all scattered throughout the area. All of these locations influenced the SQM and photometer readings that were taken to compare to the 2014 IQP project team.

Because Isla Verde is actually considered to include three smaller sections of beaches all totaling about four miles of sand and water ("The beaches of Isla Verde", 2016), it was broken down into three different phases for simplicity (see Figure 23 below as well as Figures 24 and 25 in Appendix A). We covered all of phase 1, taking inventory and measurements as we moved along the beach. There was not a set number of lighting fixtures that we evaluated because it was not previously determined which fixtures could be seen along the beach. Taking an inventory of every single light fixture would have taken more time than was allotted so we took an inventory of each type of lighting fixture within each property to get a representative inventory. For example, if there were 42 identical lighting fixtures on the same property, we only assessed one and documented the quantity. We also worked in another small rural community, located in Patillas which is along the southeast part of Puerto Rico. The Patillas area we assessed was a small section of its beach coast and primarily consisted of one-story residences, which were not as clustered as the Isla Verde area. We only were able to take pictures and analyze the purpose of the lights because of time restraints and transportation difficulties.

Figure 23: Phase 1 of Isla Verde
The green dots indicate the locations where Sky Quality readings were taken.

In order to evaluate and create an inventory of the lighting fixtures in the designated area, we had to determine which fixtures could be seen from the beach-property line. Prior to evaluating the light fixtures, we assigned each type of fixture with a light identification number which corresponded to its number used in the camera. The light identification number prevented any confusion between light fixtures in our record. In addition, each light fixture had two documentary photos taken. The first photo was broad and showed the surroundings with the fixture while the second photo was more zoomed to thoroughly evaluate and identify the light fixture. When looking at each light fixture, some of the criteria evaluated included whether the light was on or off at night, the quantity of each light fixture on the property, the type of fixture, the application of the fixture, and the color of the emitted light. Additionally, we used a photometer at the property line to assess the light trespass that was polluting the beach. We developed a checklist to assist us in conducting and collecting these observations and data. See Appendix D for a complete checklist.

The primary functionality of the lights were illuminating streets, parking lots, commercial and residential areas, sidewalks, and public areas. There were three standard types of colors emitted by these light fixtures which included warm white, bright white, and orange. Additionally, there were more in depth color selections which include red, yellow, and blue. Depending on how large the light fixture was and how close it was to the beach determined how to modify it to create the least amount of light pollution. The lights must also have some sort of shielding to prevent the light from going upwards creating sky glare.

A photometer is a device that measures the intensity of light through a light sensor and display meter which are connected by a short cable. Figure 26 below shows how a photometer comes in a carrying case and how the photometer looks once it is assembled. Using the

photometer was fairly simple and involved pointing the sensor at the light fixture along the property line, waiting until the reading stabilizes, and recording the reading (Figure 27 below). A full protocol for using the photometer can be found in Appendix E.

Figure 26: Unassembled Photometer in the Carrying Case and Assembled Photometer


Figure 27: Using the Photometer at Night

Because the readings have units of foot-candles (fc), it measured the amount of light trespass and the intensity of the light. The sensor was angled so that the face of the sensor was perpendicular to the path of the light (see Figure 28 below for a better interpretation).

(a) (b)

Figure 28: Using the Photometer

In zone 8 which was described as the beach areas used by sea turtles, the law only mentioned that a property can not have a photometer reading greater than 0.05 fc. If the reading from the photometer was greater than 0.05 fc, then the fixture was contributing to the light pollution problem and needed to be modified in some way or replaced altogether. Photometer readings of every light were not taken because the law mentions properties not each light fixture. Readings were taken for the detectable lights and were averaged in order for each property to have an overall photometer reading. All properties reading greater than 0.05 fc were not in compliance with the law. To clarify which light fixtures were completely in compliance with the law, we

identified each attribute listed on the checklist to determine which fixtures needed to be replaced, which needed to be modified, and which fixtures were in compliance with the ordinance.

To reduce the light pollution, we consulted with our sponsor about their specific expectations and guidelines. To start, fixtures which were pointing up caused the largest amount of light pollution because all of the excess light directed upward was being wasted. Containing or focusing the light onto the ground and away from the sky was one of the first steps. To contain or focus the light, shields, cones, and visors were added to direct the light elsewhere. Next, exchanging more efficient bulbs and wattages for lesser ones as well as changing the color of the bulb helped to reduce unnecessary light. Finally, we prepared a list to present to the JCA about which fixtures were the most important to modify or replace. To the list we added which types of fixtures were the greatest contributors to light pollution according to the laws and regulations.

3.3 Survey Logistics

To determine local residents' knowledge about light pollution laws and modifications of light fixtures, we distributed out surveys in Isla Verde. We developed an initial draft that was shown to our sponsor for revisions and, with their help, we translated it into Spanish. From the revisions, the survey was changed significantly to focus more on light pollution, the types of modifications that could be made to light fixtures, and the willingness of the survey participants to modify lights on their own. With a suggestion from our sponsor, we also reduced the number of questions to ten to make the survey easier and quicker for participants to take. After the survey was translated, we distributed it out amongst JCA employees to see if there were any other adjustments needed.

After final edits to the survey were completed, we went to Isla Verde on three occasions to seek out potential survey participants on the beach and at nearby residences. We focused on trying to have residents, local workers, and local visitors participate in the survey and strived to have at least 40 surveys completed. The survey was given out to participants through two means: on a piece of paper that had the link to the survey on SurveyMonkey and on physical copies of the survey, which were administered on clipboards with pens. Both versions of the survey had a brief description of the content in the survey and contact information for our sponsor. We chose to create the survey on SurveyMonkey due to our sponsor's familiarity with using it before along with how it organized and presented data. A complete list of the survey questions can be found in Appendix F. All of the information gathered from the survey was used in the development of an informational brochure and guide about light pollution, how it affects sea turtles and examples of modifications for light fixtures.

3.4 Modifying Light Fixtures

To provide examples of the simple modifications that were considered, the most common types of fixtures were purchased to test on. The fixtures that were purchased included a square flood light, a circular spotlight, a pickle jar light, and a dome light that was used over an outdoor patio. Each fixture was modified in either two or three different ways with material such as aluminum, plastic, and black spray paint. The modifications helped reduce the amount of light pollution because each light fixture modification was able to direct the light in a more concentrated area.

The square flood light emitted heat therefore aluminum and black spray paint were used in two different ways to focus the light on an area, creating more direct illumination. The first

modification was to put a shield, which was spray painted black, around the edges of the fixture (Figure 29 below) to contain the light. The shield was secured with tape for simplicity but a more permanent modification, for example screws or an epoxy glue, could be used. The second modification tested was securing an additional shield, spray painted black, on the front end of the first shield (Figure 30 below) to direct light downward and to focus it to an even more specific area.

Figure 29: One Shield Added to the Square Flood Light

Figure 30: Two Shields Added to the Square Flood Light

The circular spotlight had light emitting diodes (LED) therefore it did not emit heat so the material used was aluminum, plastic, and black spray paint. The first modification used a piece of aluminum shaped in the form of a cylinder, spray painted black, and then secured with tape on the rim of the light. This directed the light forward instead of outward, focusing the light to shine on an area (Figure 31 below). The second modification was to use a small plastic flower pot and secure it around the rim of the light fixture. In order to do so, the bottom of the flower pot was cut out and to a size which just fit over the rim of the fixture (Figure 32 below). No tape was necessary to secure the pot because it fit snug over the rim. The flower pot was also spray painted black to reduce how translucent the material was. The third modification for the circular spotlight was a combination of the two modifications prior. A small aluminum shield was spray painted black and added to the end of the flower pot to focus and direct the light (Figure 33 below).

Figure 31: Small Aluminum Shield added to the Circular Spotlight

Figure 32: Plastic Flower Pot added to the Circular Spotlight

Figure 33: Small Aluminum Shield and Plastic Flower Pot added to the Circular Spotlight

The light bulb for the pickle jar light was already encased by a hard, plastic covering therefore no heat was emitted and any type of material could be used. The first modification used a plastic flower pot which was large enough to contain all of the hard, plastic covering and black spray paint to reduce how translucent the flower pot was (Figure 34 below). This modification focused all of the light downward to create the least amount of light pollution. The end result acted as a spotlight on the ground. There was no need for tape to secure the plastic flower pot because it fit securely over the cover. The second modification used a piece of aluminum shield,

spray painted black, and coiled around the covering (Figure 35 below). The shield was longer than the pot so it focused the light even more to a direct area.

Figure 34: Flower Pot added to a Pickle Jar Light

Figure 35: Aluminum Shield added to a Pickle Jar Light

The last type of light that simple modifications were made to was a dome light that typically was found outside as a patio light. It had a glass dome covering the light bulb so the heat emitted was transferred into the glass. The first modification to this fixture was to add a shield which was made out of a wide flower pot and spray painted black (Figure 36 below). The

bottom of the flower pot was cut out in order for it to fit over the glass dome. The plastic flower pot helped capture the escaping light and to direct it downward instead of outward. The second modification that was tested was taking an aluminum shield which was longer than the flower pot and spray painted black, and curl it around the edge of the glass dome to direct the light toward the utilized area (Figure 37 below).

Figure 36: Wide Plastic Flower Pot added to a Dome Light

Figure 37: Aluminum Shield added to a Dome Light

Each of the modifications made to the four different light fixtures were to help reduce the amount of light pollution affecting the ecosystems. The shields and flower pots directed the light

away from the beach and focused it on the object or area which the light was intended to illuminate. Painting some the modification materials black reduced any reflectivity of the aluminum and made the plastic pieces less translucent.

3.5 Final Deliverables

Our final objective was to create an educational brochure to distribute amongst the community of coastal locations to raise awareness of the impacts of light pollution on the environment. We also created an educational guide that goes into more detail than the brochure. The first section of our brochure was titled “Regulation for the Control and Prevention of Light Pollution” discussed the regulations that the law put into place for beach areas that are used by sea turtles. The second section titled “Modifications” discussed the simple modifications that we designed for flood lights, spot lights, pickle jar lights and dome lights. We also included a summary of the materials that were used and an average cost. This section was adapted from guidelines that the International Dark-Sky Association (IDA) suggests. One example was implementing the B.U.G. technique, which stands for Backlight, Uplight, Glare, to better direct the light down and not out into the environment. The last section titled “Sea Turtles” discussed the direct effects that light pollution has on sea turtles and that decreasing light pollution will create better environments for sea turtles to thrive. The guide had paralleling information to the brochure, but the modification sections and the sea turtle section went into more detail. For the modifications, there were step-by-step pictures showing how we changed the light fixture. Both the brochure and the guide are available online through a link on the JCA website.

Another way we increased awareness in the community was by delivering a public presentation which was incorporated into our final presentation. While a paper copy was not intriguing or modern and was not a popular option, an informational session was more interactive and interesting for members of the community. This informational session displayed the conclusions we reached after gathering all of our data and allowed the attendees to ask questions directly. Our goal was that the residents who attended the session left with a greater understanding of light pollution and how it affects the environment of coastal locations. The presentation began with educating the community members on what light pollution is, its effects on nature, and the measures that individuals can take to reduce the amount of light pollution in their area. After the introduction, the effects of light pollution that are specific to coastal locations was described, such as how sea turtles and ecosystems are impacted. Once the community members had a better understanding of what light pollution is and the negative effects it has on the local environment, we then presented the strategies that they can implement to either modify or remove their lighting structures that are emitting too much glare. These strategies included shielding methods, replacing bulbs, and modifying their daily routine, such as turning off lights when they are not in use. Overall, between the printable brochure and the public information session, we believed that these were the most effective ways to deliver our conclusions from the survey, the categorization of light fixtures in the community, and the modifications.

4.0 Results and Analysis

After implementing the methods, we gathered results from the Sky Quality Meter (SQM) light levels, the inventory, the survey, and the modifications, all of which helped to build the brochure, guide, and public presentation. We took SQM light levels to gauge if the light pollution had gotten better or worse since the previous WPI team evaluated Isla Verde. We also built our inventory for Isla Verde and Patillas, which was broken into different categories to determine whether the light fixtures were in compliance or not. The inventory was presented to the Junta de Calidad Ambiental (JCA) so they were made aware of which lights were not in compliance with the regulation. From the survey, we were able to gauge the level of knowledge that the community members had on the regulations, the effects of light pollution on ecosystems, and what possible modifications could be implemented.

After creating the inventory, the four most common fixtures were used to design modifications. The fixtures were a square floodlight, a circular spotlight, a pickle jar light, and a dome light. To create the modifications, an aluminum sheet from a cooking tray, plastic flower pots, and black spray paint were used. After our inventory was created, the survey responses were analyzed, and the modifications were designed, we developed different forms of educational outreach. It was decided that a trifold brochure, a short booklet, and a public presentation were the best methods to reach out to the community and help inform the public about the effects of coastal light pollution on sea turtles and the simplest ways to reduce light pollution.

4.1 SQM Light Levels

The purpose of the collection of SQM data on Isla Verde was to determine the amount of illumination of the nighttime sky. The data was also collected to compare with the WPI 2014 Isla Verde team's average to determine if light pollution has increased since then, as well as the averages of other locations. When walking along the perimeter of phase 1, 100 meters were kept between each location. Over the length of phase 1, there were nineteen locations used as points to collect SQM readings. At each location, we gathered and recorded ten readings in units of magnitude per square arcsecond (mpsas). The ten readings were averaged at each location and then collectively, an overall average was obtained from those nineteen averages (see Table 1 below for a snapshot of the full table which is in Appendix A).

Table 1: Snapshot of SQM Data from Isla Verde

Location	SQM	Ave. Temp (°C)	Reading 1	Reading 2	Reading 3	Reading 4	Reading 5	Reading Average	Total Average
1	A	22.6	18.23	17.94	18.25	18.28	18.16	18.17	18.32
	B	24.0	18.45	18.44	18.46	18.45	18.51	18.46	
2	A	24.0	18.31	18.35	18.31	18.33	18.39	18.34	18.34
	B	25.0	18.33	18.35	18.36	18.38	18.30	18.34	
3	A	26.0	18.25	18.26	18.30	18.28	18.26	18.27	18.30
	B	26.0	18.28	18.41	18.33	18.37	18.26	18.33	

As shown in the complete Table 1 in Appendix A, all of the readings were between 17.00 mpsas and 18.50 mpsas. These readings indicated that there was a large amount nighttime illuminance on Isla Verde. This is reflected by how low the SQM readings were, indicating the presence of a significant amount of sky glow, and in turn, a high amount of light pollution in the area (See Appendix C for more details). Also shown in Table 1 is the decline of the readings throughout the progression of the data collection. The amount of brightness at each location varied depending on where the location point was. In particular, Location 19 had no lighting in the immediate area, but had an average reading of 17.17 mpsas. On the other hand, Location 1

was at the brightest location and had a reading of 18.32 mpsas. The regression of the readings could indicate that the SQMs were not working properly or were not calibrated properly, especially since the readings from both SQMs differed in the results at each location (see Table 1). Another way that the readings could have been affected might be due to how the surrounding light made contact with the sensor on the SQMs. Light could have entered at an angle that read as a lower reading, affecting the results in some locations. The weather conditions could have also affected the results on the night we collected data as it was partly cloudy, and it is recommended to collect data on a clear night with no clouds in the sky.

The overall average of the SQM data taken in Isla Verde was found to be 17.76 mpsas, which indicated that there were high levels of light pollution in the area. The average readings of the light levels taken in 2014 was 18.33 mpsas. Comparing the 2014 and 2016 values, the current average in Isla Verde lowered significantly, indicating that in the past two years, light pollution became worse in the area. To determine the severity of the light pollution in Isla Verde, the results were compared to other locations around the world (See Figure 38 below).

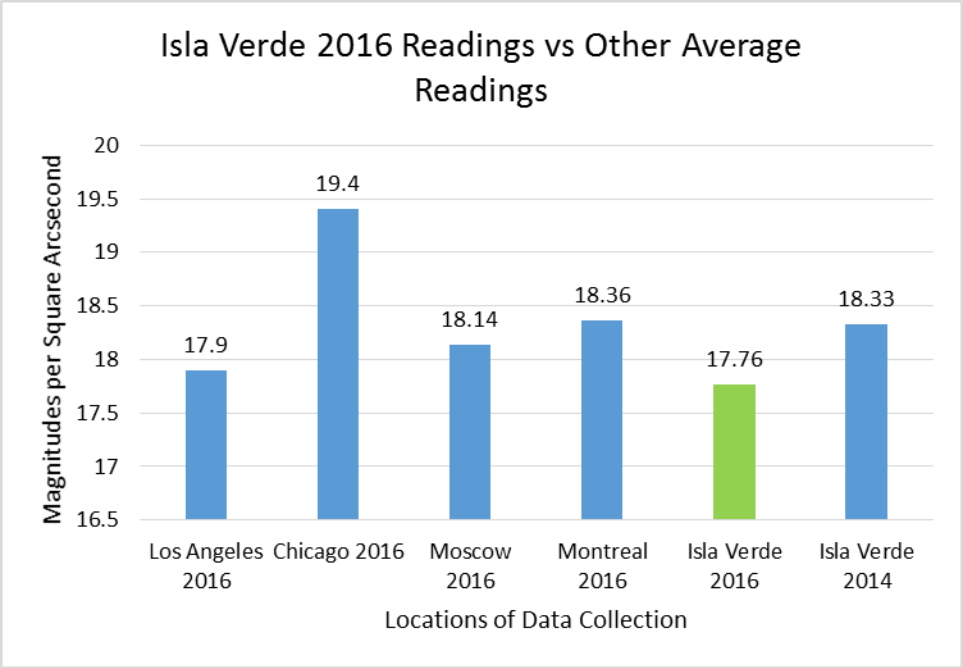


Figure 38: SQM Data from Isla Verde and World Locations
(Source: https://www.lightpollutionmap.info/#zoom=4&lat=4846116&lon=-9814369&layers=B0TFFFFT)

When compared to the SQM readings of cities like Montreal, Moscow, Chicago and Los Angeles, the 2016 Isla Verde SQM readings were still lower than all of them. Los Angeles had the closest SQM data average to Isla Verde 2016 with there being a 0.14 mpsas difference. The reading comparison indicated that the amount of nighttime brightness in Isla Verde increased from light levels of an urban neighborhood to levels similar to a city like Los Angeles. Despite efforts to decrease artificial light output in Isla Verde, current lighting practices in the area continue to rise and more light pollution has been produced in recent years. The amount of current light levels in Isla Verde has continued to be an unacceptable environment for sea turtles to nest and hatch from. The beach has an appropriate environment for turtles to lay eggs, but since there has not been any turtle nests discovered recently, it can be determined that light pollution may be a factor in deterring turtles from nesting on the beach.

4.2 Inventory

The purpose of the inventory collection and assessment was to gather an estimate of what percentage of lights in Isla Verde can be easily modified compared to needing complete replacement to become compliant with the regulation. Some of the requirements outlined by the regulation are very specific and were out of our capabilities based on equipment that was available to us, inability to request lighting analyses from property owners, our general safety, and time constraints. The area we assessed in Isla Verde falls under Class 8 which pertains to "Beaches used by Sea Turtles". Based on Regulation #8786 (2016), Rule 13, Letter H, Class 8, all lighting in this category must abide by all of the requirements of Public Lighting in Rule 19. Rule 19 serves as a base of requirements for Rule 13 which builds upon it. To assess lights on beaches used by sea turtles, there are four specific conditions that must be met to deem a light compliant. The first category that must be identified is whether or the not the light is exempt from the regulation. Holiday lighting is exempt from Regulation #8786 during the months of December and January. Emergency lighting is also exempt at all times. If a light does not fall into one of those two categories, then it must be turned off between 11p.m. and dawn. Security lighting does not need to be turned off, but must abide to following requirements:

1. the bulb must be low pressure sodium no greater than 35 watts
2. the fixture must have a permanent shield that restricts light to 70 degrees from the vertical as depicted in the center picture below

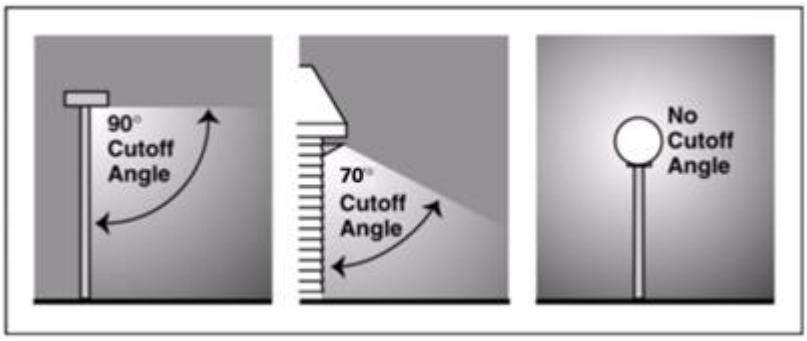


Figure 39: Varying Cutoffs on Three Lights

(Source: http://tcaa.us/Lighting.aspx)

3. the light may not be less than 560 nm in wavelength
4. the illuminance value may not exceed 0.05 foot-candles at any point on the property line

We were not able to determine whether or not the lights were on after 11p.m. because executing field work this late was a safety issue. However, our sponsor directed us toward assessing whether the lights would be compliant regardless of the time rule because a vast majority of the lighting would be considered security lighting.

To begin this assessment, we documented the location of the light based on the following map and address.

Figure 40: Map of the Properties in Isla Verde Phase 1

Two photos of the light were included in the inventory (one zoomed out and one zoomed in). The type of light was distinguished as seen in Figure 41 below between: dome, floodlight, area light, street light, canister, spotlight, lantern, lamp, string lights, pickle jar, and ceiling strip light.

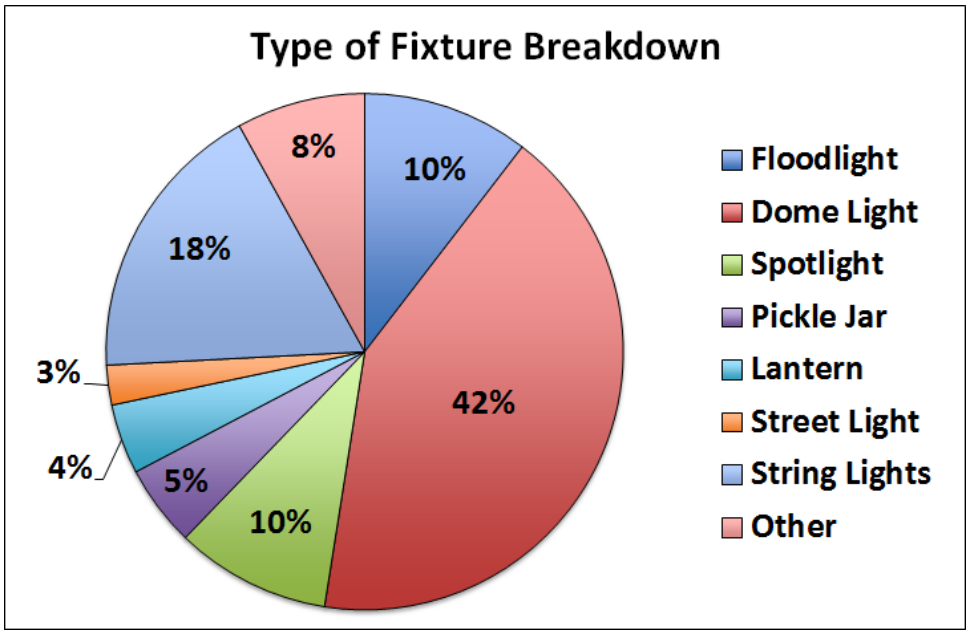


Figure 41: Pie Chart of Inventory Breakdown by Light Type

The application of the light was determined based on the categories below.

- Roads: Illumination used by roads and highways
- Entrances and paths: Illumination used for entrances and pathways
- Parking Lot/ Garage: Illumination used for parking lots and garages
- Security: Illumination used for security purposes, like lights that illuminate areas off limits and points outside the property
- Scenic: Illumination used for landscapes, fields, beaches and others
- Signage: Illumination used for promotional signs
- Garden lighting: Illumination used for outside gardens like restaurants and hotels
- Sports lighting: Illumination used for sports facilities like volleyball and basketball courts
- Parks/ Recreational Areas: Illumination used in recreational areas or parks
- Entertainment: Illumination used in the outside of concerts, theaters and others.

We observed and documented light color. Of the 843 lights included in the inventory, only 502 lights were on. Because the inventory was assessed over multiple nights, one major

problem that arose with evaluating light color was that some lights were on during some nights and off during other nights. We found this issue most common with patio lights as the majority of these type of lights are part of people's homes and manually operated. In order to fairly assess light color, dome patio lights were excluded so only 332 lights were assessed for this category of the inventory. Although we were not able to determine the type of bulb, wattage, or wavelength, compliant low pressure sodium bulbs give off an orange or amber color which was what we looked for. The distribution of light color can be seen in Figure 42 below.

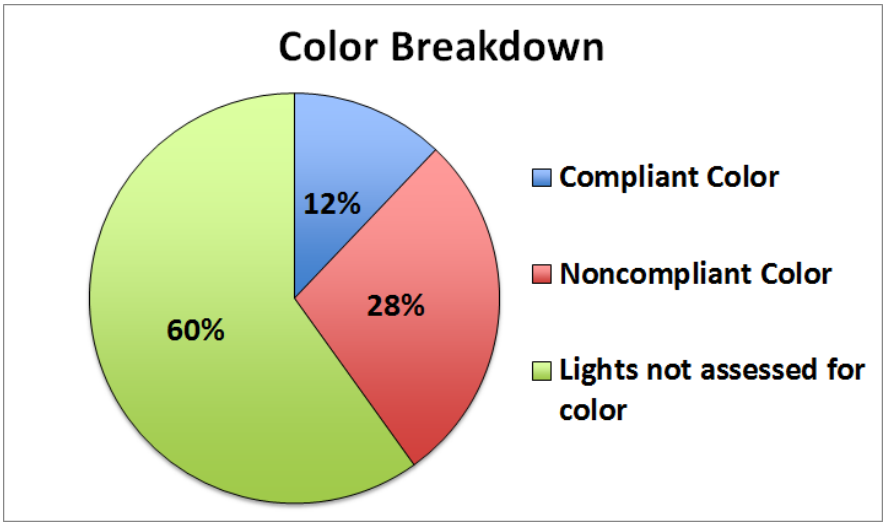


Figure 42: Pie Chart of Inventory Breakdown by Light Bulb Color
Compliant color was considered to be orange and amber tones.

Less than one-third of lights assessed were found to have an orange color which could comply with the regulation. This shows that many light bulbs on the Isla Verde coast need to be replaced.

The second category evaluated was shielding. Based on Rule 19, all public lighting must have a full cutoff shield. As stated previously, Rule 13, Letter H, Class 8, defines compliance even more specifically, so all light fixtures in this category must restrict light to 70 degrees from the vertical. Out of 502 lights observed that were on, only 15 met this requirement which was 2.98%. In addition to bulb type, this was another major area that was in need of modification

and/or replacement to achieve compliance. Because the regulation can only force people to modify fixtures and not replace them for the given time periods depending on if the light is public or private, the JCA wanted to gather an idea of what percentage of lights can be easily modified. One problem we faced when assessing lighting fixtures was that as a team, we often were not in agreement to which kind of modification was most feasible for a given light. We found that the limited time we had was not nearly enough to become experts on the subject. Conclusively, our results may differ from that of an expert who has spent the course of a career studying lighting practices. After thorough investigation of a light, we gave recommendations in the final column of the inventory. We included all possible modifications because modifications have design flexibility and some people may prefer to alter their lights in one way instead of another. Based on our assessments and understanding of the law, only 13 lights had proper shielding and would solely require a light bulb replacement. We found that 693 of the lights can meet the requirements of the regulation by adding a shield or painting an existing shield with the assumption that the bulb meets the requirements. We found that 109 of the light fixtures would need to be oriented at a different angle along with adding a shield to achieve compliance. As seen in Figure 43 below, over three-fourths of the lights we observed only require a simple shield.

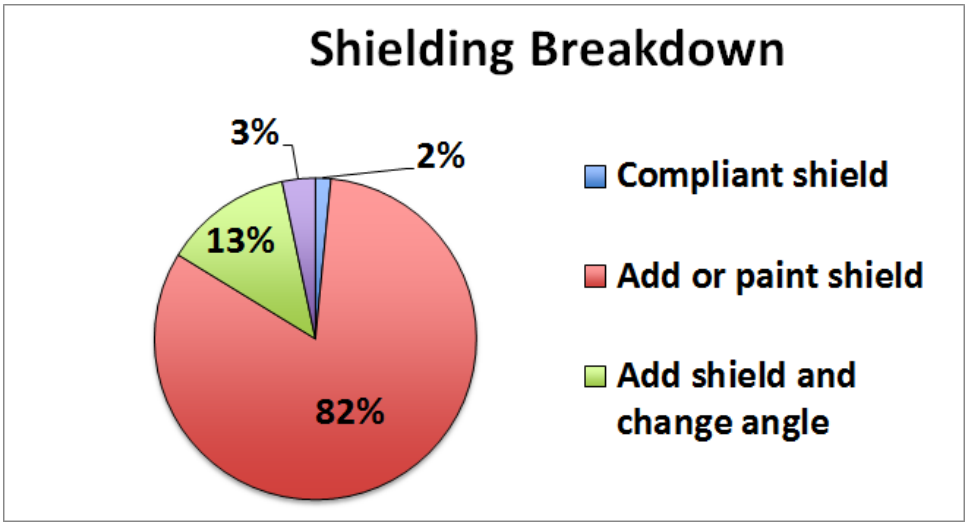


Figure 43: Pie Chart of Inventory Breakdown by Light Shielding

Based on the purpose, angle, and shape of the light, we decided that 28 lights would need to be replaced or removed and that any modification was not a feasible option. For example in Figure 44 shown below, if a light is placed in the ground it is extremely difficult if not impossible to create a 70 degree cutoff shield for it.

Figure 44: Dome Light set in the Ground

The last part of the inventory field work we completed was using a photometer to gather average illuminance readings of each light from the property line. One complication while gathering this data was that the law states that the readings must be taken on a vertical plane. This can be interpreted in two different ways, and we were not able to find someone to confidently identify which of the two was the correct plane. Because we did not find clarity pertaining to this issue, we took readings angled toward the light as we felt this made the most sense from an ecological standpoint. Inhabitants of the beach, for example sea turtles, do not only see on one vertical plane, so it is justifiable that the readings be taken at a similar angle as that to which a turtle may see the light. By taking the reading on either "vertical plane", the light becomes extremely diluted which is not how organisms register the light. The allowable level by law is 0.05 foot candles from the property line which is depicted by a red line in Figure 45 below. It can be observed that very few lights had readings that met the requirements of Regulation #8786. Precisely, out of 19 property averages only five types of lights emitted illuminance under the allowable level which is less than 26.4%.

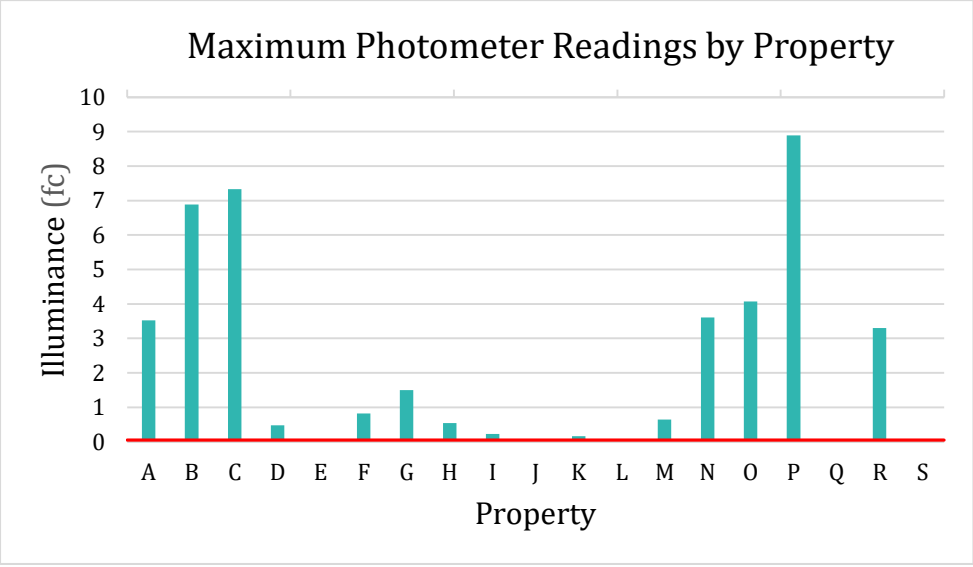


Figure 45: Photometer Readings from Properties in Isla Verde Phase 1

Isla Verde served as the main location for the inventory collection. The lights were evaluated both at night and during the daytime. A partial inventory was collected in Patillas only during daylight hours which led to a simpler assessment of the lights there. A map of the area can be seen in Figure 46 below.

Figure 46: Map of the Properties in Patillas

Only the angle of the light projection was able to be observed, and in some cases we were not able to assess this category. Sometimes, it was simple to decide that the light would exceed past 70 degrees based on the orientation of the fixture itself. However, if a fixture was full cutoff it could only be determined if it was cutoff to 70 degrees if the light was on. Because of this limitation, we were only able to decide if a light was clearly not in compliance. Of 130 total lights documented, 98 were clearly noncompliant. That left only 32 possibly compliant by terms of shielding and type of bulb.

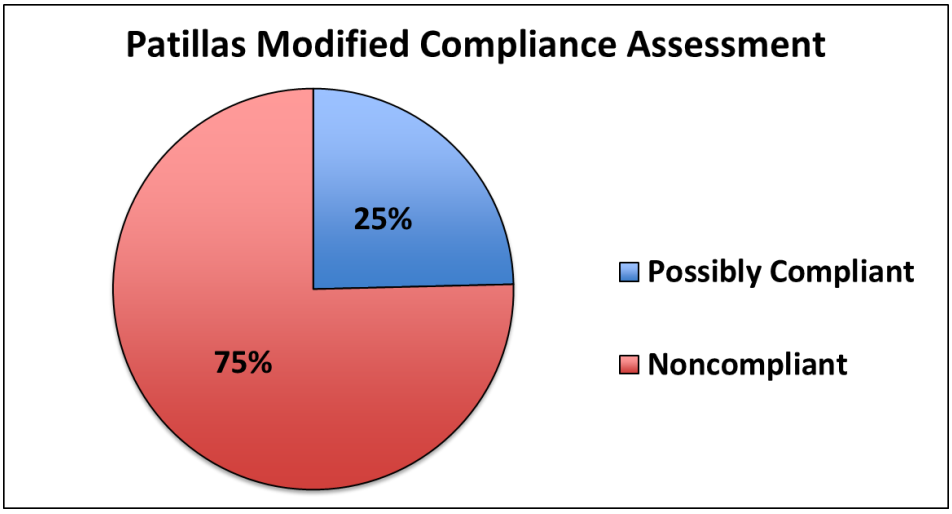


Figure 47: Pie Chart of Inventory Breakdown in Patillas

Both the highly developed Isla Verde area and the rural coast in Patillas had high noncompliance levels. Similar light types were assessed, but in different volumes. Sufficient data was not gathered to make conclusive results, however there may be correlation between the amount of illumination on a beach and whether sea turtles prefer it. Many nests were observed during our fieldwork at Patillas and none were found at Isla Verde at the time. We understand that in some areas lights cannot simply be eliminated or turned off, but if lights can be shielded properly with the right kind of bulb all beaches will be dark. This may create more turtle friendly beaches similar to Patillas. See Appendix G for the full inventory of both Isla Verde and Patillas.

4.3 Survey

The distribution of the survey in Isla Verde was to gauge the community's knowledge of Law 218, the lighting ordinance, and to determine what types of modifications people were the most willing to make regarding their current light fixtures. The responses on the surveys were used to help form our educational guide and brochure by providing the necessary information.

The total number of responses received at the conclusion of the allotted survey time was thirty-two, with eleven females and twenty one male respondents. Breaking it down by age as seen in Figure 48 below, four were 19 years old or younger, twenty four were 20 to 29 years old, two were 30 to 39 years old, one was 40 to 49 years old, none were 50 to 59 years old, and one was 60 years old or older.

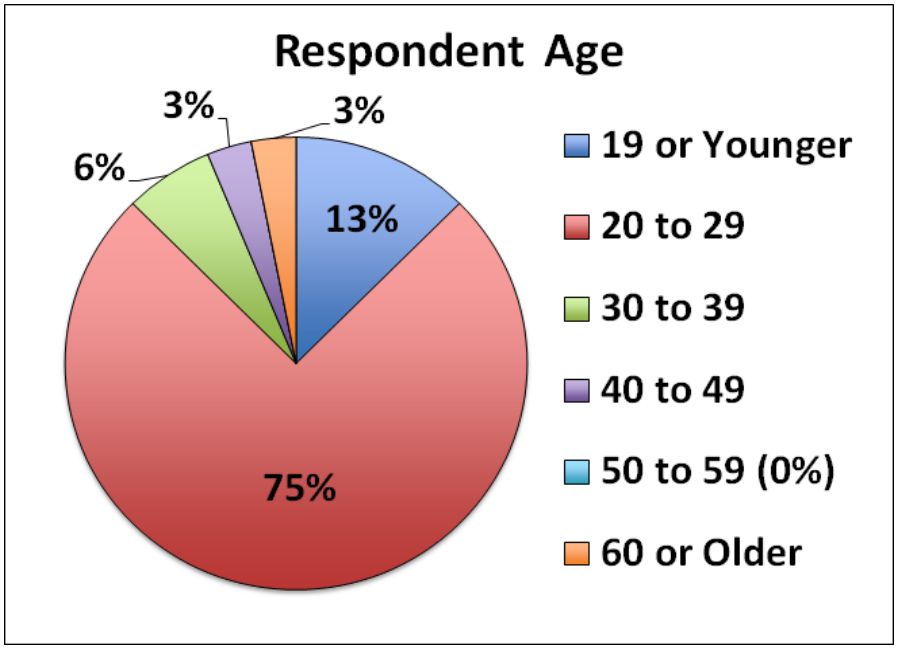


Figure 48: Pie Chart of Survey Respondent Age

Regarding the type of property respondents resided in, fourteen said they lived in a house, seven in a condominium, and eleven said they were a visitor to the area. When asked if they knew of a law or regulation about light pollution in Puerto Rico, fifteen said yes, eight said no and nine were not sure of a law existing as depicted in Figure 49.

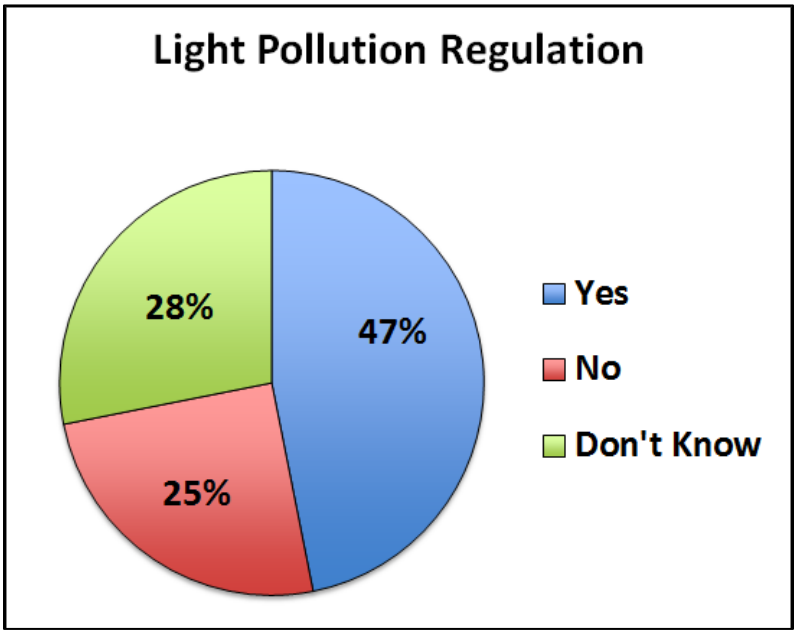


Figure 49: Pie Chart from Survey Results of Regulation Awareness

Some of the most common words and phrases that participants thought of when they heard the term "light pollution" were turtles, stars, the environment, billboards, other animals, and that there was too much light. When asked about the use of outdoor light by their residence, some of the most common responses were to illuminate any kind of structure or installation, to illuminate parking lots, to illuminate pedestrian areas like sidewalks and paths, and to illuminate for a sense of security. The most important actions that respondents deemed necessary were to modify the existing lighting to correct the issue, to permanently turn off the exterior lights that were causing the problem, and to manually turn off the lights that were causing the problem after a certain time.

Regarding the use of outdoor lighting visible at night along the beaches, thirteen believed that it affects the visibility of the stars and the coastal environment at night, two believed that more illumination was necessary to improve beach use and security, nine believed that the visible lights must be controlled and modified to reduce the light pollution problem, seven

believed that the lights disorient sea turtles in multiple ways, and one believed that no actions were necessary because all lights should be removed or modified. Almost all of the respondents were willing to invest money into making modifications to reduce light pollution as shown in Figure 50 below. Only one respondent was unwilling to spend money on a modification while eleven would spend $1 to $50, eight would spend $51 to $100, five would spend $101 to $200, and seven would spend more than $200.

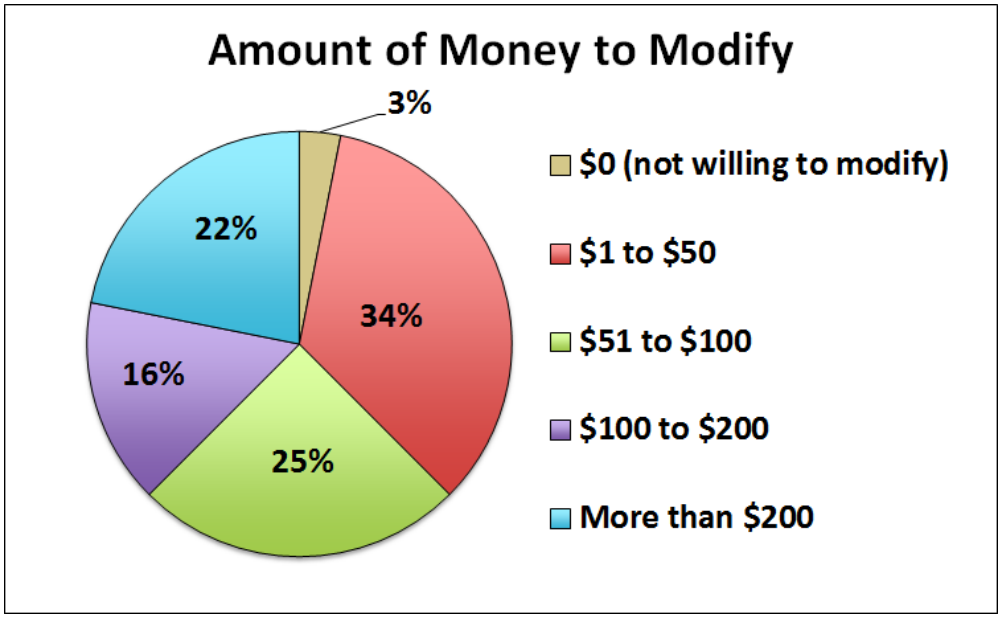


Figure 50: Pie Chart from Survey Results of Willingness to Spend Money on Modifications

Some of the most selected modifications that respondents agreed to make included changing the angle of the light, changing the bulb, installing a motion sensor, and replacing the entire fixture to comply with the law and regulation. The greatest motivating factors for respondents to make the corrective measures to light fixtures were to help save an endangered species and to avoid receiving a fine. See Appendix H for additional breakdowns of the survey responses.

The results from the surveys indicated that roughly half of the respondents did not know about the law and regulations for light pollution and exterior lighting. This is likely due to insufficient education on the effects of light pollution ecosystems from elementary school to high school. The results also indicated that only two out of thirty-two respondents were not willing to make any changes to their personal lighting fixtures. This means that the majority of the community understood that there were faults with their lighting fixtures and they were open to modifying them. The responses also show that the modifications that most people were willing to make were changing the angle of the light or focusing it down. They were also willing to replace the bulb to change the color and the level of brightness and add motion sensors to automatically turn the lights on and off. These modifications were the easiest to implement, while still meeting the parameters of the regulation. Finally, the results overall indicate that most people are willing to modify their lighting fixtures to avoid receiving a fine as well as protecting an endangered species. We concluded that the main issue with enforcing the regulation was not the willingness of the community members, but the level of knowledge about the regulation.

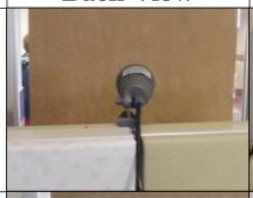
4.4 Simple Modifications

To visually see results, different types of modifications were tested with the light fixtures that were purchased, which included a square flood light, a circular spotlight, a pickle jar light, and a dome light (used over a patio). Each modification used different types of materials depending on the type of light fixture and how much heat it emitted. For the square flood light, aluminum and spray paint were used because the type of bulb emitted enough heat to melt any plastic modification. For the other three light fixtures, aluminum, plastic, and spray paint were

used as well as any combination of the three because the bulbs did not produce heat. The portion of Table 2 below shows the different angles of each modification for each type of light fixture. The back view, side view, front view, and additional view are depicted to get a sense of how each modification looked. For a full look at Table 2, see Appendix I.

Table 2: Before and After Modification

The table shows only a portion of the full version located in appendix I.

Modification	Back View	Side View	Front View	Additional View
Original Fixture				
Shield Added				

The cost for each modification was based on the prices for the material at the time of the purchase and may differ in the future. Because the materials were bought in a local hardware store, prices may vary from store to store. The portion of Table 3 below shows the type of light fixture, how it was modified, the light emitted before the modification, the light emitted after the modification, and the approximate cost of each different modification. See Appendix I for a full version of Table 3.

Table 3: Before and After Results

The table shows only a portion of the full version located in appendix I.

Type of Fixture	Type of Modification	Fixture Before Modification	Fixture After Modification	Modification Cost
Flood Light mounted on the wall	Shield Added (aluminum pan and spray paint used)			approx. $0.45
Flood Light mounted on the wall	Two Shields Added (aluminum pan and spray paint used)			approx. $0.70

All of the aluminum used was simply from a disposable, single use aluminum pan that can be found in most grocery and hardware stores. The cost for an aluminum pan was about $1.00 but for the square flood light and the circular spotlight, the aluminum pan was cut into four different pieces so the price per piece was about $0.25. However, the whole bottom of the pan was used for the pickle jar light and the dome light so the price per piece for this modification was $1.00. All of the plastic flowerpots were differently priced based on size, style, and shape but the small, medium, and wide flowerpots were each $0.20, $0.35, and $2.50 respectively. A can of spray paint was $4.00 and it was figured that each piece used less than 5% of the paint inside of the can, therefore the approximate cost to spray paint each piece was $0.20 (“Pots and Planters”, 2016).

Because there are so many options and different types of modifications for the numerous types of light fixtures, the most popular light fixtures that were found were modified as examples. The square flood light had two different modifications, which were adding one shield and adding two shields, to contain the light and they cost approximately $0.45 and $0.70

respectively. The circular spotlight had three different modifications, which were adding a shield, adding a flower pot, and adding both a shield and a flower pot, to contain the light and they cost approximately $0.45, $0.20, $0.65 respectively. The pickle jar light had two modifications, which were adding a shield and adding a flower pot, to contain the light and they cost approximately $0.35 and $1.20 respectively. The dome light had two modifications as well, which were adding a flower pot and adding a shield, to contain the light and they cost approximately $2.70 and $1.20 respectively. All of the tools used were common household tools like scissors, tape, glue, etc. and therefore the tools were not taken into account for the price.

The experimental modifications mentioned were designed to visually see results and were not meant to be permanent. For a permanent modification, more durable and sturdy materials should be used. Some examples of these solutions are thicker plastic flower pots or clay flower pots, as well as thicker metal sheets, all of which can hold up to the weather conditions that they might have to endure. It is important to take into consideration heat emitted by a given bulb when deciding the kind of material to be used. In addition, the modifications should be attached securely using epoxy, screws, etc. instead of just tape. A small flower pot made of thicker plastic and a clay flower pot that are the same size as the small flower pot used in the modification cost $1.47 and $1.97 respectively ("Pots and Planters", 2016). Even though these types of simple modifications are more expensive, the modifications will last much longer.

4.5 Brochure, Guide, and Presentation

Using the results collected from the survey, we designed a brochure and a guide intended to be uploaded on the Junta de Calidad Ambiental (JCA) website. In addition, we gave a public presentation at the Edificio de Agencias Ambientales (which was one in the same of our final presentation). The brochure was modified to display and briefly introduce topics about sea turtles and how they are affected by light pollution. It then included simple modifications that can be used on the four most common lighting fixtures we found. The guide goes more in depth into the topics introduced in the brochure with more details and images. Finally, the public presentation had similar, more specific information but allowed the community members to have their questions answered by experts.

The brochure is a simple double sided tri-fold layout (See Figure 51a below). On one side we included information about the Regulation for the Control and Prevention of Light Pollution. Specifically, we focused on Rule 13 (Beach Area used by Sea Turtles) and Rule 15 (Outdoor Lighting Emitting Sources Requirements). Because regulation efforts have been limited, many people still do not know about it. There is also a description of how light pollution affects sea turtles. On the other side of the brochure, we have included the modifications that we designed for the floodlight, the spotlight, the pickle jar light, and the dome light. This included a before and after picture of the lighting fixture and which materials were used to create our modifications, as well as where we found the materials.

Regulation for the Control and Prevention of Light Pollution

Lighting for Security Purposes-

- Low Pressure Sodium 18W bulbs
- Maximum of 35W
- Red, Orange or Amber Colors
- No colors that exceed 560 nm

Have a long cutoff of 70 Degrees and not any angle greater measured from the vertical orientation axis (0 Degrees)

Any external source of emission whose light can be seen from the following classes:

- 1 (Construction Lighting)
- 5 (Lighting for Gardens, Inside Fountains and Pools)
- 6 (Parking Lights)
- 7 (Pedestrian Lighting)
- 8 (Light outside family and multi-family residences)

Sea Turtles

Light pollution is the inappropriate or excessive use of artificial light which has a disruptive effect on natural cycles (Retrieved from http://darksky.org/light-pollution/).

Sea turtles need natural light to find their way to the brightest area of the coast, or the ocean. However, if there is another source of artificial light stronger than the ocean, the turtles will move towards the brighter light. The farther the turtles get from the ocean, the greater the chances are of them getting dehydrated or worse.

http://www.mesa.edu.au/turtles/images/cut_the_glow.jpg

La Junta de Calidad Ambiental
PR- 8838
San Juan, 00927

REDUCING COASTAL LIGHT POLLUTION

Junta de Calidad Ambiental

Figure 51a: Front Side of Brochure

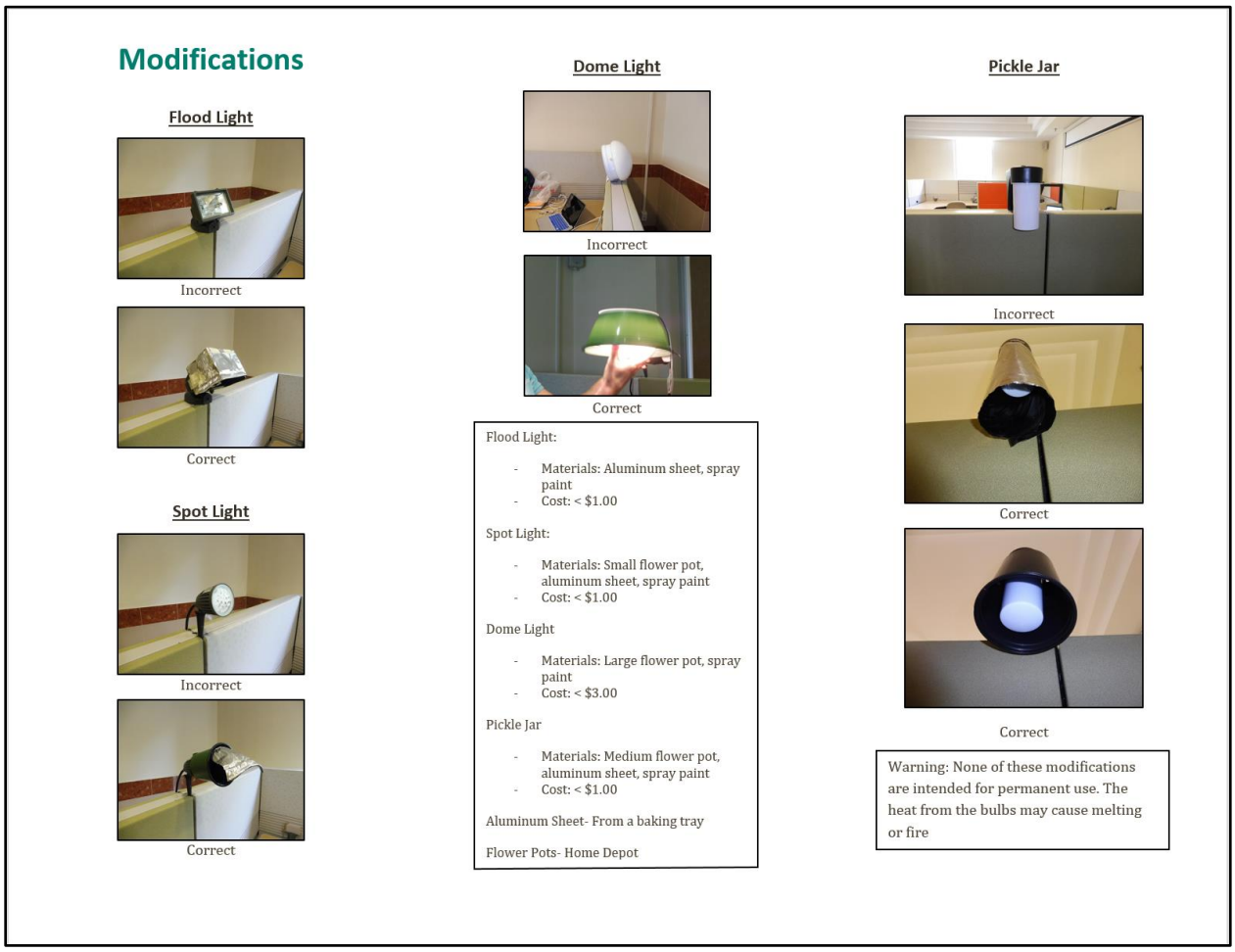


Figure 51b: Back Side of Brochure

Our guide is more detailed than the brochure with 4 double sided pages (See Appendix J). The guide goes more in depth about the effects that light pollution has on nesting sea turtles and the hatchlings. It is important to stress that there are many species of sea turtles that are endangered and that reducing light pollution is a major step in helping to protect them. The following pages discussed the regulation, but there is more focus on the modifications that we designed. Instead of just having a before and after picture, we included step-by-step instructions on how to use the materials to create the proper modification in order for the fixture to be in compliance with the law, as well as an estimated price for the total modification. Finally, the

guide includes contact information for the JCA for those who want more details, as well as links to helpful websites.

The public presentation started by giving background information on light pollution and the effects it has on sea turtles. Next, the law was discussed along with all the parameters for different light usages and locations. Finally, there was a step by step display on how to modify different kinds of lights. Both inexpensive and more costly examples were used if people would like more variety.

5.0 Conclusions and Recommendations

The goal of this project was to evaluate lighting practices on the coasts of Puerto Rico to gain an understanding of current usage and the extent of which lights are in violation of Regulation #8786 (2016). This regulation was passed in 2008 with the purpose of reducing negative environmental effects of light pollution. One of the main beneficiaries behind our project efforts were sea turtles as artificial lights along the coast attract hatchlings in the opposite direction of the ocean which inevitably leads to their death by causes such as dehydration and predation. The law states a transitional period during which the government cannot force owners to change their light fixtures, but they can demand modification of fixtures. A major problem that government agencies, specifically the Junta de Calidad Ambiental, have encountered is that many residents of Puerto Rico cannot afford to change current light fixtures. So another main aspect of our project was to develop simple and cheap modifications that can be applied to common lighting scenarios. We also developed a guide to educate the community about these modifications, the regulation, and the effect on sea turtles. A survey was administered to gauge the knowledge of the public which influenced how in depth certain topics were covered in the guide.

5.1 Influencing the Source of the Market

A major issue with the current status of the lighting market is that there are vastly more noncompliant lights available contrary to compliant ones. It would be an incredible feat to drastically change the entire lighting market, however we do believe that the market can be

influenced and educated. Hardware stores are a main source for the public to purchase lighting fixtures, however when we visited one locally there were no sections that contained compliant lighting or modifications nor was there information available about the statewide regulation in effect in Puerto Rico. We recommend connecting with hardware stores and lighting companies to present more compliant-friendly lighting options along with informational pamphlets to be available in lighting aisles. Locations where people seek the product are focal points that can push for lighting practices to change. As part of our project, we designed a set of simple modifications that can be applied to some of the most common lighting fixtures. One reason this was included in our project was that there is not an abundance of simple shields available for purchase. If lighting companies made inexpensive shields and covers that would be an even more beneficial solution to the problems that the Puerto Rican community has been facing.

5.2 Community Outreach

If citizens are not fully aware of the parameters of Regulation #8786 then it becomes tasking to request all lights to meet the requirements within 10 or 20 years, depending on public or private ownership. Therefore, we recommend more community outreach to educate those whom the law affects. At our main test site in Isla Verde, there is an informational booth that an associate of the JCA can access and hand out information. Having more hubs like this would be valuable in order for people to fully understand why the law is in place and what the law means for them. Another way to increase community awareness is to implement a school program that educates students about the lighting regulation. Targeting elementary level students would hopefully make an impact on their views while their minds are still moldable and influenced.

Targeting older ages such as high school levels would ideally influence the young adults to make more conscientious decisions once they move out on their own and become independent residents. It also would strengthen the efforts made earlier in their educational career. In addition, we recommend having more information available via the internet. With current technology, the internet is a vital tool to effectively distribute information to large groups of people. In this case, the entire state of Puerto Rico needs to be informed. Ideally, a clear cut outline of the law and the regulation would be easily accessible on the JCA website. We also created a more simplified guide of the Class 8 regulation along with our work with modifications that we intended to be linked on the JCA website.

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7.0 Glossary

Glare: excessive brightness that causes visual discomfort

Skyglow: brightening of the night sky over inhabited areas

Light trespass: light falling where it is not intended or needed

Clutter: bright, confusing and excessive groupings of light sources

*LZ0 - No ambient lighting***:** Areas where the natural environment will be seriously and adversely affected by lighting. Impacts include disturbing the biological cycles of flora and fauna and/or detracting from human enjoyment and appreciation of the natural environment. Human activity is subordinate in importance to nature. The vision of human residents and users is adapted to total darkness, and they expect to see little or no lighting. When not needed, lighting should be extinguished.

LZ1 - Low ambient lighting: Areas where lighting might adversely affect flora and fauna or disturb the character of the area. The vision of human residents and users is adapted to low light levels. Lighting may be used for safety, security and/or convenience but it is not necessarily uniform or continuous. After curfew, most lighting should be extinguished or reduced as activity levels decline.

LZ2 - Moderate ambient lighting: Areas of human activity where the vision of human residents and users is adapted to moderate light levels. Lighting may typically be used for safety, security and/or convenience but it is not necessarily uniform or continuous. After curfew, lighting may be extinguished or reduced as activity levels decline.

LZ3 - Moderately high ambient lighting: Areas of human activity where the vision of human residents and users is adapted to moderately high light levels. Lighting is generally desired for safety, security and/or convenience and it is often uniform and/or continuous. After curfew, lighting may be extinguished or reduced in most areas as activity levels decline.

LZ4 - High ambient lighting: Areas of human activity where the vision of human residents and users is adapted to high light levels. Lighting is generally considered necessary for safety, security and/or convenience

Appendix A - Additional Figures

Figure 3: Example of Skyglow Over a City

(Source: “Light pollution,” 2003)

Figure 4: Skyglow and the Empire State Building

(Source: https://upload.wikimedia.org/wikipedia/commons/d/df/Empire_State_Building_Night.jpg)

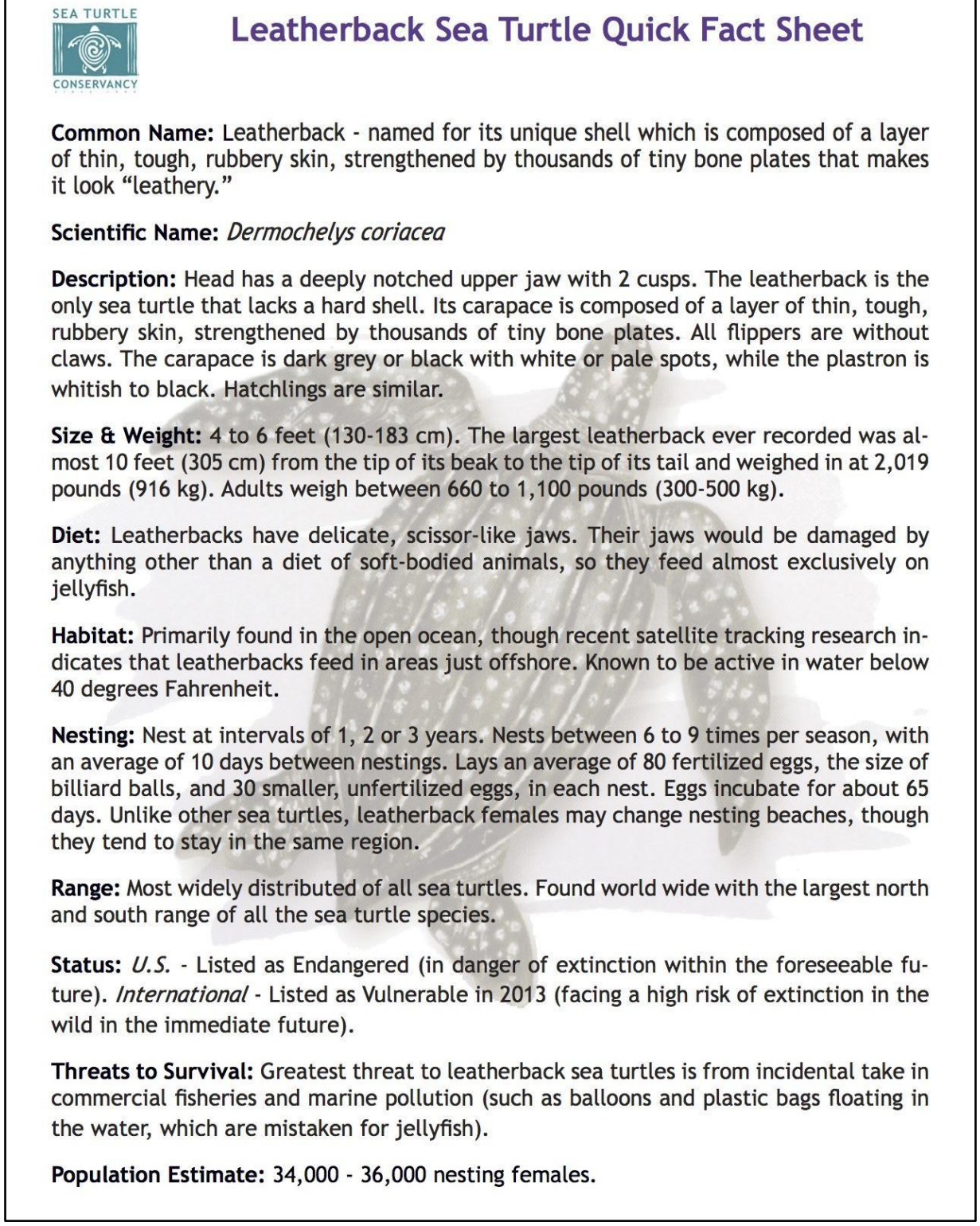
Figure 7: Example of Light Trespass

(Source: “Light pollution,” 2003)

Figure 8: Example of Light Trespass from a Hotel Fixture on a Residency

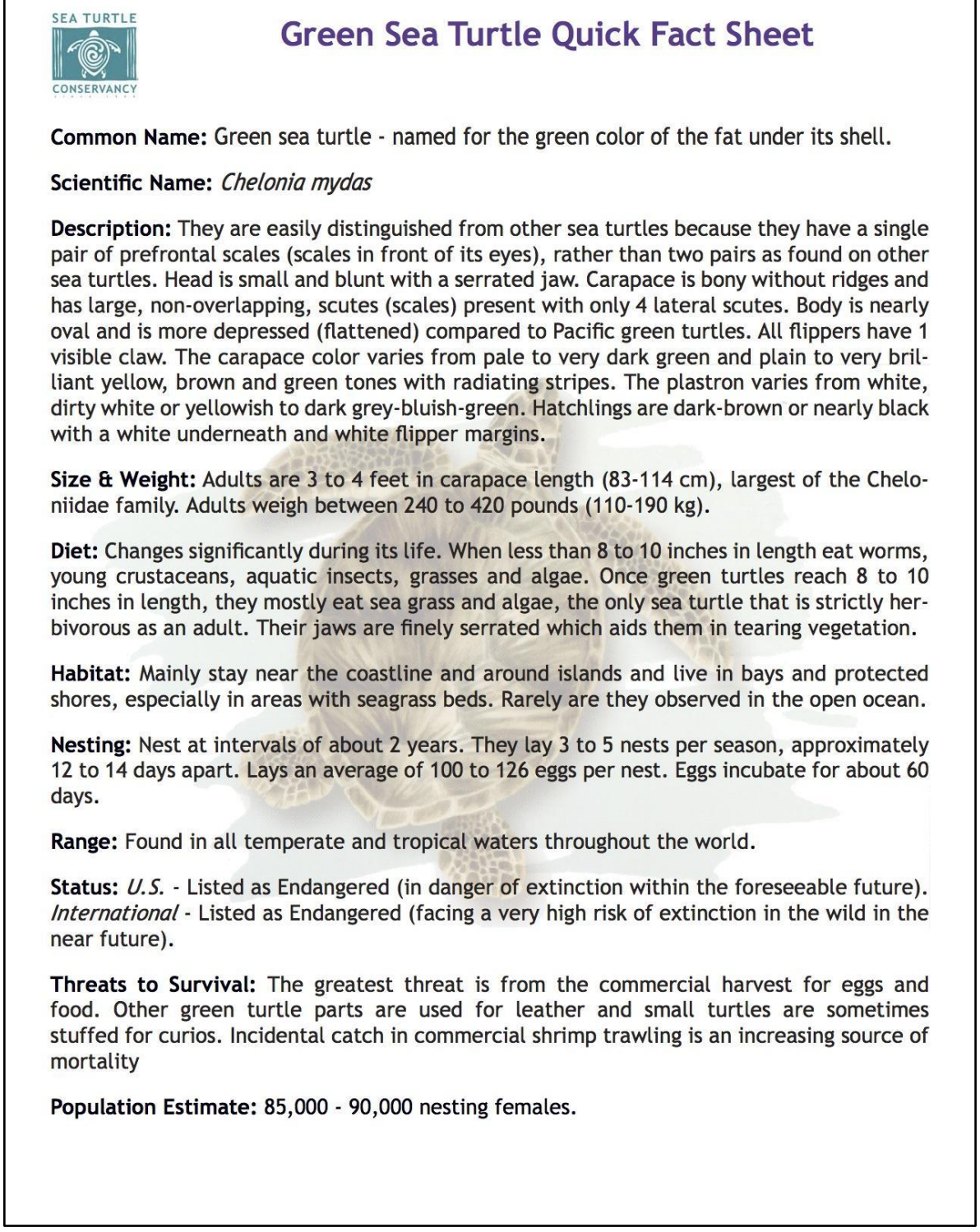
(Source: “Light pollution,” 2003)

Figure 10: Leatherback Sea Turtle Quick Fact Sheet



(Source: "Educational initiatives: Outreach materials: Sea turtle fact sheets," 2015)

Figure 12: Green Sea Turtle Quick Fact Sheet



SEA TURTLE CONSERVANCY

Green Sea Turtle Quick Fact Sheet

Common Name: Green sea turtle - named for the green color of the fat under its shell.

Scientific Name: *Chelonia mydas*

Description: They are easily distinguished from other sea turtles because they have a single pair of prefrontal scales (scales in front of its eyes), rather than two pairs as found on other sea turtles. Head is small and blunt with a serrated jaw. Carapace is bony without ridges and has large, non-overlapping, scutes (scales) present with only 4 lateral scutes. Body is nearly oval and is more depressed (flattened) compared to Pacific green turtles. All flippers have 1 visible claw. The carapace color varies from pale to very dark green and plain to very brilliant yellow, brown and green tones with radiating stripes. The plastron varies from white, dirty white or yellowish to dark grey-bluish-green. Hatchlings are dark-brown or nearly black with a white underneath and white flipper margins.

Size & Weight: Adults are 3 to 4 feet in carapace length (83-114 cm), largest of the Cheloniidae family. Adults weigh between 240 to 420 pounds (110-190 kg).

Diet: Changes significantly during its life. When less than 8 to 10 inches in length eat worms, young crustaceans, aquatic insects, grasses and algae. Once green turtles reach 8 to 10 inches in length, they mostly eat sea grass and algae, the only sea turtle that is strictly herbivorous as an adult. Their jaws are finely serrated which aids them in tearing vegetation.

Habitat: Mainly stay near the coastline and around islands and live in bays and protected shores, especially in areas with seagrass beds. Rarely are they observed in the open ocean.

Nesting: Nest at intervals of about 2 years. They lay 3 to 5 nests per season, approximately 12 to 14 days apart. Lays an average of 100 to 126 eggs per nest. Eggs incubate for about 60 days.

Range: Found in all temperate and tropical waters throughout the world.

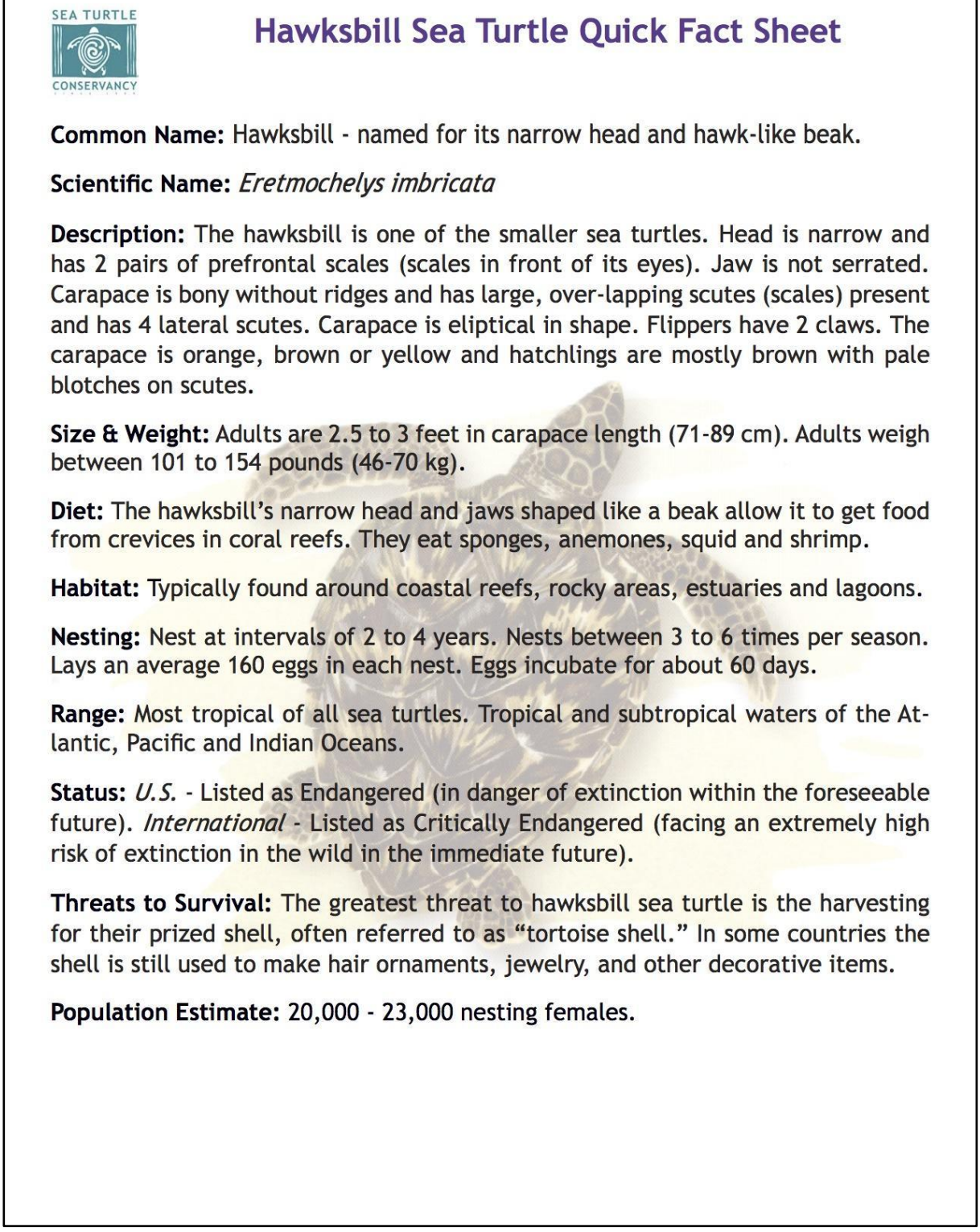
Status: *U.S.* - Listed as Endangered (in danger of extinction within the foreseeable future). *International* - Listed as Endangered (facing a very high risk of extinction in the wild in the near future).

Threats to Survival: The greatest threat is from the commercial harvest for eggs and food. Other green turtle parts are used for leather and small turtles are sometimes stuffed for curios. Incidental catch in commercial shrimp trawling is an increasing source of mortality

Population Estimate: 85,000 - 90,000 nesting females.

(Source: "Educational initiatives: Outreach materials: Sea turtle fact sheets," 2015)

Figure 14: Hawksbill Sea Turtle Quick Fact Sheet



SEA TURTLE CONSERVANCY

Hawksbill Sea Turtle Quick Fact Sheet

Common Name: Hawksbill - named for its narrow head and hawk-like beak.

Scientific Name: *Eretmochelys imbricata*

Description: The hawksbill is one of the smaller sea turtles. Head is narrow and has 2 pairs of prefrontal scales (scales in front of its eyes). Jaw is not serrated. Carapace is bony without ridges and has large, over-lapping scutes (scales) present and has 4 lateral scutes. Carapace is eliptical in shape. Flippers have 2 claws. The carapace is orange, brown or yellow and hatchlings are mostly brown with pale blotches on scutes.

Size & Weight: Adults are 2.5 to 3 feet in carapace length (71-89 cm). Adults weigh between 101 to 154 pounds (46-70 kg).

Diet: The hawksbill's narrow head and jaws shaped like a beak allow it to get food from crevices in coral reefs. They eat sponges, anemones, squid and shrimp.

Habitat: Typically found around coastal reefs, rocky areas, estuaries and lagoons.

Nesting: Nest at intervals of 2 to 4 years. Nests between 3 to 6 times per season. Lays an average 160 eggs in each nest. Eggs incubate for about 60 days.

Range: Most tropical of all sea turtles. Tropical and subtropical waters of the Atlantic, Pacific and Indian Oceans.

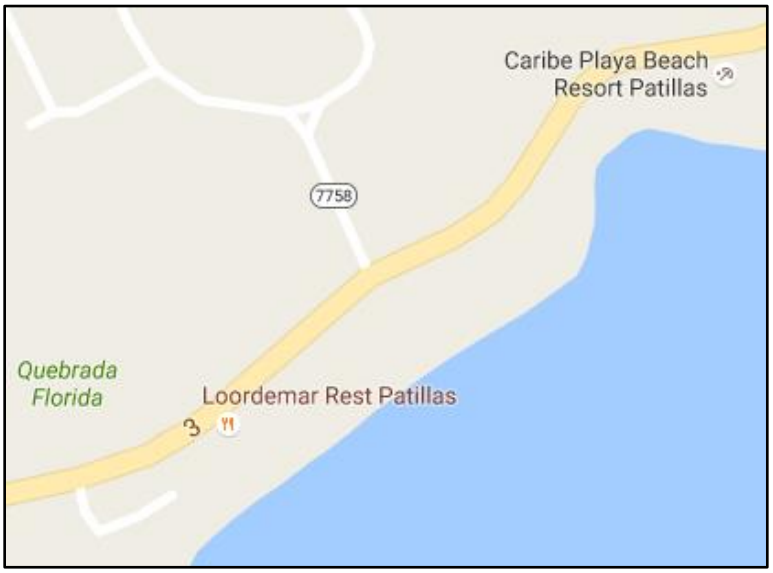
Status: *U.S.* - Listed as Endangered (in danger of extinction within the foreseeable future). *International* - Listed as Critically Endangered (facing an extremely high risk of extinction in the wild in the immediate future).

Threats to Survival: The greatest threat to hawksbill sea turtle is the harvesting for their prized shell, often referred to as "tortoise shell." In some countries the shell is still used to make hair ornaments, jewelry, and other decorative items.

Population Estimate: 20,000 - 23,000 nesting females.

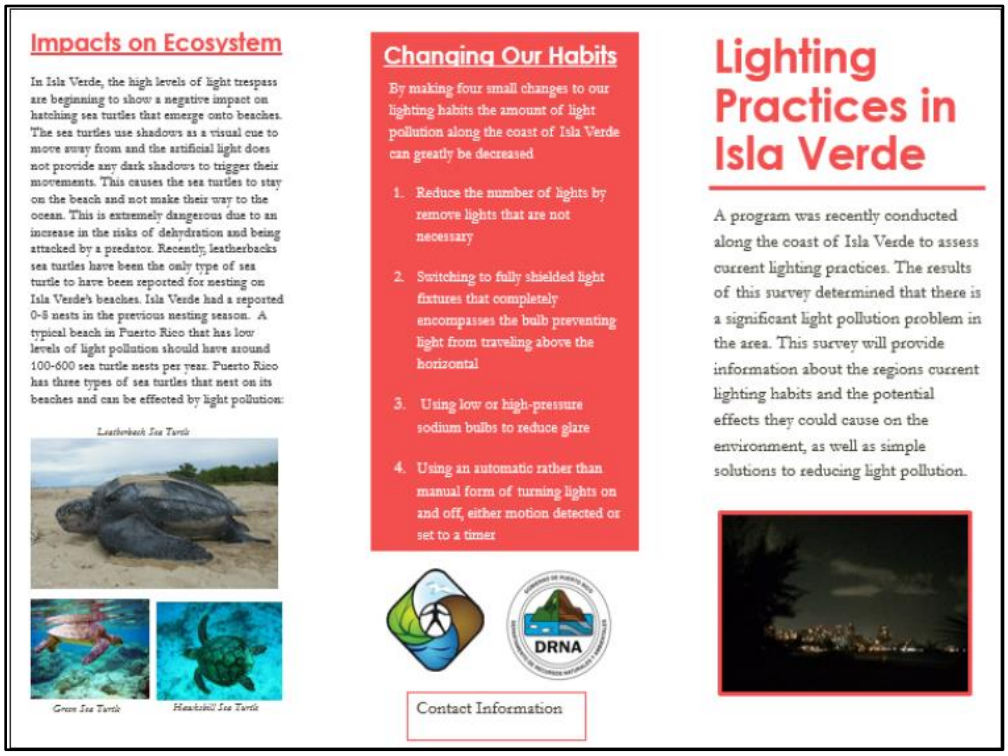
(Source: "Educational initiatives: Outreach materials: Sea turtle fact sheets," 2015)

Figure 16: Google Map of Patillas



(Source: https://www.google.com.pr/maps/@17.9749275,-65.9366335,16.68z)

Figure 18a: Isla Verde Light Pollution Brochure (page one)



Impacts on Ecosystem

In Isla Verde, the high levels of light trespass are beginning to show a negative impact on hatching sea turtles that emerge onto beaches. The sea turtles use shadows as a visual cue to move away from and the artificial light does not provide any dark shadows to trigger their movements. This causes the sea turtles to stay on the beach and not make their way to the ocean. This is extremely dangerous due to an increase in the risks of dehydration and being attacked by a predator. Recently, leatherbacks sea turtles have been the only type of sea turtle to have been reported for nesting on Isla Verde's beaches. Isla Verde had a reported 0-8 nests in the previous nesting season. A typical beach in Puerto Rico that has low levels of light pollution should have around 100-600 sea turtle nests per year. Puerto Rico has three types of sea turtles that nest on its beaches and can be effected by light pollution:

Leatherback Sea Turtle

Green Sea Turtle

Hawksbill Sea Turtle

Changing Our Habits

By making four small changes to our lighting habits the amount of light pollution along the coast of Isla Verde can greatly be decreased

1. Reduce the number of lights by remove lights that are not necessary
2. Switching to fully shielded light fixtures that completely encompasses the bulb preventing light from traveling above the horizontal
3. Using low or high-pressure sodium bulbs to reduce glare
4. Using an automatic rather than manual form of turning lights on and off, either motion detected or set to a timer

DRNA

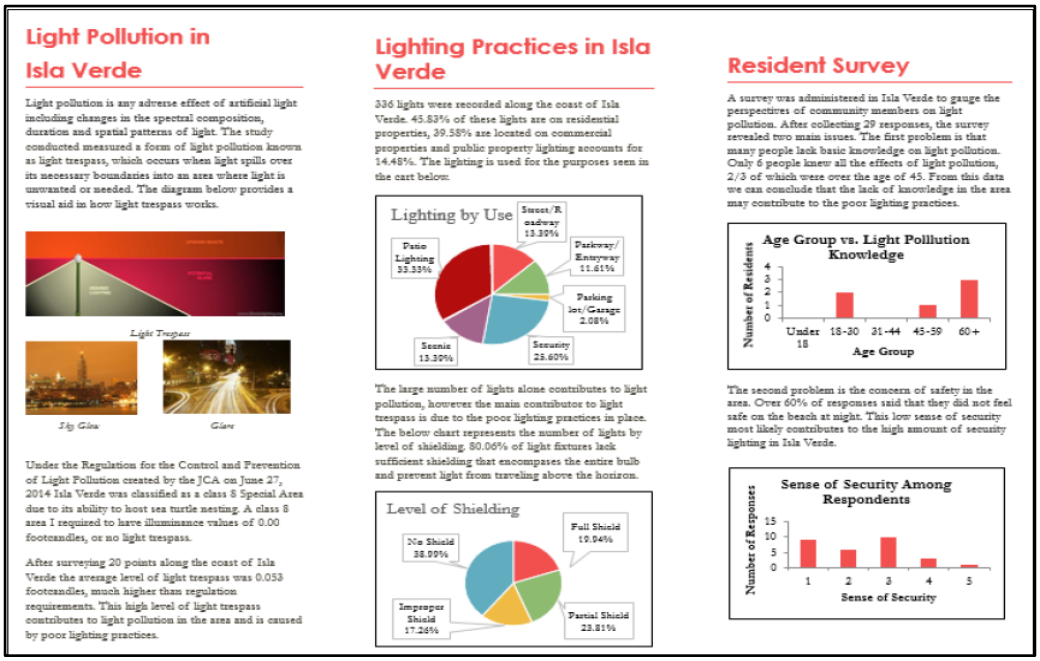
Contact Information

Lighting Practices in Isla Verde

A program was recently conducted along the coast of Isla Verde to assess current lighting practices. The results of this survey determined that there is a significant light pollution problem in the area. This survey will provide information about the regions current lighting habits and the potential effects they could cause on the environment, as well as simple solutions to reducing light pollution.

(Gabriel, Greenbaum, Holmes, Ouellette. 2014)

Figure 18b: Isla Verde Light Pollution Brochure (page two)



(Gabriel, Greenbaum, Holmes, Ouellette. 2014)

Figure 24: Phase 2 of Isla Verde

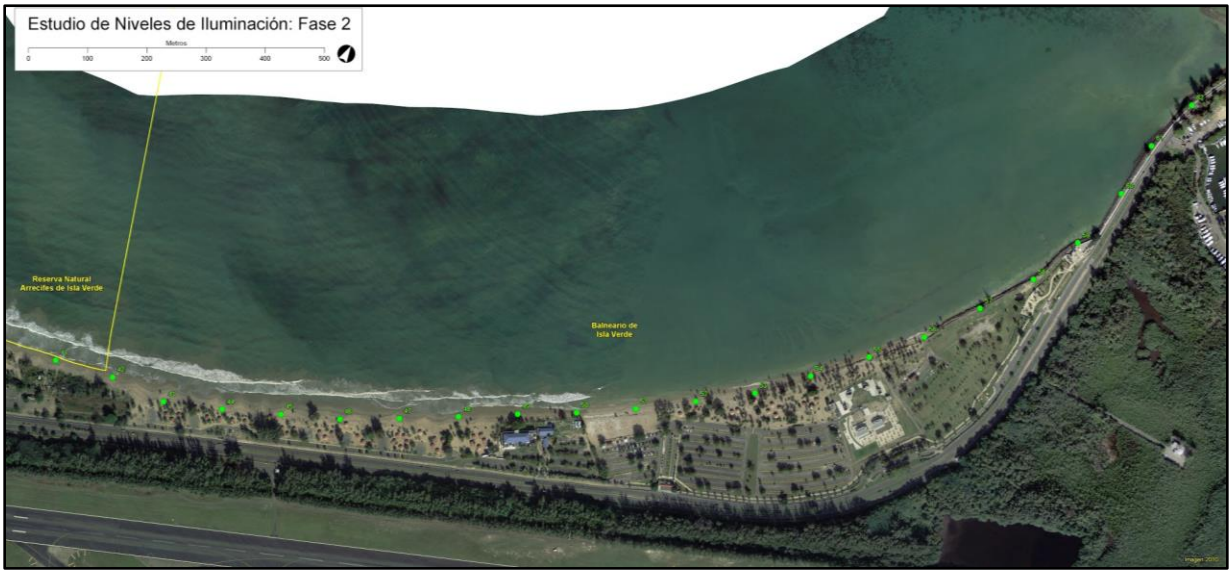


Figure 25: Phase 3 of Isla Verde

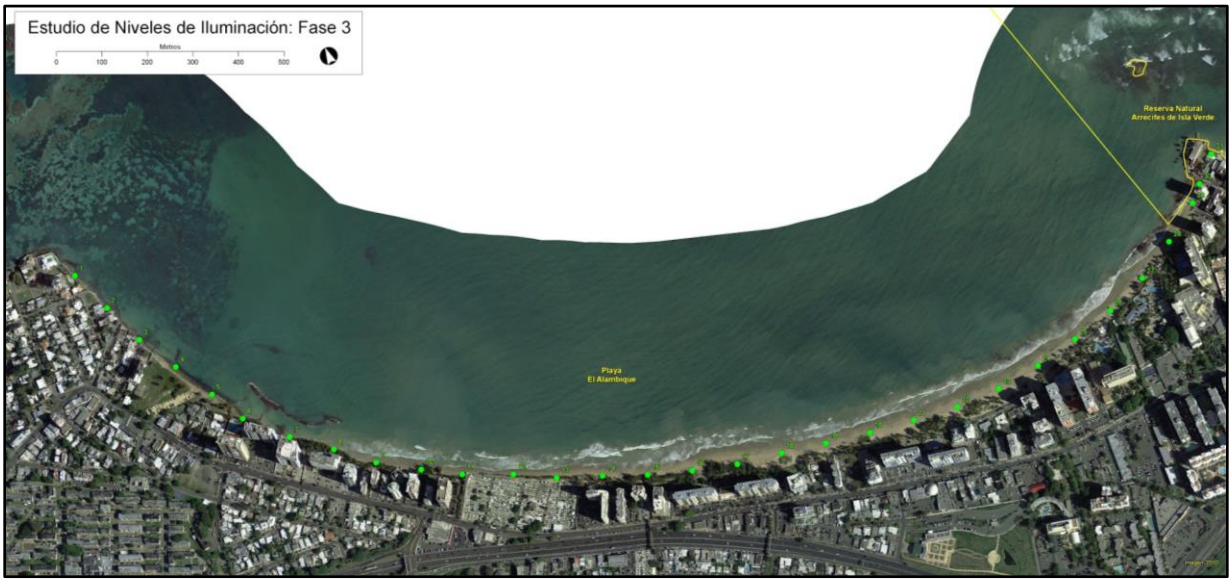


Table 1: SQM Data from Isla Verde

Location	SQM	Ave. Temp (°C)	Reading 1	Reading 2	Reading 3	Reading 4	Reading 5	Reading Average	Total Average
1	A	22.6	18.23	17.94	18.25	18.28	18.16	18.17	18.32
	B	24.0	18.45	18.44	18.46	18.45	18.51	18.46	
2	A	24.0	18.31	18.35	18.31	18.33	18.39	18.34	18.34
	B	25.0	18.33	18.35	18.36	18.38	18.30	18.34	
3	A	26.0	18.25	18.26	18.30	18.28	18.26	18.27	18.30
	B	26.0	18.28	18.41	18.33	18.37	18.26	18.33	
4	A	28.0	18.11	18.01	17.90	17.88	18.05	17.99	18.17
	B	28.0	18.34	18.28	18.36	18.38	18.39	18.35	
5	A	28.0	18.06	17.89	17.91	18.06	18.00	17.98	18.09
	B	28.0	18.18	18.18	18.20	18.23	18.21	18.20	
6	A	28.0	18.01	17.83	17.98	17.92	17.92	17.93	18.02
	B	28.0	18.19	17.95	18.12	18.12	18.17	18.11	
7	A	28.0	17.87	17.87	17.92	17.89	17.82	17.87	17.97
	B	28.0	18.06	18.04	18.05	18.05	18.08	18.06	
8	A	29.0	17.81	17.83	17.75	17.80	17.91	17.82	17.95
	B	28.00	18.14	18.08	18.04	18.05	18.06	18.074	
9	A	29.0	17.81	17.78	17.78	17.81	17.79	17.79	17.91
	B	28.0	18.02	17.99	18.03	18.01	18.06	18.02	
10	A	29.0	17.82	17.81	17.75	17.81	17.70	17.78	17.86
	B	28.0	17.92	17.93	17.96	17.95	17.97	17.95	
11	A	29.0	17.71	17.56	17.57	17.59	17.51	17.59	17.74
	B	28.0	17.79	17.91	17.92	17.89	17.95	17.89	
12	A	29.0	17.59	17.47	17.50	17.43	17.44	17.49	17.62
	B	28.0	17.80	17.76	17.75	17.76	17.74	17.76	
13	A	29.0	17.54	17.42	17.41	17.40	17.40	17.43	17.56
	B	28.0	17.65	17.65	17.69	17.72	17.70	17.68	
14	A	29.0	17.39	17.36	17.25	17.23	17.34	17.31	17.42
	B	28.0	17.49	17.54	17.52	17.53	17.55	17.53	
15	A	29.0	17.11	16.68	17.14	17.19	17.19	17.06	17.27
	B	28.0	17.57	17.57	17.42	17.43	17.41	17.48	
16	A	29.0	17.34	17.25	17.23	17.12	17.19	17.23	17.31
	B	28.0	17.41	17.43	17.38	17.39	17.40	17.40	
17	A	29.0	17.34	17.20	17.20	17.10	17.17	17.20	17.23
	B	28.0	17.23	17.26	17.24	17.24	17.27	17.25	
18	A	29.0	17.16	17.18	17.01	17.15	17.14	17.13	17.17
	B	28.0	17.23	17.24	17.21	17.17	17.24	17.22	
19	A	29.0	17.17	17.13	17.10	17.07	17.11	17.12	17.17
	B	28.0	17.26	17.21	17.21	17.21	17.24	17.23	

*all units are in magnitude per square arc second unless specified otherwise

Appendix B - Rule 13 Letter H from Regulations for the Control and Prevention of Light Pollution (English Translation)

RULE 13 - KINDS OF OUTDOOR LIGHTING

Kinds of foreign and special areas, will be defined in the classification map of outdoor Areas and special, whose final version shall be taken by the Planning Board. As long as this does not happen, the same will be demarcated in accordance with what has the law No. 218. These classes are listed below according to their characteristics of lighting:

Letter H. class 8 - Special Area for the beaches used by sea turtles - special area comprising all the coastline which serves as a place of nesting and spawning grounds for sea turtles in their annual visit by the coasts of Puerto Rico.

In addition to the requirements for the lighting of public origin expressed in of this regulation, the value of lighting in the vertical plane, taken outside the border of the illuminated property, must not be greater than 0. 05fc. If necessary the use of lighting for security purposes, all lighting that produces light that is visible from the area described in this class, will be limited to the use of the following luminaires: low pressure (LPS) 18w maximum 35w sodium; diodes (LED) red, orange or amber (true red, orange or amber, filters); true red neon; or other fixtures that produce light of 560 nm or more. It is the statutory requirement to place permanently protective visors that prevent as far as possible the direct incidence of light to sea turtle nesting beaches as delimited by the agencies with jurisdiction. The EQB may require adjacent landowners to

develop and maintain vegetative barriers such as elements of a system of shadows that reduce and mitigate the lighting to these shores.

All fixture in this class, adjacent to another kind of lower lighting requirement, must comply with the lighting level lower than those that apply to each class.

Appendix C - Unihedron Sky Quality Meter - L

Thank you for purchasing a Sky Quality Meter (SQM-L) from Unihedron!

Features

The SQM-L has the following features:

- It is sensitive only to visual light (there is a near-infrared blocking filter in front of the sensor).
- The effects of temperature on the "dark frequency" of the sensor are removed.
- The effects of temperature on the microcontroller oscillator are removed.
- It is protected against accidental reversal of battery polarity.
- Each SQM-L is calibrated using a NIST-traceable light meter. The absolute precision of each meter is believed to be ±10% (±0.10 mag/arcsec²). The difference in zeropoint between each calibrated SQM-L is typically ±10% (±0.10 mag/sq arcsec)
- The brightness of the numeric LED display has two (automatic) settings. Under dark skies, you won't have your dark adaption ruined by use of your SQM-L! Under urban skies, the display will be correspondingly brighter.
- A repeating audible beep indicates when a measurement is in progress.
- Any kind of 9V battery is usable. The SQM-L contains a voltage regulator to power the sensor, microcontroller and other components.
- After reading is taken and displayed, the meter automatically turns itself off.
- The Half Width Half Maximum (HWHM) of the angular sensitivity is ~10°. The Full Width Half Maximum (FWHM) is then ~20°. The sensitivity to a point source ~19° off-axis is a factor of 10 lower than on-axis. A point source ~20° and ~40° off-axis would register 3.0 and 5.0 magnitudes fainter, respectively.

✳ ✷ ✳

Quick Start

The SQM-L is very simple to use. Point the lens towards the zenith. Press the Start button once and release. Under urban skies, a reading will be displayed almost immediately. Under the very darkest conditions (no moon in the sky, far from civilization) the meter may take up to a minute to complete its measurement. Please ensure that you maintain the orientation of the meter until the reading is displayed.
The SQM-L's reading is indicative of the sky brightness within its field of view. There must be no direct illumination or shading of the sensor by a terrestrial light source if the reading is to be meaningful.

✳ ✷ ✳

Typical Readings

Magnitudes per square arcsecond is a logarithmic measurement. Therefore large changes in sky brightness correspond to relatively small numerical changes. A difference of 1 magnitude is defined to be a factor of $(100)^{(1/5)}$ in received photons. Therefore a sky brightness 5.0 mag/arcsec² fainter corresponds to a reduction in photon arrival rate of a factor of 100.

The following schematic gives a rough idea of of how to interpret the readings:

At the darkest sites, natural variations in conditions such as airglow and the brightness of the zodiacal light are limiting factors.

* * *

Temperature reading

The temperature in °C then °F are displayed when you press and hold the button a second time. Also, the model and serial number are displayed after the temperature.

* * *

Care of your SQM-L

The SQM-L is a fairly simple and robust device. Avoid dropping, immersing, and compressing it and it will give you years of dependable service. Keep the faceplate clean and ensure that the battery still has useful capacity. If you have left your SQM-L for a long period of time (i.e. years) and see a white, powdery substance around one of the battery contacts, your battery will need to be replaced and the contacts cleaned before you can expect reliable operation.

The SQM-L should not be negatively affected by dew during normal operation EXCEPT for the reduction in received light by the sensor. Make sure that the sensor faceplate has been wiped before making measurements.

During storage, make sure that the push-button is not being continuously pressed since the meter will draw current from the battery and drain it in that situation.

Do not point the meter at the Sun.

* * *

Troubleshooting

After I push the button, no reading is displayed.

Are you in a very dark location?

Yes → The Sky Quality Meter may take up to a minute to acquire a reading when the sky is very dark. If your meter is operating properly, you will here a soft beeping sound while the measurement is in progress. When complete, the sky brightness will be displayed for a fixed number of seconds.

No → Your 9V battery may need to be replaced.

OR

The connector to your 9V battery may be loose.

If, after you have checked for both of these possibilities and your SQM-L still won't display a reading under normal operating conditions, contact Unihedron for further information and a possible replacement.

I don't know how to make sure the SQM-L is off.

The SQM-L functions in such a way that it is only temporarily on and turns itself off automatically. This is a design feature to maximize battery life.

The readings don't repeat exactly.

Are you pointing the SQM-L in the same direction each time? Under dark conditions, you must keep the SQM-L pointed in the same direction until the reading appears on the LED display.

Your SQM-L must be pointed at an angle sufficiently high above the horizon that it will not detect light directly from terrestrial sources (cars, buildings, streetlights). It is normally the zenith sky brightness which is measured.

The readings do not change when pointing to various parts of the night sky.

Each SQM-L reading must be initiated by pressing the button. The displayed reading will stay on for 10 seconds before shutting down. After the unit has shut down, press the button to initiate another reading.

The readings are numerically lower (brighter) than expected.

Make sure that no stray light from street lights or other sources directly illuminates the lens/sensor.

The readings are numerically higher (darker) than expected.

Make sure that nothing shades the field of view of the lens/sensor (such as a tall stand of trees or the side of a building).

When I use the meter during the day, all I see is a ∩∩∩∩ on the display.

The SQM-L has a fantastically large range over which it will report accurate sky brightnesses. However, to be sensitive in the darkest conditions, it is necessary to sacrifice the ability to record daytime sky surface brightnesses. Normal lux meters can be used in such circumstances once the effective solid angle for the lux meter's sensor is known. The ∩∩∩∩ indicates that the sensor is saturated.

All I see is a UUUU on the display.

The UUUU indicates that the sensor was unable to produce a reading. This can occur in a light-tight dark room or if the sensor is faulty.

Sometimes the first reading is different.

As the temperature of the unit changes slightly due to being powered up, the very first reading may be slightly higher than the following readings. Ignore this first reading and average the following ones for the most accurate value.

Other scales

To convert the SQM-L mag/arcsec² reading to cd/m², use the following formula:

$$[cd/m^2] = 10.8 \times 10^4 \times 10^{(-0.4*[mag/arcsec2])}$$

Unanswered Questions

Help us to inform you and other customers better by forwarding unanswered questions about the SQM-L and measuring light pollution to:

info@unihedron.com

Further Information

Check the Unihedron.com website for updates and additional information.

Mailing List

Join the SQM mailing list for notifications and to share experiences with other users by sending an e-mail to:

sqm-subscribe@unihedron.com

* * *

Contact Information

Unihedron
4 Lawrence Ave
Grimsby, ON L3M 2L9
Canada
Tel: (905) 945-1197

* * *

Unihedron is a proud member of the International Dark-Sky Association (www.ida.org) and supports its goals. Please consider joining to help preserve the beauty of the night sky for future generations.

* * *

Warranty

Unihedron warrants this product 1 year.

* * *

Last updated: February 11, 2008

Appendix D - Field Collection Checklist

The checklist that we will be using out in the field when evaluating the lighting fixtures

Light Identification Number:

Photo Number (in camera):

On or Off at night (circle): ON OFF

Quantity of light fixture on the property:

Property Letter and Address:

Type of Light Fixture: dome spotlight flood light street light

area light wall pack pickle jar

Other:_____

Application: Street Path Patio Garden Scenic Sports

Parking Lot Entrance Enhancement Recreational Security

Other:_____

Light Color: Warm White Bright White Yellow Orange

Other Descriptions: _____

Direction of Light (circle all that apply): Upward Downward Exceeds 70 grades

Other: _____

Full Cutoff Shield: Yes No

Compliance with Lighting Ordinance (No. 218): Yes No

Photometer Readings: 1) _____ 2) _____ 3) _____

4) _____ 5) _____ Avg: _____

Possible Modifications :

Additional Comments:

Appendix E - Using the Photometer

Each model of photometer is slightly different; however, they all assemble in similar fashions and perform relatively the same functions. Each device has an external light sensor that connects to the meter through a short cable.

Before powering the devices on, it is necessary to note the calibration of the device. Most light meters are factory calibrated and must be sent to the manufacturer annually to be recertified and calibrated. To see whether the meter requires this or not, see the manual for the meter and/or any Certificates of Calibration provided with the device. Other meters are factory calibrated, but perform a "zero adjustment" each time they are started and at certain intervals while they are running. To perform this "zero adjustment", you usually need to connect the light sensor and start the device; however, it is important that you read the manual for your light meter to understand any device-specific instructions.

The standard unit for measuring light is the foot-candle. The meter reads in different units, and this is usually changed by either toggling through a variety of units through a "Units" button or switch. The LCD interface generally indicates which unit has been selected.

There are many buttons for performing different operations on different types of meters. For this methodology, however, only the "Hold" function of the light meter is necessary. This button is standard on nearly all instantaneous photometers. The measurements must be performed in the standard illuminance measurement mode, not a tangential or differential mode that may be provided on the meter.

Appendix F – Survey Questions

English Version

Personnel of the Light Pollution Division of the Environmental Quality Board are doing a study on the use of outdoor lighting in the special areas by the beaches of nesting marine turtles, the study includes the area where you are located.

As part of the study, we are conducting a brief survey to learn the opinion of residents and visitors about the practices and use of outdoor lighting on your property and in the community. Its participation, by completing the questionnaire online, is voluntary and all the answers are anonymous. Your help will be very useful for this project and the study on the issue of light pollution in Puerto Rico.

Many thanks for your participation. For more details you can communicate with our offices by phone at (787) 767-8181 ext. 3206 or by email at josealicea@jca.gobierno.pr.

1. Age Group (in years)

	Female	Male
19 or less	☐	☐
20 to 29	☐	☐
30 to 39	☐	☐
40 to 49	☐	☐
50 to 59	☐	☐
60 or more	☐	☐

2. Type of property where you reside in this area
   - ☐ House
   - ☐ Condominium
   - ☐ "Walk-Up"
   - ☐ Visitor (non-resident)
   - ☐ Commercial/Business
   - ☐ Other _____

3. Do you know if there is any law or regulation in Puerto Rico about Light Pollution caused by the use of outdoor lighting?

- ☐ Yes
- ☐ No
- ☐ Not Sure

4. Mention 3 things that come to mind when you hear the term “Light Pollution”.
   i. _____
   ii. _____
   iii. _____

5. Regarding the use of outdoor light by your home or residence, select all that apply to your property.
   - ☐ to illuminate any kind of structure or installation
   - ☐ to illuminate gardens
   - ☐ Parking Lot Lighting
   - ☐ to illuminate pedestrian areas (e.g. sidewalks, paths, pavements)
   - ☐ to illuminate the exterior of single-family and multi-family homes
   - ☐ to illuminate with a purpose to provide a sense of security
   - ☐ to illuminate water or sand
   - ☐ to illuminate a pool
   - ☐ other (specify) _____

6. Of the following options, rank the order of importance (1 being the greatest, 8 being the least) that you would take in your home or business to correct the situation with outdoor lighting that could be causing problems of lighting to the community or to the environment.
   _____ Turn off exterior lights that are causing the problem permanently
   _____ Change the outdoor lighting with a new, better design
   _____ Hire an electrician or architect for recommendations and corrections
   _____ Modify the existing lighting to correct the issue
   _____ Manually turn off the lights that cause the problem after a certain time
   _____ Put a motion sensor to turn on and off automatically
   _____ Plant vegetation that act as a barrier to the light but not out of my property
   _____ None of the above

7. Regarding the use of outdoor residential or commercial lighting that is visible at night from the beaches, select the option you agree most with.
   - ☐ Affects the visibility of the stars and coastal environment at night

- ☐ More illumination on the beaches at night is required to improve the recreational use and security
- ☐ Must be controlled and modified to reduce the magnitude of the problem in these areas
- ☐ Produces disorientation of the adult sea turtles and newly hatched sea turtles because they are attracted towards the lights
- ☐ None is a priority because visible lights are required to be removed or modified
- ☐ Other (specify) _____

8. How much money are you willing to invest to modify the lighting fixtures of your home or business to correct outdoor lighting problems?
   - ☐ $0 (not willing to spend money for modifications)
   - ☐ $1 - $50
   - ☐ $51 - $100
   - ☐ $100 - $200
   - ☐ more than $200

9. Which of the following modifications would you be willing to make to your light fixtures to prevent the excess impacts of lighting on the coastal night environment (Select all that apply)?
   - ☐ Add a cover to the fixture to eliminate the amount of visible light from the beach
   - ☐ Paint any part of an existing light fixture cover to eliminate the amount of visible light from the beach
   - ☐ Change the angle of the light or focus it downward
   - ☐ Replace the bulb with a different color and more efficient bulb according to the law or regulation applicable
   - ☐ Replace the light fixture completely with a new one that complies with the law and applicable regulations
   - ☐ Put a motion sensor on the light fixture
   - ☐ Put a plant or shrub barrier so that the light fixture is less visible
   - ☐ None of the above changes (Would not make any changes)
   - ☐ Other (specify) _____

10. Of the following options, rank them in order of priority (1 being the greatest, 7 being the least) to indicate which would be the reason or reasons that would move you to take corrective measures for the use of outdoor lighting on your property.

_____ To avoid receiving a fine or penalty from the government
_____ To help save a species in danger of extinction
_____ To save money on energy costs
_____ To improve the quality of the night sky and to see the stars
_____ To improve the aesthetic quality of the outdoor lighting that is used on my property
_____ To create a more natural night environment around my home
_____ none of the above

Spanish Version

EQB-WPI_2016

Personal de la División de Contaminación Lumínica de la Junta de Calidad Ambiental están realizando un estudio sobre el uso de alumbrado exterior en las Zonas de Iluminación Especial por ser playas de anidación de tortugas marinas, estudio que incluye el área donde usted se encuentra.

Como parte del estudio, estamos realizando una breve encuesta para conocer la opinión de los residentes y visitantes sobre las prácticas y uso de la iluminación exterior en su propiedad y en la comunidad. Su participación, completando el cuestionario en línea, es voluntaria y todas las respuestas son anónimas. Su ayuda será de gran utilidad para este proyecto y el estudio del tema de la contaminación lumínica en Puerto Rico.

Muchas gracias por su participación. Para más detalles se puede comunicar con nuestras oficinas al (787) 767-8181 ext. 3206 o en josealicea@jca.gobierno.pr .

1. Grupo de Edad (años)

	Femenio	Masculino
19 o menos	○	○
20 a 29	○	○
30 a 39	○	○
40 a 49	○	○
50 a 59	○	○
60 o mas	○	○

2. Tipo de propiedad donde reside en esta zona

- ○ Casa
- ○ Condominio
- ○ "Walk up"
- ○ Visitante (no residente)
- ○ Comercial
- ○ Otro (especifique)

3. ¿Conoce si hay alguna Ley o Reglamento en Puerto Rico sobre contaminación ambiental causada por el uso de iluminación exterior?

- ○ Sí
- ○ No
- ○ No sé

4. Mencione 3 cosas que le vienen a la mente cuando escucha el termino "contaminación lumínica"

1)
2)
3)

5. Sobre el uso de iluminación exterior en su hogar y residencial, seleccione los que apliquen a su propiedad.

- [ ] Alumbrar fachadas de estructuras e instalaciones de todo tipo.
- [ ] Alumbrar jardines.
- [ ] Alumbrar estacionamientos.
- [ ] Alumbrar áreas peatonales (e.g. aceras, veredas, caminos).
- [ ] Alumbrar el exterior de residencias unifamiliares y multifamiliares
- [ ] Alumbrar con propósitos de proveer sentido de seguridad.
- [ ] Iluminación del agua o la arena.
- [ ] Iluminación para piscina o fuente.
- [ ] Otro (especifique)

6. De las siguientes opciones, indique en orden de prioridad (1 siendo la mayor), las medidas que tomaría usted en su hogar o negocio para corregir alguna situación con alumbrado exterior que pudiera estar causando problemas de iluminación al vecino o al medioambiente.

- ⠿ [ ] Apagar de forma permanente las luces exteriores que causen el problema.
- ⠿ [ ] Cambiar las luces exteriores por otras nuevas con un mejor diseño.
- ⠿ [ ] Modificar las luces existentes para corregir el asunto.
- ⠿ [ ] Contratar los servicios de un electricista o arquitecto para recomendaciones y correcciones.
- ⠿ [ ] Manualmente apagar la luces que causen el problema despues de cierta hora.
- ⠿ [ ] Ponerle un sensor de movimiento para que apaguen y prendan solas.
- ⠿ [ ] Sembrar vegetación que actue como barrera para que la luz no salga de mi propiedad.
- ⠿ [ ] Ninguna de las anteriores.

7. Sobre el uso de iluminación residencial o comercial exterior que es visible en la noche desde las playas seleccione con las que esta de acuerdo:

- ◯ Afecta la visibilidad de las estrellas y al ambiente costero nocturno.
- ◯ Es necesaria más iluminación en las playas de noche para mejorar el uso recreativo de las mismas y seguridad.
- ◯ Debe ser controlada y modificada para reducir la magnitud de la problemática en dichas áreas.
- ◯ Produce desorientación de las tortugas marinas adultas y recién nacidas porque son atraídas hacia ellas.
- ◯ No es prioridad para mí el que se elimine o modifiquen las luminarias visibles, ya que siempre son necesarias.
- ◯ Otro (especifique)

8. ¿Cuánto dinero estarías dispuesto a invertir para modificar las luminarias de tu hogar o negocio para corregir problemas de iluminación exterior?

- ◯ $0 (No estoy dispuesto a gastar dinero para modificaciones)
- ◯ $1-$50
- ◯ $51-$100
- ◯ $100-$200
- ◯ Más que $200

9. ¿Cuál de las siguientes modificaciones estarías dispuesto a hacer a tus luminarias para impedir que el exceso de iluminación impacte el ambiente costero nocturno? (Seleccione todas las que apliquen).

- [ ] Añadir una vicera o "cover" a la luminaria que tengo para que no sea visible desde la playa.
- [ ] Pintar parte de cobertor de la luminaria existente para que no sea visible desde la playa.
- [ ] Cambiar el ángulo de la luz o focalizarla hacia abajo.
- [ ] Sustituir la bombilla por el color y nivel de brillantes apropidad segun la Ley o reglamento aplicable.
- [ ] Sustituir la lámpara completamente por una nueva que cumpla con la ley y reglamento aplicable.
- [ ] Poner sensor de movimiento para que paguen y prendan solas.
- [ ] Sembrar una barrera de plantas o arbustos para evitar sean visibles.
- [ ] Ninguna de las anteriores. No haria cambios.
- [ ] Otro (especifique)

10. De las siguientes opciones, en orden de prioridad (#1 siendo el de mayor prioridad), indique cual sería la razón o razones que le motivarían a usted a tomar medidas correctivas para el uso de iluminación exterior en su propiedad.

- Evitar recibir una multa o penalidad del gobierno.
- Ayudar a salvar una especie en peligro de extinción.
- Para ahorrar dinero en costos energético.
- Para mejorar la calidad del cielo nocturno y se puedan ver las estrellas.
- Para mejorar la calidad estética de la iluminación exterior que uso en mi propiedad.
- Para crear un ambiente nocturno más natural en mi propiedad.
- Ninguna de las anteriores.

Appendix G - Inventory

Isla Verde Inventory

Light ID #	Quantity	Property	Address	Photo	Photo (Zoom)	Type	Light Application	Light Color	Angle exceeds 70 degrees	Full Cutoff Shield	Complies with Regulation	Average Photometer Reading (fc)	Recommendations
102-003	3	A	6165 Av. Isla Verde			Floodlight	Path/ Garden/ Security	Bright White	Yes	Yes	1/3	3.528	Correct angle Add shield Change light bulb
102-006	1	A	6165 Av. Isla Verde			Floodlight	Path/ Garden/ Security	Unknown	Yes	No	0/3		Correct angle Add shield Change light bulb
102-008	1	A	6165 Av. Isla Verde			Area Light	Path/ Garden/ Security	Unknown	Yes	No	0/3		Paint existing shield Add shield Change light bulb
102-010	1	A	6165 Av. Isla Verde			Floodlight	Security/ Recreation	Bright White	Yes	Yes	1/3	no reading detected	Correct angle Add shield Change light bulb
102-012	42	A	6165 Av. Isla Verde			Dome	Patio	Warm Orange and Warm White	Yes	No	0/3	no reading detected	Add shield Change light bulb
102-014	1	A	6165 Av. Isla Verde			Floodlight	Path/ Garden/ Security	Bright White	Yes	Yes	1/3	1.956	Correct angle Add shield Change light bulb
102-016	7	A	6165 Av. Isla Verde			Area Light	Path/ Garden/ Security	Warm White	Yes	No	0/3	no reading detected	Add shield Change light bulb
102-018	5	A	6165 Av. Isla Verde			Floodlight	Security	Unknown	Yes	Yes	1/3		Correct angle Add shield Change light bulb
102-020	2	A	6165 Av. Isla Verde			Dome	Security/ Entrance	Warm White	Yes	No	0/3	no reading detected	Paint existing shield Add shield Change light bulb
102-022	2	A	6165 Av. Isla Verde			Dome	Security/ Entrance	Warm Orange	Yes	No	1/3	no reading detected	Paint existing shield Add shield
102-024	17	A	6165 Av. Isla Verde			Spotlight	Scenic/ Garden	Blue	Yes	Yes	1/3	0.656	Change angle Change light bulb
102-027	72	B	9 Calle Gardenia			Dome	Patio	Warm White, Warm Orange, Blue	Yes	No	0/3	no reading detected	Paint existing shield Add shield Change light bulb
102-032	2	B	9 Calle Gardenia			Floodlight	Parking Lot/ Security	Bright White	Yes	Yes	1/3	6.882	Correct angle Add shield Change light bulb
102-035	5	B	9 Calle Gardenia			Street Light	Parking Lot/ Security	Warm White	Yes	No	0/3	1.042	Add shield Change light bulb
102-037	2	C	1 Calle Amapola			Area Light	Parking Lot/ Security	Bright White	Yes	No	0/3	1.164	Paint existing shield Add shield Change light bulb
102-039	4	C	1 Calle Amapola			Floodlight	Parking Lot/ Security	Bright White	Yes	No	0/3	0.648	Correct angle Add shield Change light bulb
102-043	1	C	1 Calle Amapola			Dome	Entrance/ Security	Warm White	Yes	No	0/3	2.282	Add shield Change light bulb
102-045	2	C	1 Calle Amapola			Floodlight	Path/ Security	Warm Orange	Yes	Yes	2/3	7.328	Correct angle Add shield
102-047	47	C	1 Calle Amapola			Dome	Patio	Warm White, Warm Orange	Yes	No	0/3	no reading detected	Add shield Change light bulb
102-049	3	C	1 Calle Amapola			Dome	Entrance	Bright White	Yes	No	0/3	2.742	Add shield Change light bulb
102-051	1	C	1 Calle Amapola			Wall Light	Entrance/ Scenic	Unknown	Yes	No	0/3		Paint existing shield Add shield Change light bulb
102-0634	5	D	Calle Gardenia			Wall Light	Path/ Security	Bright White	Yes	No	0/3	0.112	Correct angle Paint existing shield Add shield Change light bulb
102-0636	4	D	Calle Gardenia			Wall Light	Path/ Security	Bright White	Yes	No	0/3	0.48	Paint existing shield Add shield Change light bulb

102-055	2		Calle Amapola		Street Light	Road	Warm Orange	Yes	Yes	2/3	2.366	Add shield
102-057	1	E	End of Calle Amapola		Floodlight	Parking Lot	Unknown	Yes	Yes	1/3		Correct angle Add shield Change light bulb
102-059	50	F	6 Calle Amapola		String Lights	Scenic	Warm Orange	Yes	No	1/3	0.796	Paint bulb Add shields Remove fixture
102-0868	1	F	6 Calle Amapola		Spotlight	Entrance	Warm Yellow	No	Yes	2/3	no reading detected	Change light bulb
102-064	8	F	6 Calle Amapola		Lantern	Path	Warm Orange	Yes	No	1/3	0.654	Add shield
102-0638	1	F	6 Calle Amapola		Canister Light	Path/ Parking Lot	Unknown	Unknown	Yes	1/3		Add shield Change light bulb
102-0640	1	F	6 Calle Amapola		Floodlight	Parking Lot	Bright White	Yes	Yes	1/3	0.818	Add shield Change light bulb
102-0642	1	F	6 Calle Amapola		Spotlight	Scenic/ Garden	Warm Yellow	Yes	Yes	1/3	no reading detected	Correct angle Add shield Remove fixture
102-066	3	G	8 Calle Amapola		Wall Light	Parking Lot/ Security	Warm Orange, Warm White	Yes	No	0/3	1.496	Add shield Paint existing shield Change light buld
102-068	2	G	8 Calle Amapola		Dome	Patio	Unknown	Yes	No	0/3		Add shield Change light bulb
102-0875	3	H	10 Calle Amapola		Floodlight	Parking Lot	Bright White	Yes	No	0/3	0.546	Correct angle Add shield Change light bulb
102-071	1	I	14 Calle Amapola		Floodlight	Scenic (beach)	Unknown	Yes	Yes	1/3		Correct angle Add shield Change light bulb
102-075	56	I	14 Calle Amapola		Dome	Patio	Unknown	Yes	No	0/3		Add shield Change light bulb
102-078	3	I	14 Calle Amapola		Floodlight	Parking Lot/ Security	Bright White	Yes	Yes	1/3	no reading detected	Add shield Change light bulb
102-0880	4	I	14 Calle Amapola		Wall Light	Patio/ Path	Bright White	Yes	No	0/3	0.224	Add shield Change light bulb
102-080	7	J	16 Calle Amapola		Pickle Jar	Patio	Warm Yellow	Yes	No	0/3	no reading detected	Paint existing shield Add shield Change light bulb
102-082	2	J	16 Calle Amapola		Floodlight	Entrance/ Security	Warm Orange	Yes	No	1/3	0.024	Paint existing shield Add shield
102-084	1	J	16 Calle Amapola		Floodlight	Scenic (beach)	Unknown	Yes	Yes	1/3		Correct angle Add shield Change light bulb
102-086	10	K	18 Calle Amapola		Dome	Patio	Unknown	Yes	No	0/3		Paint existing shield Add shield Change light bulb
102-088	1	K	18 Calle Amapola		Floodlight	Garden	Bright White	Yes	No	0/3	0.158	Correct angle Add shield Change light bulb
102-090	1		Calle Dalia		Street Light	Street	Warm Orange	Yes	Yes	2/3	0.504	Add shield
102-096	4	M	Calle Iris		Spotlight	Entertainment (bar)	Unknown	Yes	Yes	1/3		Correct angle Add shield Change light bulb
102-0100	10	M	Calle Iris		Floodlight	Sports	Bright White	Yes	Yes	1/3	0.406	Add shield Change light bulb
102-0102	3	M	Calle Iris		Floodlight	Entertainment/ Sports	Unknown	Yes	No	0/3		Correct angle Add shield Change light bulb

102-0104	4	M	Calle Iris			Dome	Path	Unknown	Yes	No	0/3		Add shield Change light bulb
102-0886	6	M	Calle Iris			Lantern	Path	Unknown	Yes	No	0/3		Add shield Change light bulb
102-0110	9	M	Calle Iris			Ceiling Strip Light	Path	Bright White	Yes	Yes	1/3	no reading detected	Add shield Change light bulb
102-0112	1	M	Calle Iris			Floodlight	Scenic (beach)	Unknown	Yes	Yes	1/3		Correct angle Add shield Change light bulb
102-0114	9	M	Calle Iris			Dome	Entertainment (restaurant)	Warm Orange	Yes	No	1/3	0.644	Paint existing shield Add shield Add window curtains
102-0117	1	M	Calle Iris			Floodlight	Entrance/ Security	Unknown	Yes	No	0/3		Correct angle Add shield Change light bulb
102-0119	4		Calle Violeta			Post light	Street	Warm Orange	Yes	No	1/3	0.062	Paint existing shield Add shield
102-0121	20	N	6961 Ave Gobernadores			Spotlight	Scenic/ Garden	Warm White	Yes	Yes	1/3	3.61	Correct angle Change light bulb
102-0228	18	N	6961 Ave Gobernadores			Lantern	Entertainment (restaurant)	Unknown	Yes	No	0/3		Add shield Change light bulb
102-0891	5	N	6961 Ave Gobernadores			Spotlight	Entertainment (restaurant)	Warm White	Yes	Yes	1/3	0.034	Correct angle Change light bulb
102-0230	1	N	6961 Ave Gobernadores			Post Light	Entertainment (pool)	Warm Yellow	Yes	No	0/3	no reading detected	Paint existing shield Add shield Change light bulb
102-0239	1	N	6961 Ave Gobernadores			Street Light	Path/ Security	Bright White	Yes	No	0/3	0.14	Add shield Change light bulb
102-0892	2	N	6961 Ave Gobernadores			Floodlight	Entrance/ Security	Bright White	Yes	No	0/3	no reading detected	Correct angle Add shield Change light bulb
102-0237	11	O	Calle Horizante			Floodlight	Parking Lot/ Security	Bright White	Yes	Yes	1/3	no reading detected	Add shield Change light bulb
102-0241	1	O	Calle Horizante			Floodlight	Entrance/ Security	Warm White	No	Yes	2/3	4.076	Change light bulb
102-0243	1	O	Calle Horizante			Floodlight	Security	Unknown	Unknown	Yes	1/3		Add shield Change light bulb
102-0245	1	O	Calle Horizante			Street Light	Entertainment	Unknown	Yes	Yes	1/3		Add shield Change light bulb
102-0247	12	O	Calle Horizante			Dome	Path/ Security	Warm Orange	Yes	No	1/3	no reading detected	Paint existing shield Add shield
102-0249	1	O	Calle Horizante			Floodlight	Security	Bright White	No	Yes	2/3	no reading detected	Change light bulb
102-0251	1	O	Calle Horizante			Street Light	Parking Lot/ Security	Bright White	Yes	Yes	1/3	0.034	Add shield Change light bulb
102-0253	19	P	Carr. Boca De Cangrejos			Spotlight	Path/ Security	Bright White	Yes	Yes	1/3	no reading detected	Paint existing shield Add shield Change light bulb
102-0256	36	P	Carr. Boca De Cangrejos			Pickle Jar	Entrance/ Path	Unknown	Yes	No	0/3		Paint existing shield Add shield Change light bulb
102-0258	1	P	Carr. Boca De Cangrejos			Spotlight	Entrance/ Security	Unknown	Yes	Yes	1/3		Correct angle Add shield Change light bulb
102-0260	1	P	Carr. Boca De Cangrejos			Spotlight	Entrance/ Security	Unknown	Yes	No	0/3		Correct angle Add shield Change light bulb

102-0262	1	P	Carr. Boca De Cangrejos		Ceiling Strip Light	Entrance	Warm Yellow	No	Yes	2/3	8.894	Change light bulb
102-0264	4	P	Carr. Boca De Cangrejos		Floodlight	Path	Bright White	No	Yes	2/3	0.036	Change light bulb
102-0268	60	Q	7061 Puerto Rico, PR-187		Dome	Patio	Unknown	Yes	No	0/3		Paint existing fixture Change light bulb
102-0270	2	Q	7061 Puerto Rico, PR-187		Floodlight	Scenic (beach)	Unknown	Yes	Yes	1/3		Correct angle Add shield Change light bulb
102-0272	3	Q	7061 Puerto Rico, PR-187		Street Light	Parking Lot	Unknown	Yes	Yes	1/3		Add shield Change light bulb
102-0275	5	Q	7061 Puerto Rico, PR-187		Street Light	Parking Lot	Warm White	Yes	Yes	1/3	no reading detected	Add shield Change light bulb
102-0277	1	R	6981 Boca de Cangrejos Avenue		Area Light	Path	Unknown	Yes	No	0/3		Paint existing shield Add shield Change light bulb
102-0279	2	R	6981 Boca de Cangrejos Avenue		Floodlight	Scenic (beach)	Unknown	Yes	Yes	1/3		Correct angle Add shield Change light bulb
102-0281	3	R	6981 Boca de Cangrejos Avenue		Floodlight	Scenic (beach)	Unknown	Yes	No	1/3		Correct angle Add shield Change light bulb
102-0283	4	R	6981 Boca de Cangrejos Avenue		Canister Light	Entrance/ Path/ Security	Warm Orange	Yes	Yes	2/3	0.11	Add shield
102-0898	2	R	6981 Boca de Cangrejos Avenue		Floodlight	Path/ Security	Bright White	Yes	No	0/3	0.14	Correct angle Add shield Change light bulb
102-0285	1	R	6981 Boca de Cangrejos Avenue		Street Light	Parking Lot	Unknown	Unknown	Yes	1/3		Add shield Change light bulb
102-0288	20	R	6981 Boca de Cangrejos Avenue		Dome	Path	Bright White	Yes	No	0/3	no reading detected	Paint existing shield Add shield Change light bulb
102-0900	1	R	6981 Boca de Cangrejos Avenue		Dome	Scenic	Warm Yellow	Yes	No	0/3	3.304	Remove light fixture
102-0291	4	S	7012 Boca de Cangrejos Avenue		Floodlight	Security	Bright White	Yes	No	0/3	no reading detected	Paint existing shield Add shield Change light bulb
102-0293	12	S	7012 Boca de Cangrejos Avenue		Dome	Path	Bright White	Yes	Yes	1/3	no reading detected	Add shield Change light bulb
102-0295	1	S	7012 Boca de Cangrejos Avenue		Floodlight	Security	Unknown	Yes	Yes	1/3		Correct angle Add shield Change light bulb
102-0297	20	S	7012 Boca de Cangrejos Avenue		Lamp	Entertainment (restaurant)	Warm Yellow	Yes	No	0/3	no reading detected	Paint existing shield Add shield Change light bulb Remove fixture
102-0903	6	S	7012 Boca de Cangrejos Avenue		Spotlight	Scenic/ Garden	Warm Orange	Yes	No	1/3	no reading detected	Remove light fixture
102-0299	3	S	7012 Boca de Cangrejos Avenue		Floodlight	Scenic (beach)	Unknown	Yes	Yes	1/3		Correct angle Add shield Change light bulb
102-0301	~100	S	7012 Boca de Cangrejos Avenue		String Lights	Scenic/ Garden	Unknown	Yes	No	0/3		Paint bulb Add shields Remove fixture
102-0303	7	S	7012 Boca de Cangrejos Avenue		Spotlight	Garden	Warm White	No	Yes	2/3	no reading detected	Change light bulb
102-0305	2	S	7012 Boca de Cangrejos Avenue		Floodlight	Security	Unknown	Yes	Yes	1/3		Correct angle Add shield Change light bulb
102-0307	2	S	7012 Boca de Cangrejos Avenue		Lantern	Scenic/ Entertainment	Unknown	Yes	No	0/3		Add shield Remove fixure Change light bulb

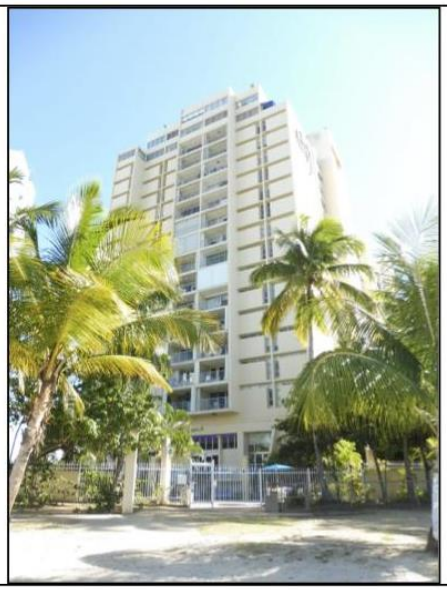
102-0309	3	S	7012 Boca de Cangrejos Avenue			Lantern	Scenic/ Entertainment	Unknown	Yes	No	0/3		Add shield Remove fixure Change light bulb
102-0311	1	Woods by S	7012 Boca de Cangrejos Avenue			Street Light	Parking Lot	Unknown	Yes	Yes	1/3		Correct angle Add shield Change light bulb
102-0905	1	Woods by S	7012 Boca de Cangrejos Avenue			Floodlight	Parking Lot	Bright White	Yes	Yes	1/3	no reading detected	Correct angle Add shield Change light bulb

Patillas Inventory

Light ID #	Quantity	Property	Photo	Photo (Zoom)	Type	Light Application	Angle exceeds 70 degrees	Full Cutoff Shield	Complies with No. 218	Recommendations
102-0370	5	A			Post Light	Scenic	Yes	No	No	Add shield Change light bulb
102-0372	3 strands	A			String Lights	Scenic	Yes	No	No	Remove light fixture
102-0374	7	A			Floodlight	Path/ Security	Yes	No	No	Correct angle Add shield Change light bulb
102-0376	3	A			Dome	Path/ Entrance	Yes	No	No	Paint existing shield Add shield Change light bulb
102-0378	2	A			Spotlight	Path/ Security	Yes	Yes	No	Correct angle Add shield Change light bulb
102-0380	3	A			Dome	Entertainment	Yes	No	No	Add shield Change light bulb
102-0382	1	A			Wall Light	Path	Yes	No	No	Correct angle Add shield Change light bulb
102-0384	3 trees	A			String Lights	Garden	Yes	No	No	Remove light fixture
102-0386	1	Street			Street Light	Road	Unknown	Yes	Unknown	Add shield Change light bulb
102-0395	1	D			Dome	Path	Yes	No	No	Paint existing shield Add shield Change light bulb
102-0399	2	D			Dome	Path	Yes	No	No	Paint existing shield Add shield Change light bulb
102-0401	2	D			Dome	Path/ Entrance	Yes	No	No	Add shield Change light bulb
102-0403	3	D			Post Light	Path	Yes	No	No	Add shield Change light bulb
102-0405	2	E			Post Light	Path/ Garden	Yes	No	No	Add shield Change light bulb
102-0410	1	G			Floodlight	Security/ Scenic	Yes	Yes	No	Correct angle Add shield Change light bulb
102-0412	14	H			Post Light	Entertainment (restaurant)	Yes	No	No	Add shield Change light bulb
102-0414	2	H			Spotlight	Scenic/ Path	Yes	No	No	Correct angle Add shield Change light bulb
102-0416	2	H			Floodlight	Entrance/ Path	Yes	No	No	Correct angle Add shield Change light bulb
102-0418	3	I			Dome	Path	Yes	No	No	Add shield Change light bulb
102-0420	1	I			Wall Light	Path/ Security	Yes	No	No	Correct angle Add shield Change light bulb

102-0429	2	J		Spotlight	Entrance/ Path/ Security	Yes	No	No	Correct angle Add shield Change light bulb
102-0441	1	M		Spotlight	Entrance/ Path	Yes	No	No	Correct angle Add shield Change light bulb
102-0443	2	N		Dome	Entertainment	Yes	No	No	Paint existing shield Add shield Change light bulb
102-0445	2	N		Spotlight	Path/ Security	Yes	Yes	No	Correct angle Add shield Change light bulb
102-0447	1	N		Post Light	Path	Yes	No	No	Add shield Change light bulb
102-0449	1	O		Dome	Entertainment/ Path	Yes	No	No	Paint existing shield Add shield Change light bulb
102-0451	2	O		Spotlight	Path/ Security	Yes	Yes	No	Correct angle Add shield Change light bulb
102-0453	1	O		Dome	Entrance	Yes	No	No	Paint existing shield Add shield Change light bulb
102-0455	1	O		Dome	Entertainment	Yes	No	No	Paint existing shield Add shield Change light bulb
102-0477	2	Q		Area Light	Security	Yes	No	No	Add shield Change light bulb
102-0479	6	Q		Area Light	Security	Yes	No	No	Correct angle Add shield Change light bulb
102-0481	2	Q		Floodlight	Path/ Security	Yes	Yes	No	Correct angle Add shield Change light bulb
102-0483	4	Q		Spotlight	Path/ Security	Yes	No	No	Correct angle Add shield Change light bulb
102-0485	26	Q		Dome	Path	Unknown	Yes	Unknown	Add shield Change light bulb
102-0487	6	Q		Floodlight	Path/ Entrance/ Security	Yes	Yes	No	Correct angle Add shield Change light bulb
102-0489	1	Q		Spotlight	Path/ Security	Yes	No	No	Correct angle Add shield Change light bulb
102-0491	5	Q		Lantern	Path	Unknown	Yes	Unknown	Add shield Change light bulb
102-0493	1	Q		Floodlight	Security	Yes	No	No	Correct angle Add shield Change light bulb
102-0495	3	Q		Dome	Entertainment	Yes	No	No	Paint existing shield Add shield Change light bulb

Property Labels for Isla Verde

A	B
	
C	**D**
	

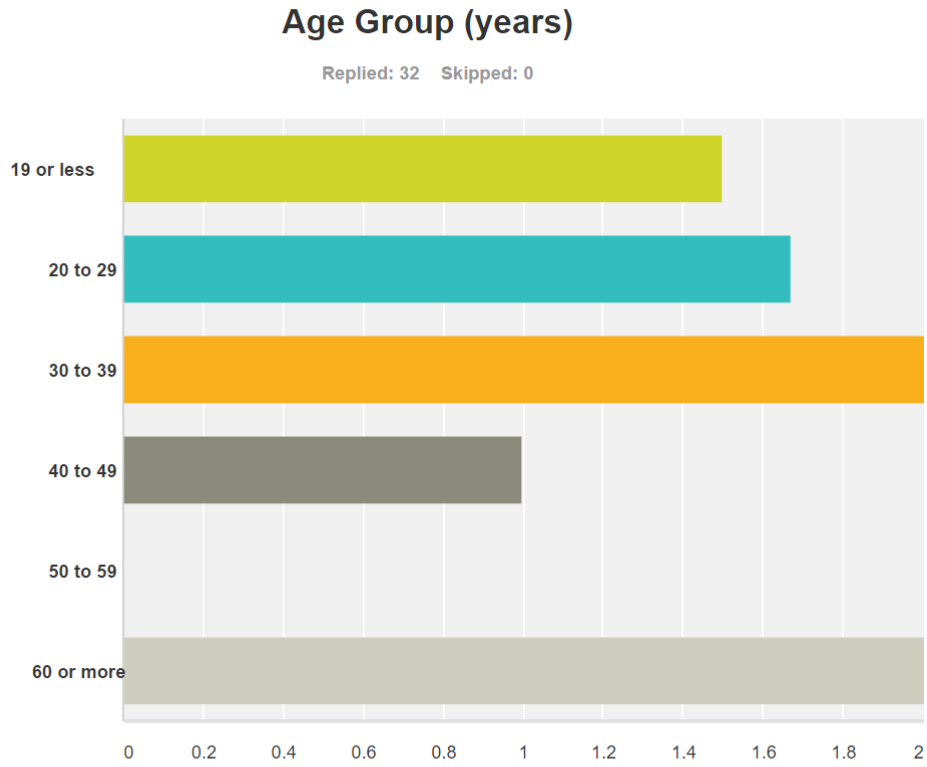
E	F
	
G	**H**
	
I	**J**
	

K	L
	N/A
M	**N**
	
O	**P**
	

Q	R
	

S

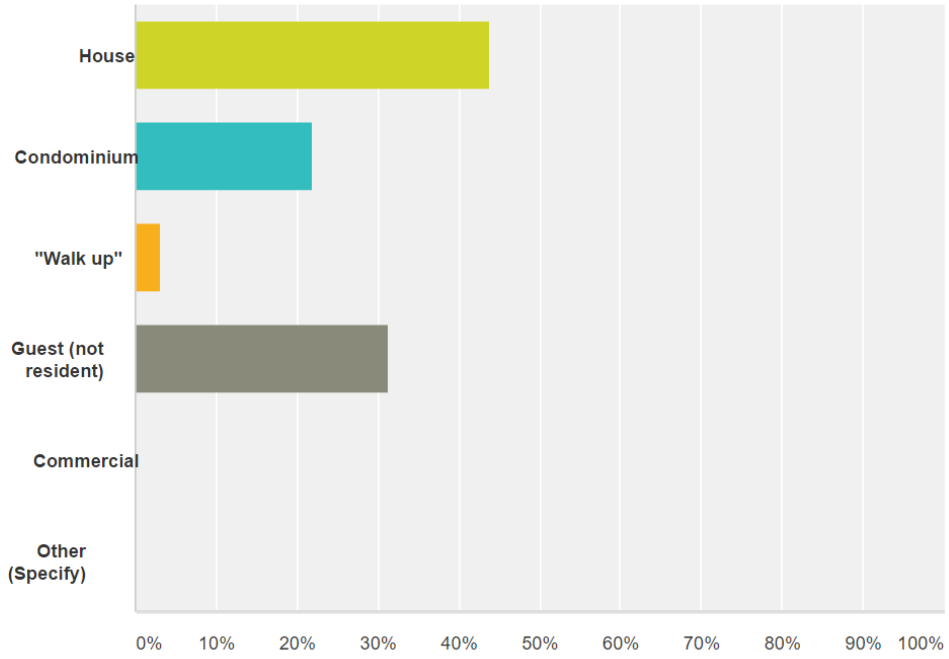

Appendix H - Survey Responses



	Femenio	male	Total	Weighted average
19 or less	50.00% 2	50.00% 2	4	1.50
20 to 29	33.33% 8	66.67% 16	24	1,67
30 to 39	0.00% 0	100.00% 2	2	2.00
40-49	100.00% 1	0.00% 0	1	1.00
50 to 59	0.00% 0	0.00% 0	0	0.00
60 or more	0.00% 0	100.00% 1	1	2.00

Property type which resides in this area

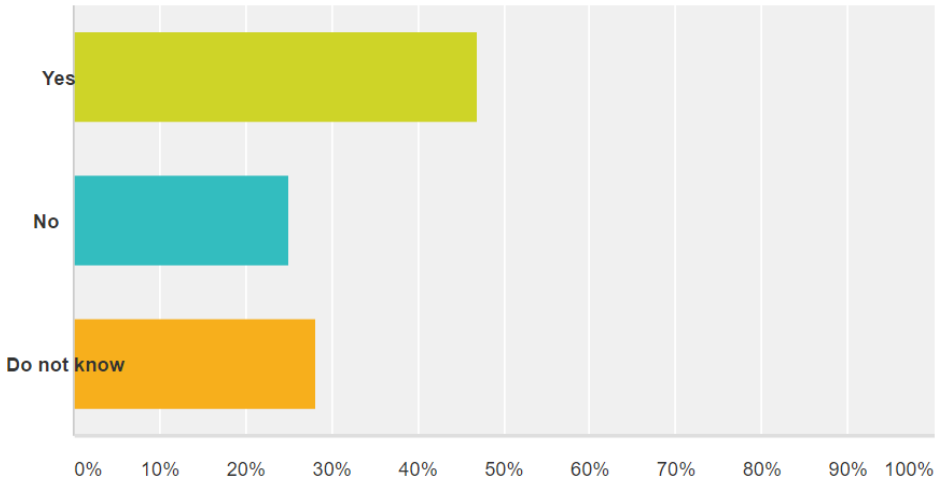
Replied: 32 Skipped: 0



Response options		answers	
Home		43.75%	14
Condominium		21.88%	7
"Walk up"		3.13%	1
Guest (non-resident)		31.25%	10
Commercial		0.00%	0
Other (specify)	replies	0.00%	0
Total			32

Do you know if any Law or Regulation in Puerto Rico on environmental pollution caused by the use of outdoor lighting?

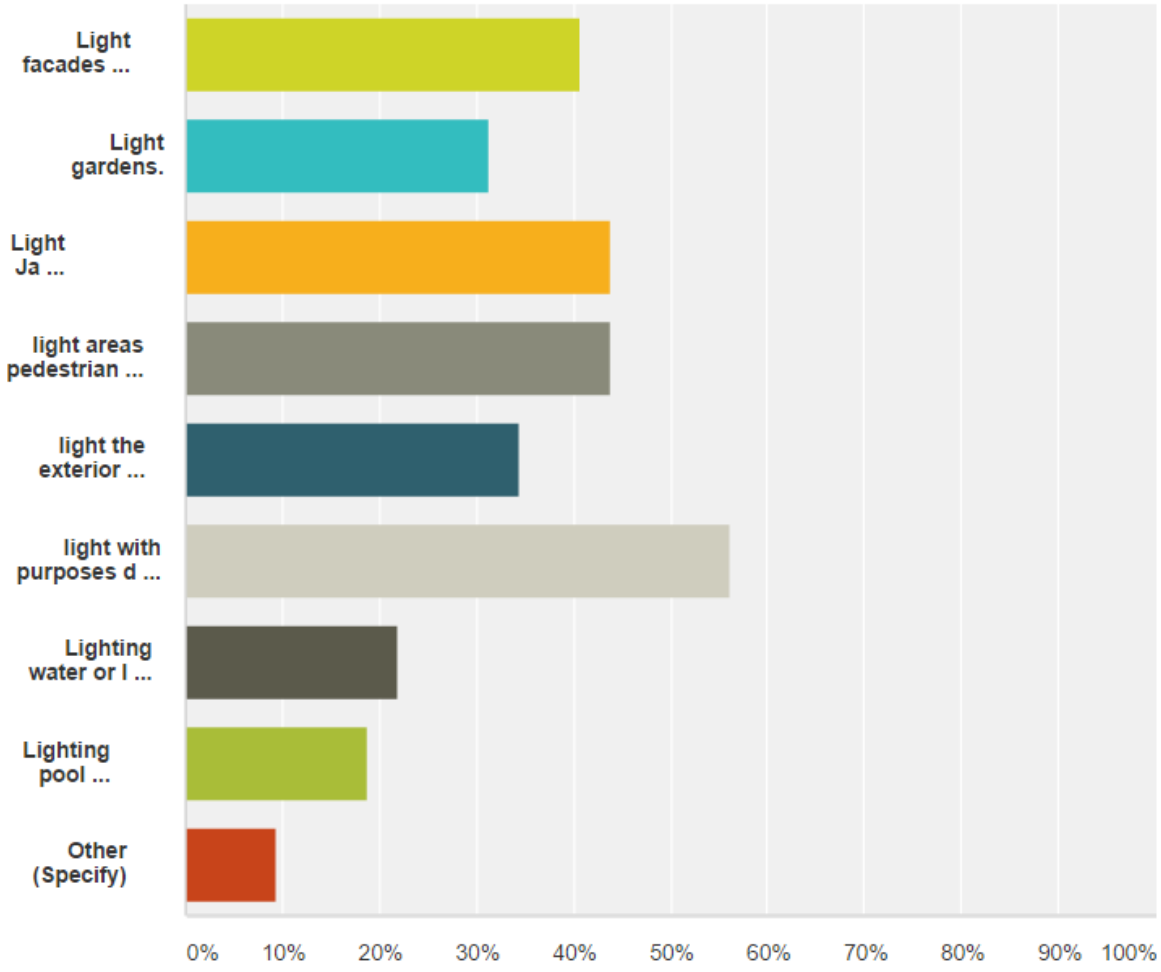
Replied: 32 Skipped: 0



Response options	answers	
Yes	**46.88%**	fifteen
Do not	**25.00%**	8
I dont know	**28.13%**	9
Total		32

On the use of outdoor lighting in your home and residential, select those that apply to your property.

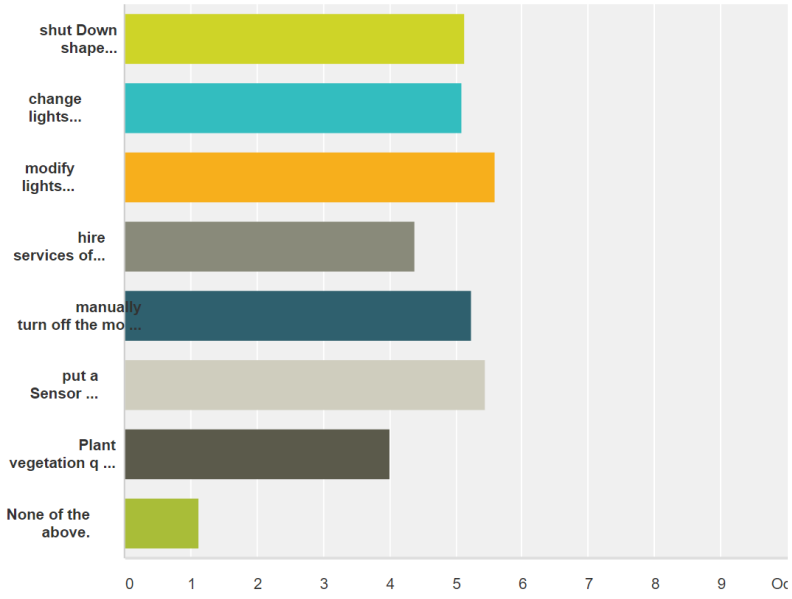
Replied: 32 Skipped: 0



Response options		answers	
Lighting facades of structures and facilities of all kinds.		40.63%	13
Enlighten gardens.		31.25%	10
Parking light.		43.75%	14
Lighting pedestrian areas (eg sidewalks, sidewalks, roads).		43.75%	14
Lighting the exterior of single-family homes and multifamily		34.38%	eleven
Lighting purposes of providing security sense.		56.25%	18
Lighting water or sand.		21.88%	7
Lighting for pool or fountain.		18.75%	6
Other (specify)	replies	9.38%	3
Total respondents: 32			

Of the following options, indicate in order of priority (1 being the highest), the steps you take in your home or business to correct any situation with exterior lighting that could be causing problems lighting the neighbor or the environment.

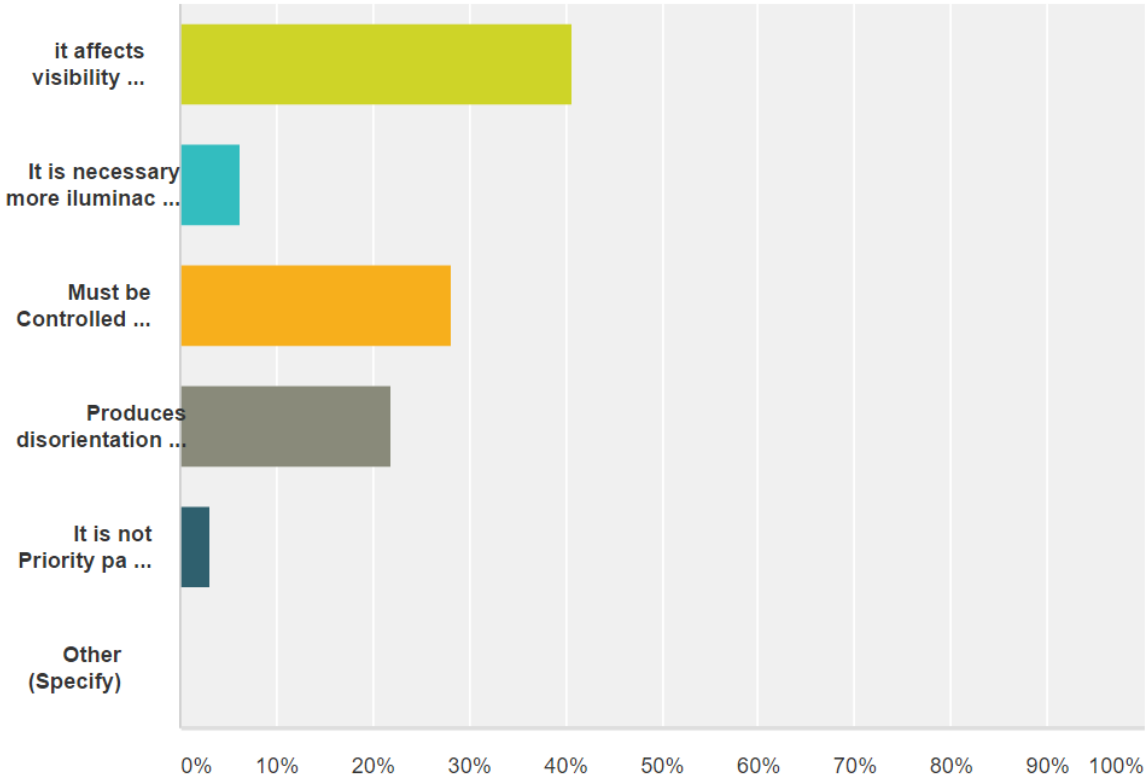
Replied: 32 Skipped: 0



	1	2	3	4	5	6	7	8	Total	score
Permanently turn off outside lights that cause the problem.	21.88% 7	9.38% 3	9.38% 3	21.88% 7	9.38% 3	15.63% 5	9.38% 3	3.13% 1	32	5,13
Change the outside lights with new ones with better design.	12.50% 4	18.75% 6	12.50% 4	12.50% 4	18.75% 6	15.63% 5	9.38% 3	0.00% 0	32	5.09
Modify existing lights to correct the matter.	21.88% 7	12.50% 4	15.63% 5	15.63% 5	21.88% 7	12.50% 4	0.00% 0	0.00% 0	32	5.59
Hiring the services of an electrician or architect for advice and corrections.	12.50% 4	6.25% 2	6.25% 2	15.63% 5	21.88% 7	15.63% 5	21.88% 7	0.00% 0	32	4.38
Turn off the lights manually causing the problem after some time.	15.63% 5	12.50% 4	18.75% 6	21.88% 7	12.50% 4	6.25% 2	9.38% 3	3.13% 1	32	5.25
Put a motion sensor to turn off and ignite alone.	12.50% 4	21.88% 7	21.88% 7	12.50% 4	12.50% 4	9.38% 3	9.38% 3	0.00% 0	32	5.44
Planting vegetation that acts as a barrier so that the light does not leave my property.	3.13% 1	18.75% 6	15.63% 5	0.00% 0	3.13% 1	18.75% 6	40.63% 13	0.00% 0	32	4.00
None of the above.	0.00% 0	0.00% 0	0.00% 0	0.00% 0	0.00% 0	6.25% 2	0.00% 0	93.75% 30	32	1,13

On the use of residential or commercial exterior lighting that is visible at night from the beaches point with which you agree:

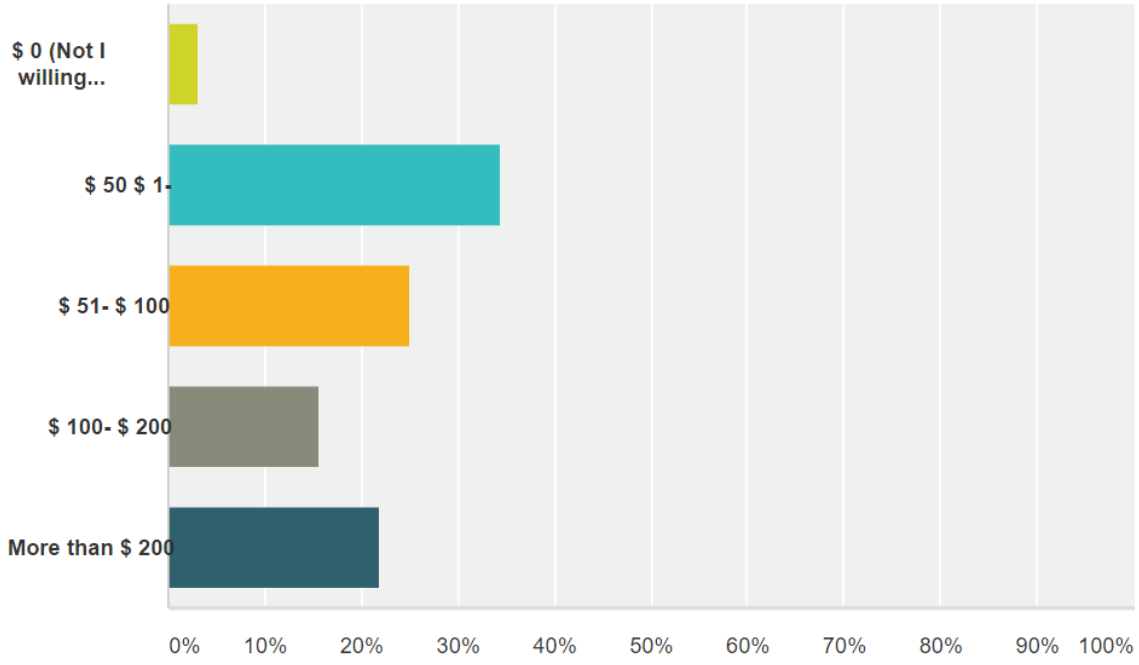
Replied: 32 Skipped: 0



Response options	answers
It affects the visibility of the stars and the night coastal environment.	40.63% 13
more lighting on the beaches at night is necessary to improve the recreational use of the same and security.	6.25% 2
It must be controlled and modified to reduce the magnitude of the problem in these areas.	28.13% 9
It produces disorientation of adult and newborn sea turtles because they are attracted to them.	21.88% 7
It is not a priority for me to eliminate or modify the visible lights, because they are always needed.	3.13% 1
Other (specify) replies	0.00% 0
Total	32

How much money are you willing to invest to change the lighting in your home or business to correct problems outdoor lighting?

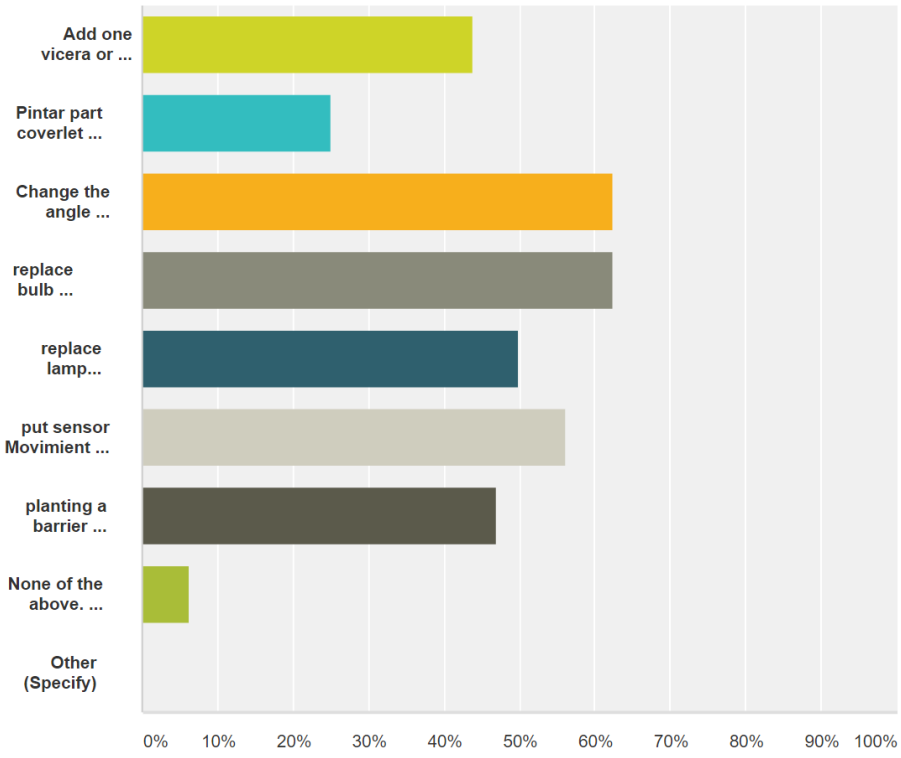
Replied: 32 Skipped: 0



Response options	answers	
$ 0 (I'm not willing to spend money to change)	**3.13%**	1
$ 1- $ 50	**34.38%**	eleven
$ 51- $ 100	**25.00%**	8
$ 100- $ 200	**15.63%**	5
More than $ 200	**21.88%**	7
Total		32

Which of the following changes would you be willing to do your lights to prevent excessive impact night lighting coastal environment? (Select all that apply).

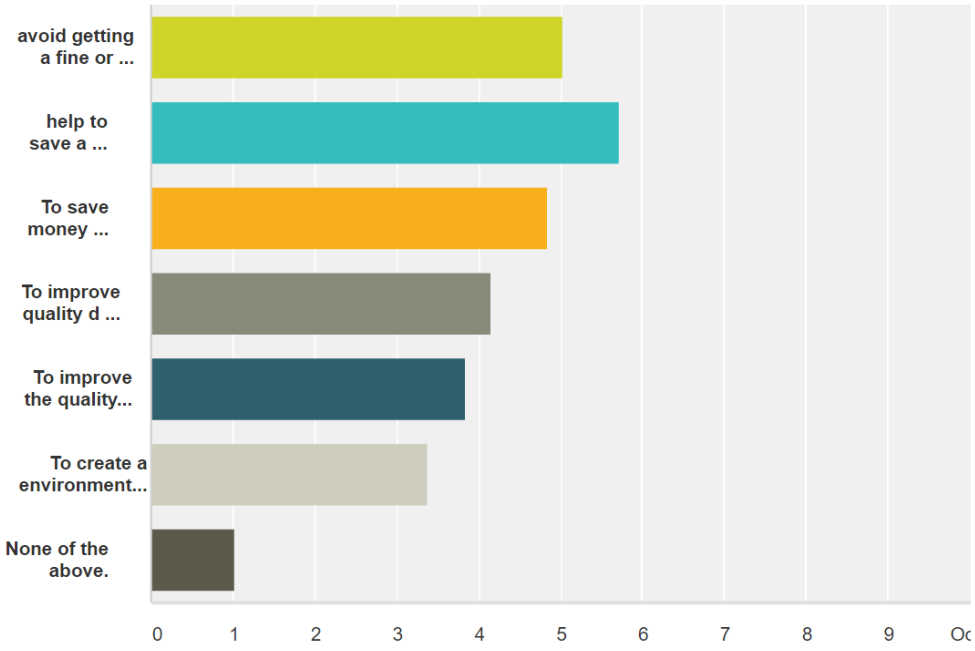
Replied: 32 Skipped: 0



Response options	answers
Adding a vicera or "cover" to the luminaire I have for that is not visible from the beach.	43.75% 14
Paint cover part of the existing luminaire which is not visible from the beach.	25.00% 8
Changing the angle of the light or focusing it down.	62.50% twenty
Replace the bulb color and bright apropidad level according to law or regulation.	62.50% twenty
Completely replace the lamp with a new one that complies with applicable laws and regulations.	50.00% 16
Put motion sensor for pay and ignite alone.	56.25% 18
Plant a barrier of plants or shrubs to prevent them visible.	46.88% fifteen
None of the above. Not make changes.	6.25% 2
Other (specify) replies	0.00% 0
Total respondents: 32	

Of the following, in order of priority (# 1 being the highest priority), which would indicate the reason or reasons that will motivate you to take corrective measures for the use of outdoor lighting on your property.

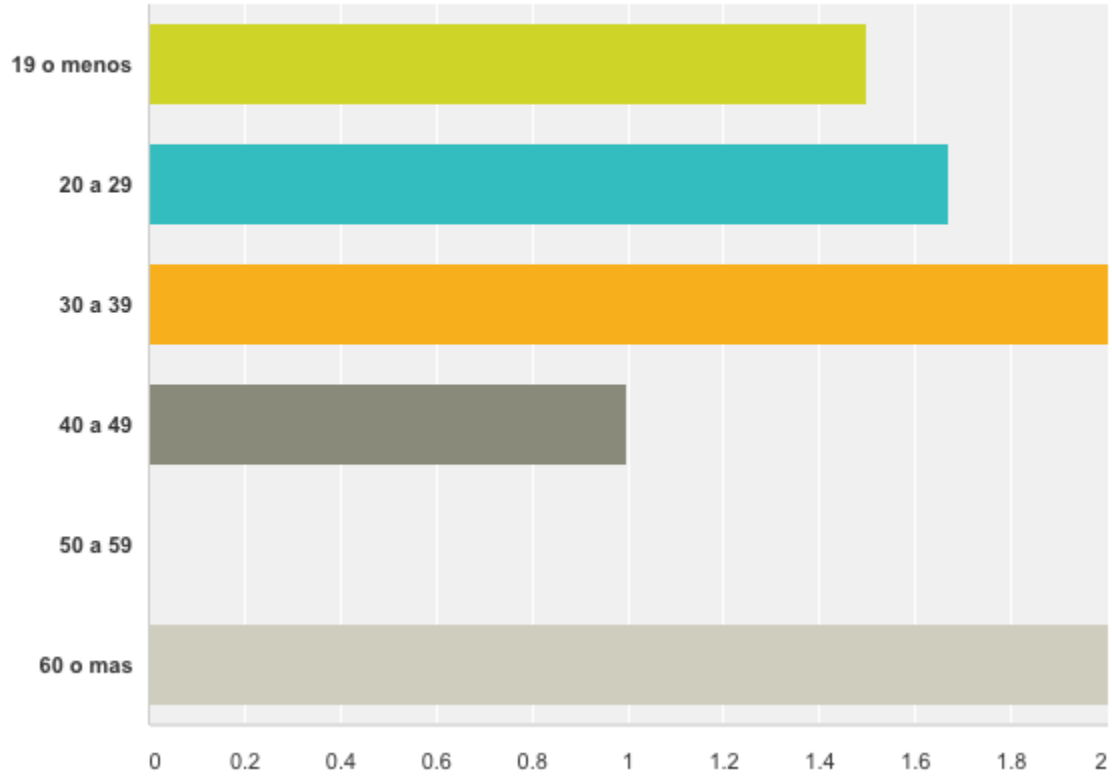
Replied: 32 Skipped: 0



	1	2	3	4	5	6	7	Total	score
Avoid receiving a fine or penalty of government.	31.25% 10	28.13% 9	9.38% 3	0.00% 0	6.25% 2	25.00% 8	0.00% 0	32	5.03
Help save a endangered species.	43.75% 14	28.13% 9	12.50% 4	0.00% 0	3.13% 1	12.50% 4	0.00% 0	32	5.72
To save money on energy costs.	18.75% 6	18.75% 6	25.00% 8	12.50% 4	15.63% 5	9.38% 3	0.00% 0	32	4.84
To improve the quality of the night sky and you can see the stars.	0.00% 0	9.38% 3	28.13% 9	37.50% 12	18.75% 6	6.25% 2	0.00% 0	32	4,16
To improve the aesthetic quality of exterior lighting I use on my property.	3.13% 1	12.50% 4	9.38% 3	28.13% 9	34.38% eleven	12.50% 4	0.00% 0	32	3.84
To create a more natural nightlife on my property.	3.13% 1	3.13% 1	15.63% 5	21.88% 7	21.88% 7	31.25% 10	3.13% 1	32	3.38
None of the above.	0.00% 0	0.00% 0	0.00% 0	0.00% 0	0.00% 0	3.13% 1	96.88% 31	32	1,03

Grupo de Edad (años)

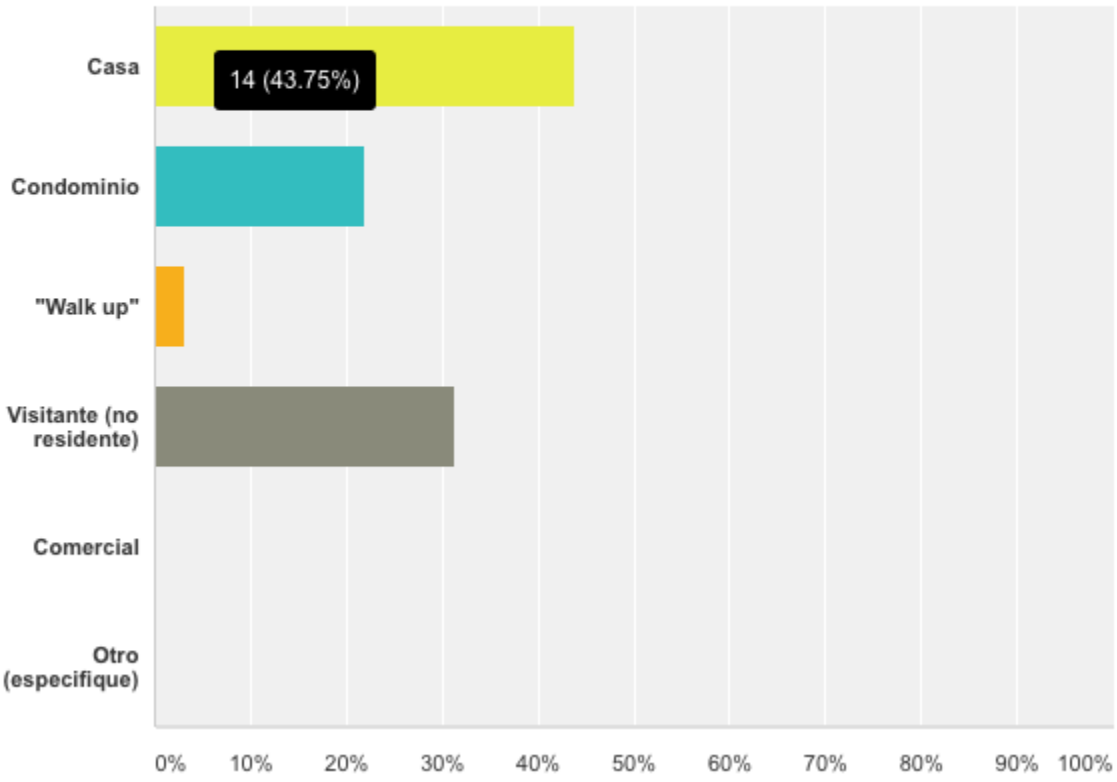
Answered: 32 Skipped: 0



	Femenio	Masculino	Total	Weighted Average
19 o menos	50.00% 2	50.00% 2	4	1.50
20 a 29	33.33% 8	66.67% 16	24	1.67
30 a 39	0.00% 0	100.00% 2	2	2.00
40 a 49	100.00% 1	0.00% 0	1	1.00
50 a 59	0.00% 0	0.00% 0	0	0.00
60 o mas	0.00% 0	100.00% 1	1	2.00

Tipo de propiedad donde reside en esta zona

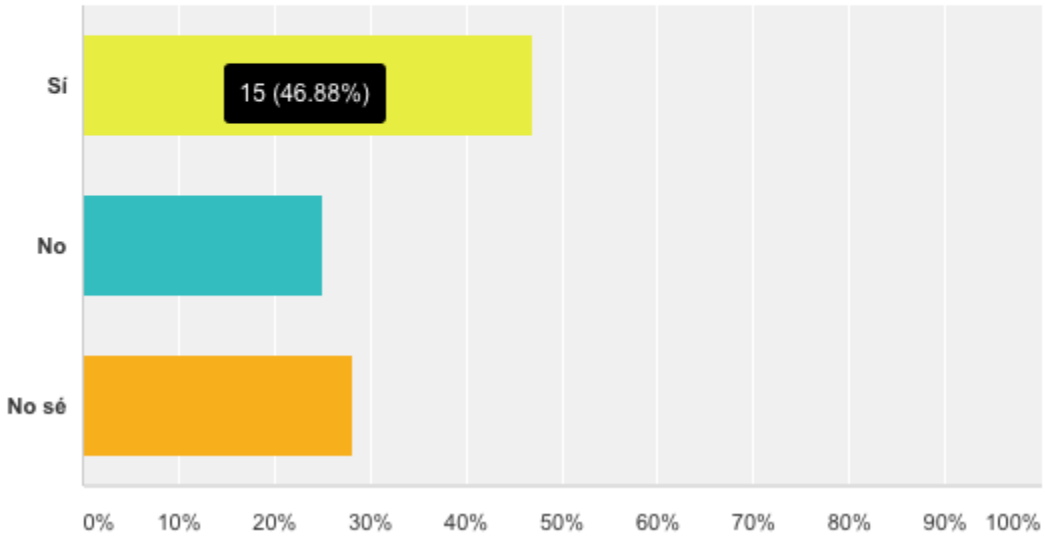
Answered: 32 Skipped: 0



Answer Choices	Responses	
Casa	43.75%	14
Condominio	21.88%	7
"Walk up"	3.13%	1
Visitante (no residente)	31.25%	10
Comercial	0.00%	0
Otro (especifique) Responses	0.00%	0
Total		32

¿Conoce si hay alguna Ley o Reglamento en Puerto Rico sobre contaminación ambiental causada por el uso de iluminación exterior?

Answered: 32 Skipped: 0



Answer Choices	Responses	
Sí	**46.88%**	15
No	**25.00%**	8
No sé	**28.13%**	9
Total		32

Mencione 3 cosas que le vienen a la mente cuando escucha el termino "contaminación lumínica"

Answered: 32 Skipped: 0

Answer Choices		Responses	
1)	Responses	100.00%	32
2)	Responses	81.25%	26
3)	Responses	62.50%	20

Answers

Showing **32** responses

luces
Ciudades grandes
Contaminación a los animales
estrellas
no sé
tortugas
menos visualizacion la cielo
rayos solares
hamo
mucha claridad
energia electrica
energia electrica
exceso de luz
exceso de luz
exceso de luz
exceso de luz
exceso de luz en la calles
light contamination
exceso de luz
tortugas
objetos que causen mucha lue
billboards en la calle
focos
luces de más encendidas
exterior lights in houses
luz

animales
luz
alumbrado, de más
pocas posibilidades de disfruta de las estrellas
Las luces
Exceso de iluminación que molesta

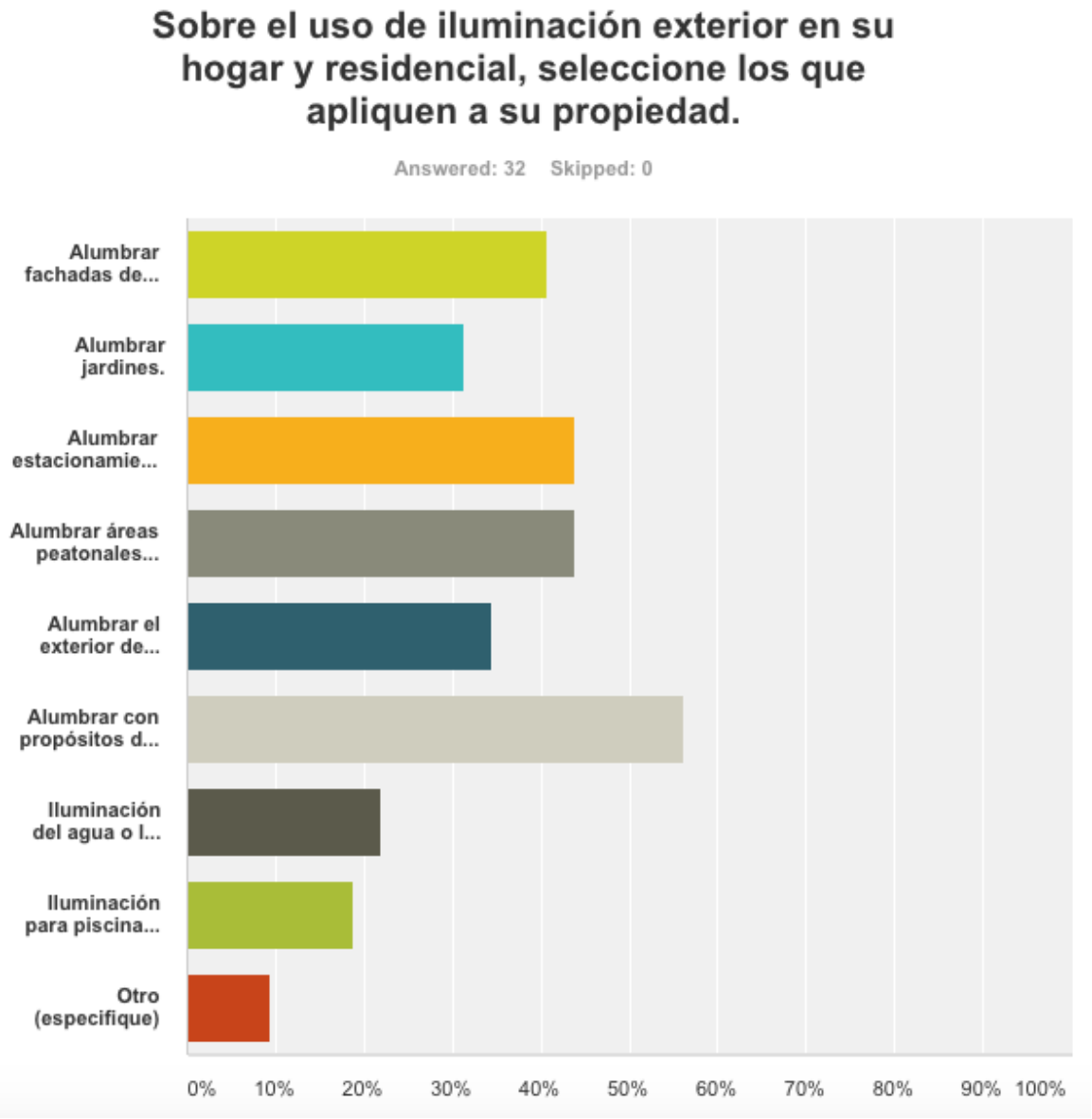
Showing **26** responses

ciudad
Animales
Problemas con reciclando
tortugas
pajaros
menos contacto a la naturaleza
contaminacion copa de ozono
basura
tortugas se pierden debido a la luz
luces
afecta vida marine
muchos lugares encendidos
cities infecting air
no se ven las estrellas
luz brillante
cristales
postes
linternas
street lamps
ambiente
ambiente
animales
postes cerca de areas rurales
problemas con la anidaeion de tortugas marinas
El sol
Billboards iluminados

Showing **20** responses

el medio ambiente
Contaminación de compañías

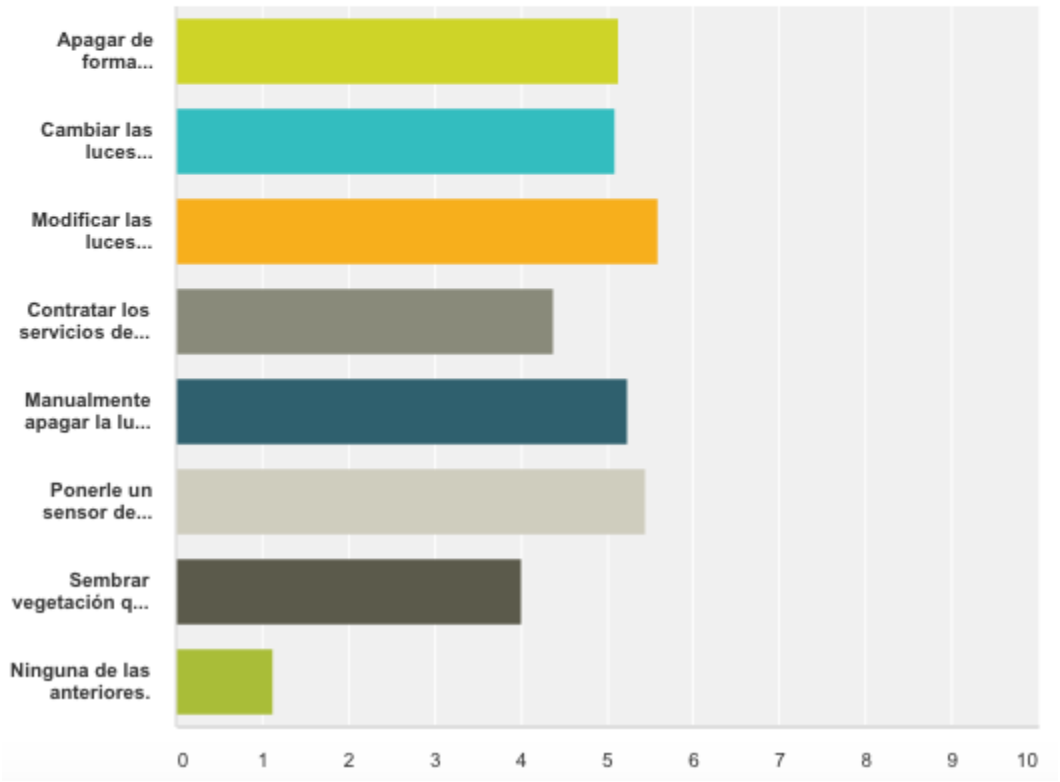
coquis
mas dependencia a la luz electronica
vehiculos
chemicos
luz de mas en las areas
gases
afecta la visibilidad
noche sin estrellas
aluminio
sobre iluminacion en la calle
baterias
hotel lights
humeros
ambiente
sobre urbanizacion
alto consumo de conbustible
El lumen
Nidos de Tortugas


Sobre el uso de iluminación exterior en su hogar y residencial, seleccione los que apliquen a su propiedad.
Answered: 32 Skipped: 0
Alumbrar fachadas de...
Alumbrar jardines.
Alumbrar estacionamie...
Alumbrar áreas peatonales...
Alumbrar el exterior de...
Alumbrar con propósitos d...
Iluminación del agua o l...
Iluminación para piscina...
Otro (especifique)
0%
10%
20%
30%
40%
50%
60%
70%
80%
90%
100%

Answer Choices		Responses	
Alumbrar fachadas de estructuras e instalaciones de todo tipo.		40.63%	13
Alumbrar jardines.		31.25%	10
Alumbrar estacionamientos.		43.75%	14
Alumbrar áreas peatonales (e.g. aceras, veredas, caminos).		43.75%	14
Alumbrar el exterior de residencias unifamiliares y multifamiliares		34.38%	11
Alumbrar con propósitos de proveer sentido de seguridad.		56.25%	18
Iluminación del agua o la arena.		21.88%	7
Iluminación para piscina o fuente.		18.75%	6
Otro (especifique)	Responses	9.38%	3
Total Respondents: 32			

De las siguientes opciones, indique en orden de prioridad (1 siendo la mayor), las medidas que tomaría usted en su hogar o negocio para corregir alguna situación con alumbrado exterior que pudiera estar causando problemas de iluminación al vecino o al medioambiente.

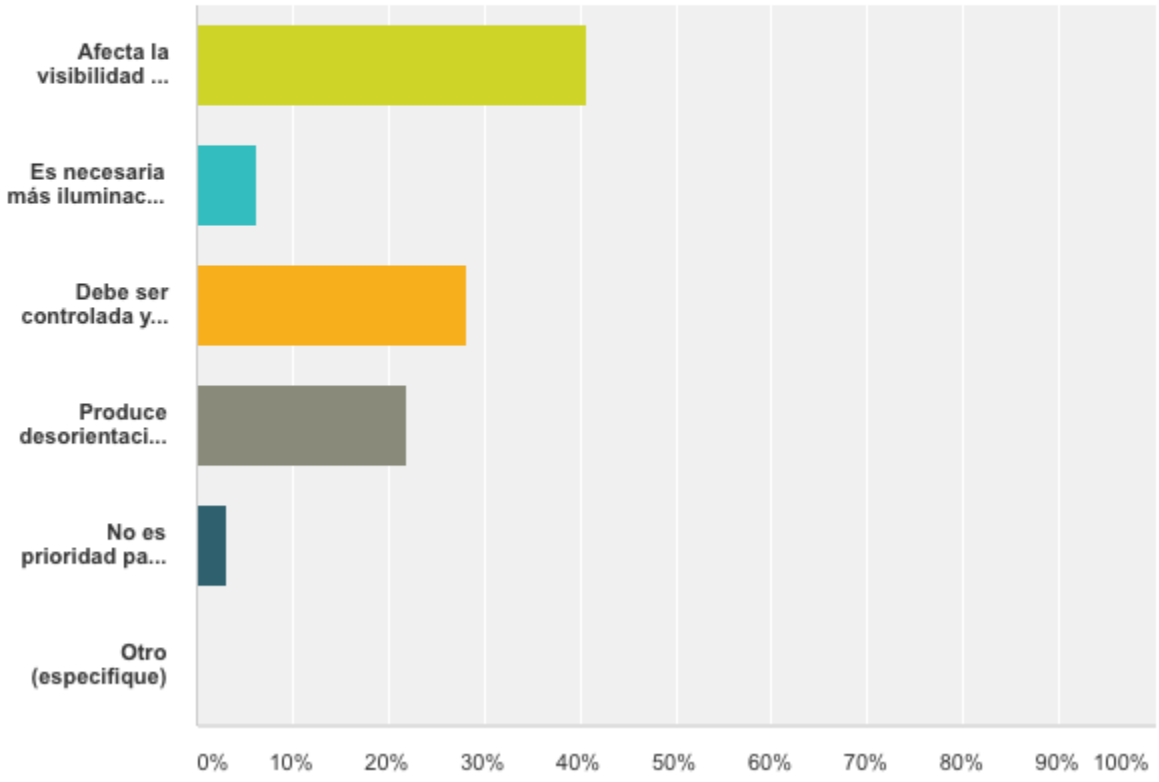
Answered: 32 Skipped: 0



	1	2	3	4	5	6	7	8	Total	Score
Apagar de forma permanente las luces exteriores que causen el problema.	**21.88%** 7	**9.38%** 3	**9.38%** 3	**21.88%** 7	**9.38%** 3	**15.63%** 5	**9.38%** 3	**3.13%** 1	32	5.13
Cambiar las luces exteriores por otras nuevas con un mejor diseño.	**12.50%** 4	**18.75%** 6	**12.50%** 4	**12.50%** 4	**18.75%** 6	**15.63%** 5	**9.38%** 3	**0.00%** 0	32	5.09
Modificar las luces existentes para corregir el asunto.	**21.88%** 7	**12.50%** 4	**15.63%** 5	**15.63%** 5	**21.88%** 7	**12.50%** 4	**0.00%** 0	**0.00%** 0	32	5.59
Contratar los servicios de un electricista o arquitecto para recomendaciones y correcciones.	**12.50%** 4	**6.25%** 2	**6.25%** 2	**15.63%** 5	**21.88%** 7	**15.63%** 5	**21.88%** 7	**0.00%** 0	32	4.38
Manualmente apagar la luces que causen el problema despues de cierta hora.	**15.63%** 5	**12.50%** 4	**18.75%** 6	**21.88%** 7	**12.50%** 4	**6.25%** 2	**9.38%** 3	**3.13%** 1	32	5.25
Ponerle un sensor de movimiento para que apaguen y prendan solas.	**12.50%** 4	**21.88%** 7	**21.88%** 7	**12.50%** 4	**12.50%** 4	**9.38%** 3	**9.38%** 3	**0.00%** 0	32	5.44
Sembrar vegetación que actue como barrera para que la luz no salga de mi propiedad.	**3.13%** 1	**18.75%** 6	**15.63%** 5	**0.00%** 0	**3.13%** 1	**18.75%** 6	**40.63%** 13	**0.00%** 0	32	4.00
Ninguna de las anteriores.	**0.00%** 0	**0.00%** 0	**0.00%** 0	**0.00%** 0	**0.00%** 0	**6.25%** 2	**0.00%** 0	**93.75%** 30	32	1.13

Sobre el uso de iluminación residencial o comercial exterior que es visible en la noche desde las playas seleccione con las que esta de acuerdo:

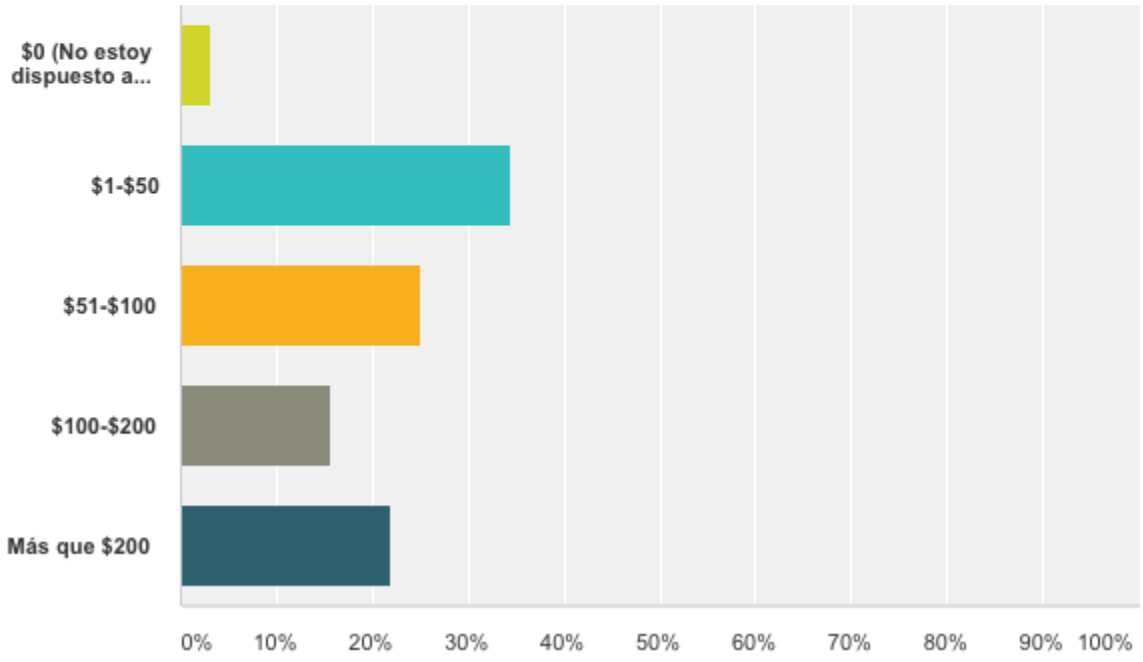
Answered: 32 Skipped: 0



Answer Choices	Responses	
Afecta la visibilidad de las estrellas y al ambiente costero nocturno.	40.63%	13
Es necesaria más iluminación en las playas de noche para mejorar el uso recreativo de las mismas y seguridad.	6.25%	2
Debe ser controlada y modificada para reducir la magnitud de la problemática en dichas áreas.	28.13%	9
Produce desorientación de las tortugas marinas adultas y recién nacidas porque son atraídas hacia ellas.	21.88%	7
No es prioridad para mí el que se elimine o modifiquen las luminarias visibles, ya que siempre son necesarias.	3.13%	1
Otro (especifique) Responses	0.00%	0
Total		32

¿Cuánto dinero estarías dispuesto a invertir para modificar las luminarias de tu hogar o negocio para corregir problemas de iluminación exterior?

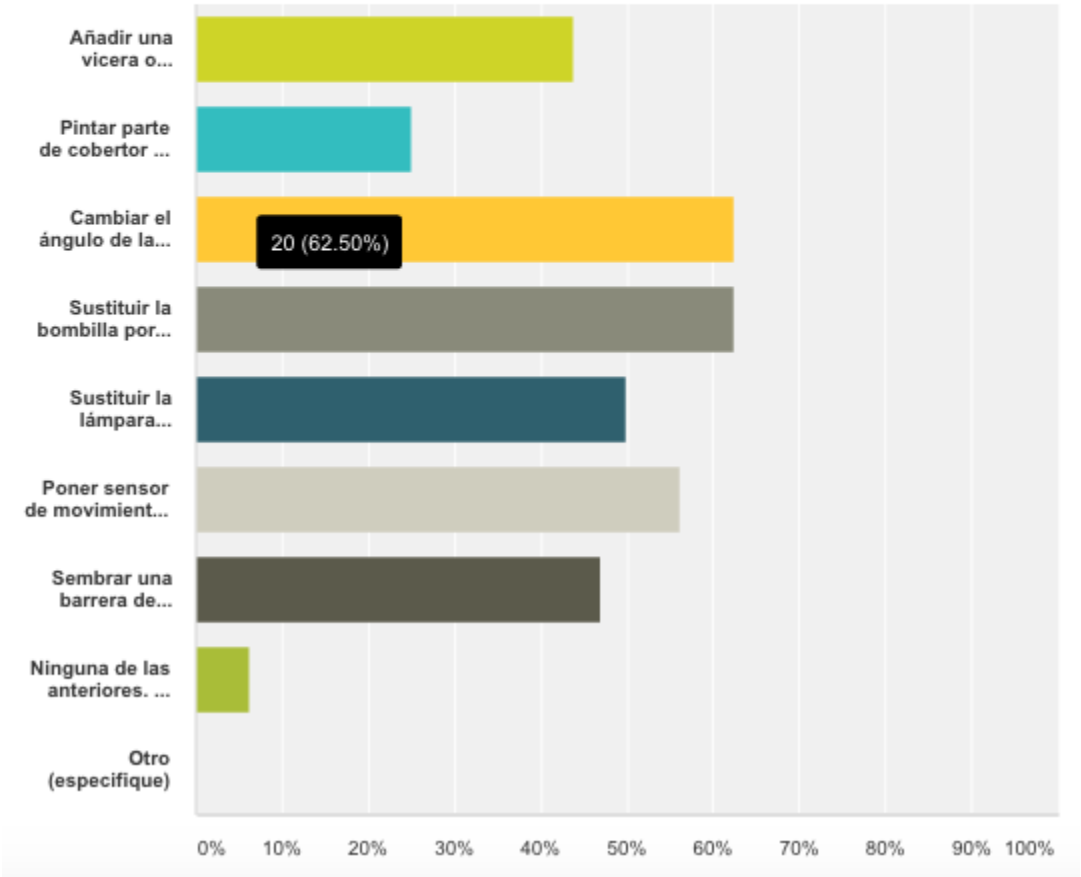
Answered: 32 Skipped: 0



Answer Choices	Responses	
$0 (No estoy dispuesto a gastar dinero para modificaciones)	3.13%	1
$1-$50	34.38%	11
$51-$100	25.00%	8
$100-$200	15.63%	5
Más que $200	21.88%	7
Total		32

¿Cuál de las siguientes modificaciones estarías dispuesto a hacer a tus luminarias para impedir que el exceso de iluminación impacte el ambiente costero nocturno? (Seleccione todas las que apliquen).

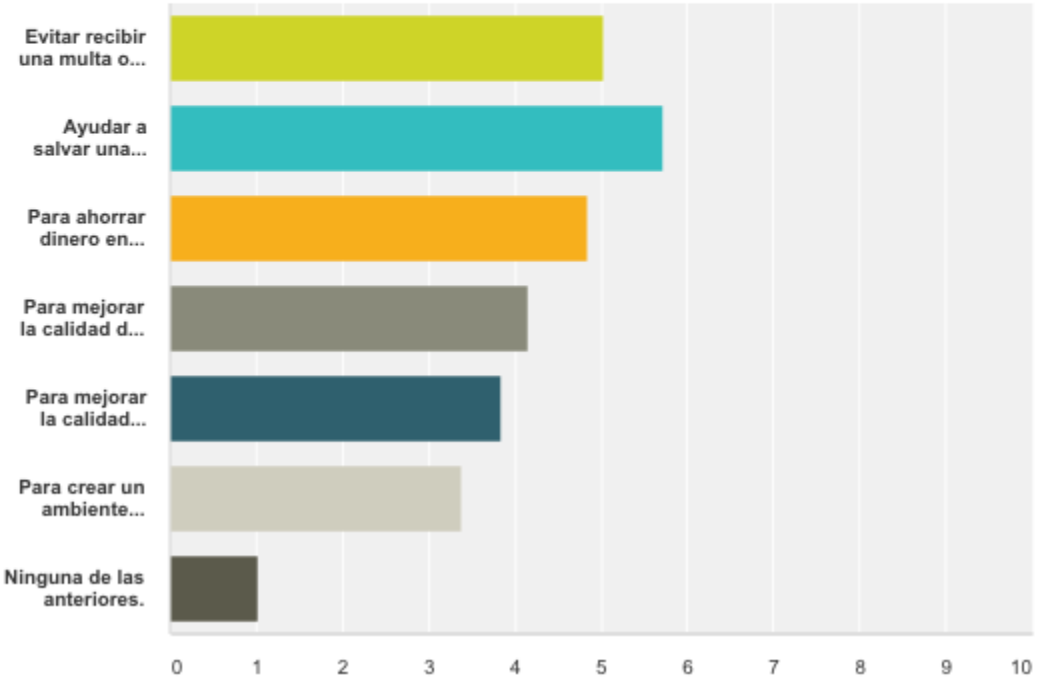
Answered: 32 Skipped: 0



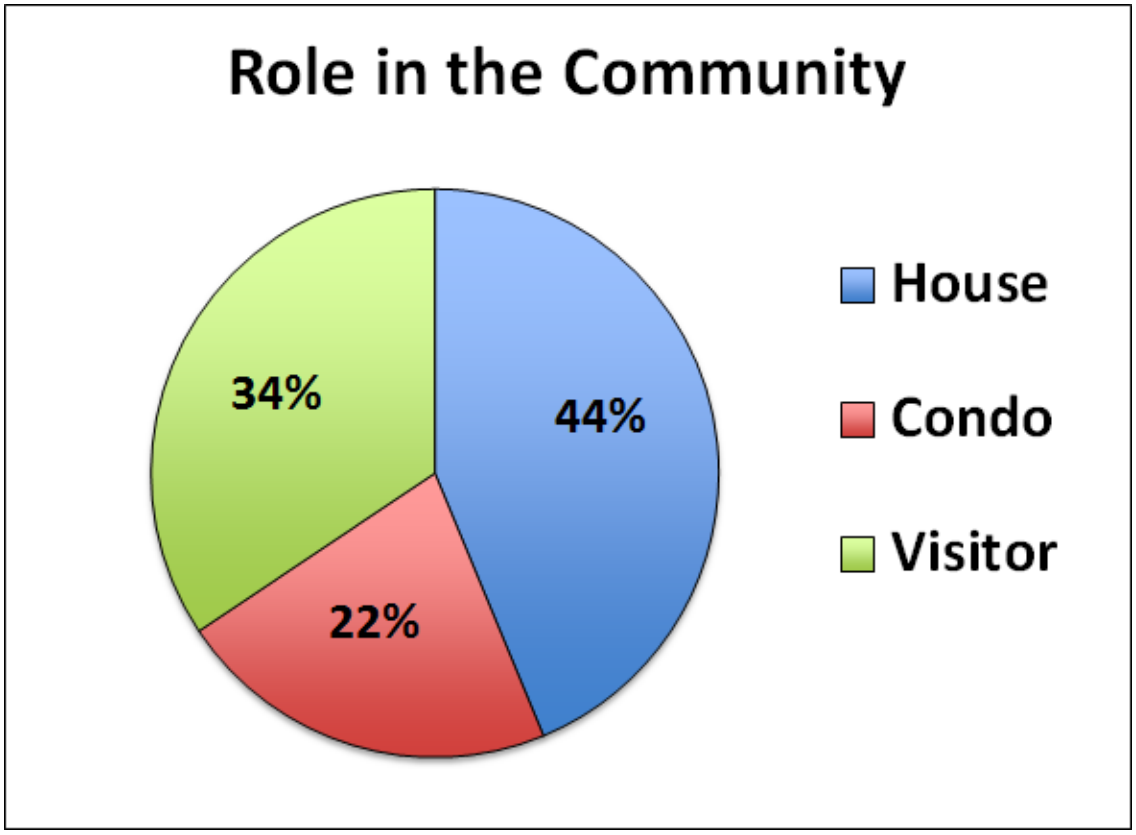
Answer Choices	Responses
Añadir una vicera o "cover" a la luminaria que tengo para que no sea visible desde la playa.	43.75% 14
Pintar parte de cobertor de la luminaria existente para que no sea visible desde la playa.	25.00% 8
Cambiar el ángulo de la luz o focalizarla hacia abajo.	62.50% 20
Sustituir la bombilla por el color y nivel de brillantes apropidad segun la Ley o reglamento aplicable.	62.50% 20
Sustituir la lámpara completamente por una nueva que cumpla con la ley y reglamento aplicable.	50.00% 16
Poner sensor de movimiento para que paguen y prendan solas.	56.25% 18
Sembrar una barrera de plantas o arbustos para evitar sean visibles.	46.88% 15
Ninguna de las anteriores. No haria cambios.	6.25% 2
Otro (especifique) Responses	0.00% 0
Total Respondents: 32	

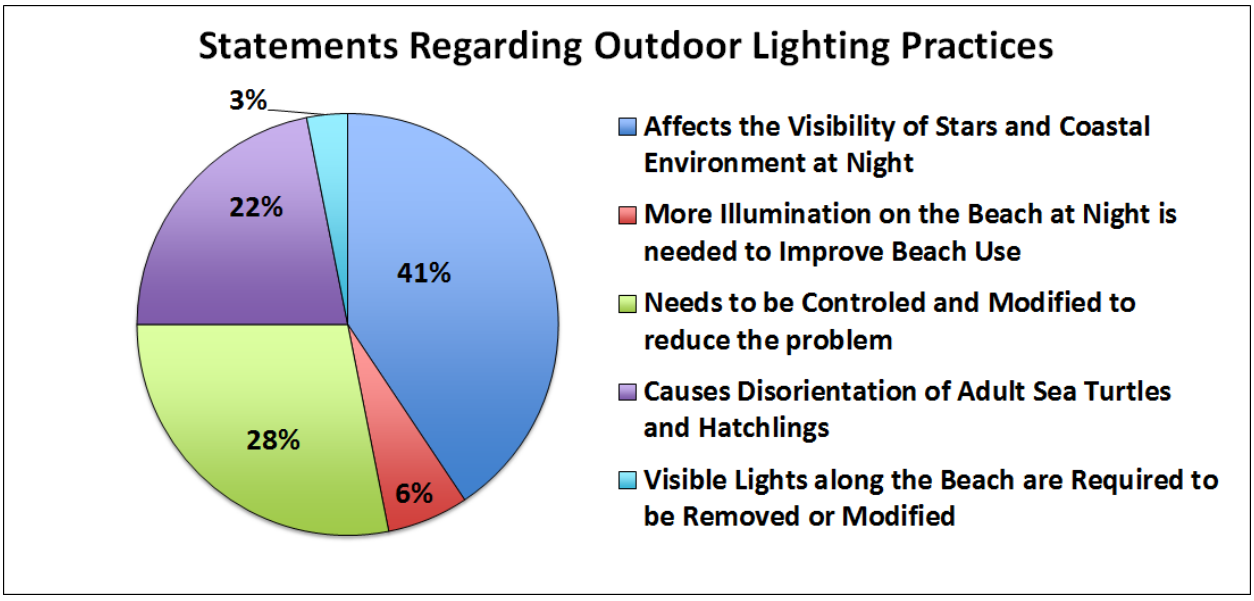
De las siguientes opciones, en orden de prioridad (#1 siendo el de mayor prioridad), indique cual sería la razón o razones que le motivarían a usted a tomar medidas correctivas para el uso de iluminación exterior en su propiedad.

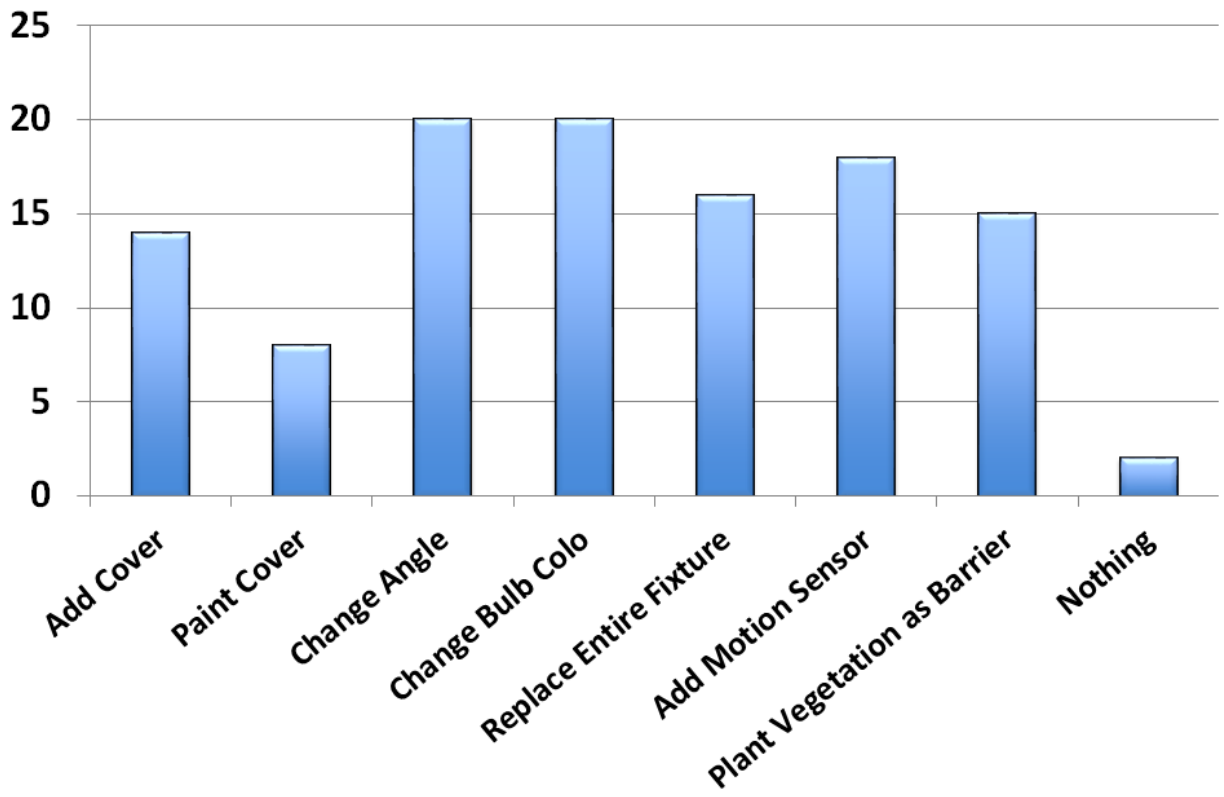
Answered: 32 Skipped: 0



	1	2	3	4	5	6	7	Total	Score
Evitar recibir una multa o penalidad del gobierno.	31.25% 10	28.13% 9	9.38% 3	0.00% 0	6.25% 2	25.00% 8	0.00% 0	32	5.03
Ayudar a salvar una especie en peligro de extinción.	43.75% 14	28.13% 9	12.50% 4	0.00% 0	3.13% 1	12.50% 4	0.00% 0	32	5.72
Para ahorrar dinero en costos energético.	18.75% 6	18.75% 6	25.00% 8	12.50% 4	15.63% 5	9.38% 3	0.00% 0	32	4.84
Para mejorar la calidad del cielo nocturno y se puedan ver las estrellas.	0.00% 0	9.38% 3	28.13% 9	37.50% 12	18.75% 6	6.25% 2	0.00% 0	32	4.16
Para mejorar la calidad estética de la iluminación exterior que uso en mi propiedad.	3.13% 1	12.50% 4	9.38% 3	28.13% 9	34.38% 11	12.50% 4	0.00% 0	32	3.84
Para crear un ambiente nocturno más natural en mi propiedad.	3.13% 1	3.13% 1	15.63% 5	21.88% 7	21.88% 7	31.25% 10	3.13% 1	32	3.38
Ninguna de las anteriores.	0.00% 0	0.00% 0	0.00% 0	0.00% 0	0.00% 0	3.13% 1	96.88% 31	32	1.03


Role in the Community
34%
44%
22%
House
Condo
Visitor


Statements Regarding Outdoor Lighting Practices
3%
22%
41%
28%
6%
Affects the Visibility of Stars and Coastal Environment at Night
More Illumination on the Beach at Night is needed to Improve Beach Use
Needs to be Controled and Modified to reduce the problem
Causes Disorientation of Adult Sea Turtles and Hatchlings
Visible Lights along the Beach are Required to be Removed or Modified


25
20
15
10
5
0
Add Cover
Paint Cover
Change Angle
Change Bulb Colo
Replace Entire Fixture
Add Motion Sensor
Plant Vegetation as Barrier
Nothing

Appendix I - Modifications

Table 2: Before and After Modification

Modification	Back View	Side View	Front View	Additional View
Original Fixture				
Shield Added				
Cone Added				
Cone and Shield Added				
Original Fixture				
Shield Added				
Two Shields Added				

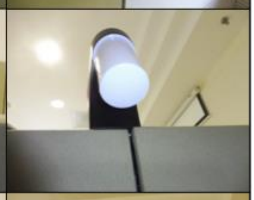
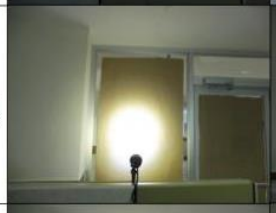
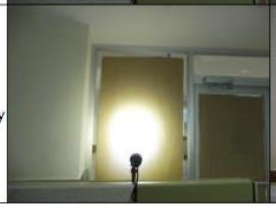
Original Fixture					
Cone Added					
Shield Added					
Original Fixture					
Long Shield Added					
Cone Added					

Table 3: Before and After Results

Type of Fixture	Type of Modification	Fixture Before Modification	Fixture After Modification	Modification Cost
Flood Light mounted on the wall	Shield Added (aluminum pan and spray paint used)			approx. $0.45
Flood Light mounted on the wall	Two Shields Added (aluminum pan and spray paint used)			approx. $0.70
Spot Light on the ground	Shield Added (aluminum pan and spray paint used)			approx. $0.45
Spot Light on the ground	Cone Added (small plastic flower pot used)			approx. $0.20
Spot Light on the ground	Shield and Cone Added (aluminum pan, small plastic flower pot, and spray paint used)			approx. $0.65

Type of Fixture	Type of Modification	Fixture Before Modification	Fixture After Modification	Modification Cost
Pickle Jar mounted on the wall	Cone Added (medium plastic flower pot used)			approx. $0.35
Pickle Jar mounted on the wall	Shield Added (aluminum pan and spray paint used)			approx. $1.20
Ceiling Light for a Patio	Cone Added (wide plastic flower pot and spray paint used)			approx. $2.70
Ceiling Light for a Patio	Shield Added (aluminum pan and spray paint used)			approx. $1.20

Appendix J - Guide

Reducing Light Pollution in Coastal Locations

JUNTA DE CALIDAD AMBIENTAL

Sea Turtles

Sea turtles use the natural light from the moon and stars to find their way back to the ocean from beaches. Without artificial light, the ocean ends up being the brightest area seen from the coast. However, on many of the coastal locations in Puerto Rico, there are high levels of artificial light and the turtles instinctively go away from the ocean.

Nesting female turtles look for the darkest and quietest locations to lay their eggs. If there is too much artificial light on the beach they feel unsafe and will look for other beaches, even though they may be less than optimal. This can result in fewer, if any, eggs hatching.

Hatchlings are also greatly affected by light pollution. When sea turtles hatch from their eggs they look for the brightest point, which is naturally the moon and stars reflecting off the ocean. However, if there are any sources of artificial light, this can confuse the hatchlings. They can end up going towards the lights and risk dying from dehydration, exhaustion, terrestrial predation and cars.

http://www.mesa.edu.au/turtles/images/cut_the_glow.jpg

1

Regulation #8786

Taken from the Regulation for the Control and Prevention of Light Pollution

Rule 13

This is a special class that is comprised of the entire coastline that is used by the turtles for nesting and spawning grounds for marine turtles in their annual visit along the coast of Puerto Rico.

If security lighting is necessary, all the luminaries that produce visible light from the beach must follow these guidelines:

- Low Pressure Sodium bulbs from 18W to 35W; Red, Orange or Amber LED bulbs; Only use bulbs that produce light of no more than 560 NM
- If there is illumination that shines on the beach, it is recommended that there is a physical barrier that reduces the shadows and lighting

Rule 15

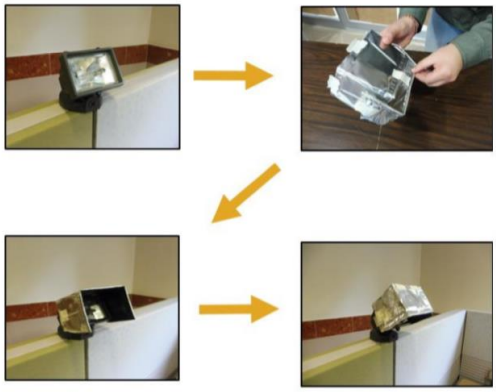
Any external source of emission whose light can be seen from the following classes is allowed:

- 1 (Construction Lighting)
- 5 (Lighting for Gardens, Inside Fountains and Pools)
- 6 (Parking Lights)
- 7 (Pedestrian Lighting)
- 8 (Light outside family and multi-family residences)

All luminaries must have a long cutoff of 70 Degrees measured from the vertical axis orientation

Modifications

Flood Light



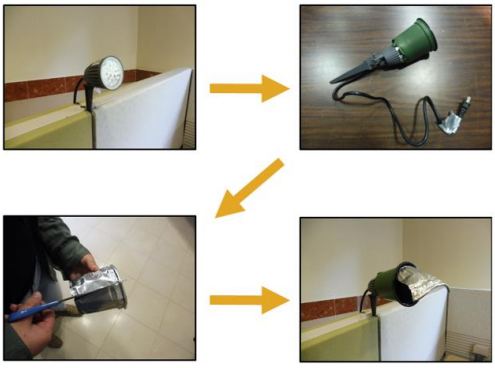
Materials: Aluminum sheet, spray paint

Cost: < $1.00

Description: Bend the aluminum sheet into two rectangular sheets to create a box like shield. Then spray paint the inside to decrease reflectivity. Attach the modification to the fixture using screws or clamps.

Modifications

Spot Light



Materials: Flower pot, aluminum sheet, spray paint

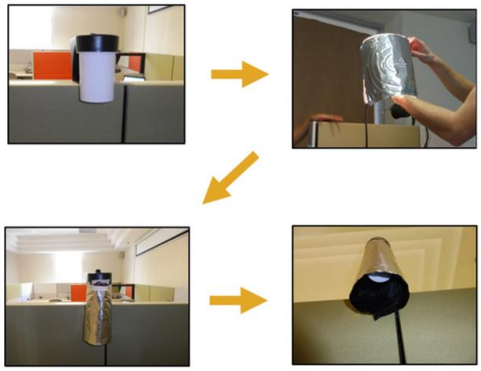
Cost: < $1.00

Description: Cut a hole in the bottom of the flower pot to fit around the light fixture. Then attach a small piece of the aluminum sheet and angle it downward. Finally, spray paint the inside of the aluminum to decrease reflectivity. Attach the modification to the fixture using glue, screws or clamps.

4

Modifications

Pickle Jar



Materials Used: Aluminum sheet, spray paint

Total Price: < $1.00

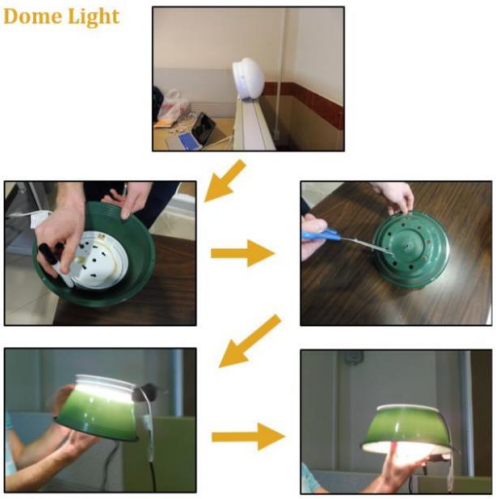
Description: Bent the aluminum sheet into a cylindrical shape and spray paint it to decrease reflectivity. Attach the modification onto the fixtures using screws, clamps or glue.

Warning: None of these modifications are intended for permanent use. The heat from the bulbs may cause melting or fire.

5

Modifications

Dome Light



Materials: Large flower pot, marker, spray paint

Cost: < $3.00

Description: Cut a hole in the bottom of the flower pot to fit around the light fixture. Then, spray paint the inside of the pot to decrease translucency. Attach the modification to the fixture using glue or screws.

6

Contact Us

For more details, you can communicate with our offices at:

Phone: (787)-767-8181 ext. 3206
Email: josealicea@jca.gobierno.pr
Web: http://www.jca.gobierno.pr/

For more information about

- Sea Turtles: https://conserveturtles.org/
- Light Pollution: http://darksky.org/
- The Regulation: http://www.jca.gobierno.pr/

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