December 2014

A Protocol for Evaluating Lighting Practices and Light Pollution in Coastal Locations

Benjamin Marx Greenbaum
Worcester Polytechnic Institute

Cody John Holmes
Worcester Polytechnic Institute

Felicia Marie Gabriel
Worcester Polytechnic Institute

Noelle Dionne Ouellette
Worcester Polytechnic Institute

A Protocol for Evaluating Lighting Practices and Light Pollution in Coastal Locations

An Interactive Qualifying Project proposal to be submitted to the faculty of

Worcester Polytechnic Institute in partial fulfillment of the requirements for the

Degree of Bachelor of Science

December 18, 2014

Submitted by:

Felicia Gabriel
Benjamin Greenbaum
Cody Holmes
Noelle Ouellette

Submitted to:

Departamento de Recursos Naturales y Ambientales

Junta de Calidad Ambiental

Project Advisors:

Lauren Mathews
Tina-Marie Ranalli

Executive Summary

Excess artificial lighting has become a growing problem around the world. There are many benefits to artificial lighting, but if good lighting practices are not applied a serious problem may arise, and this is referred to as light pollution. High levels of artificial light result in adverse effects, including sky glow, glare, light trespass and light clutter. Sky glow is caused by the accumulation of light from many fixtures that each emits a portion of light directly upward into the sky where light scatters and cumulatively increases nighttime illumination. Light trespass refers to light that spills over its necessary boundaries into areas where light is unwanted or needed (Longcore & Rich, 2004).

Organizations around the world are beginning to take steps to assess and improve lighting habits. In Puerto Rico, light pollution is a main concern due to the coast's ability to support sea turtle nesting. Under Puerto Rico regulations, there should be no light trespass on a potential sea turtle nesting beach. Two organizations, the Departamento de Recursos Naturales y Ambientales (Department of Natural and Environmental Resources) and the Junta de Calidad Ambiental (Environmental Quality Board), are developing a protocol to measure coastal light levels in order to evaluate lighting practices in coastal regions of Puerto Rico.

Methodology & Results

The goal of this project is to assist the Departamento de Recursos Naturales y Ambientales and the Junta de Calidad Ambiental in developing a program to measure light levels and evaluate lighting practices for coastal communities in Puerto Rico. The program will involve a protocol for measuring light levels, creating an inventory of current light fixtures, and a survey to gauge the perspectives of community members on light pollution and its impacts on these communities. Our protocol is in part a modification of an existing protocol (Devries et. al, 2013) used by the JCA which we adapted for coastal conditions, but also includes additional measurements that were not present in the existing protocol. Our work will allow the DRNA and JCA to develop, promote and perform other projects around the coast using this protocol.

The first step in creating the protocol was to develop a system for measuring sky glow and light trespass. This required careful selection of a sampling schedule so as to accurately

measure the brightness of the sky without interference. Our protocol uses a GIS program to select data points. To develop our protocol for measuring light trespass, we started with the existing protocol developed for the JCA by a past IQP group (Devries et. al., 2013) for measuring light trespass in urban and rural locations. As our protocol was intended specifically for coastal locations, we used trial and error to determine what changes needed to be made for this protocol to yield the desired data in coastal regions. We began by testing the 10x10 meter square quadrant system used to take readings. The process of initial preparation and perimeter set up was completed in the field. The second part of the protocol involved creating daytime and nighttime site assessments which include geographical and observational data. To evaluate the daytime and nighttime assessment protocols, we visited the site both at daytime and nighttime hours to pilot test the initial system and note any changes that needed to be made. To create a method for collecting light trespass measurements along the coast, our team tested the protocol to see if any problems or limitations arose. To complete this, our team went to the coast and completed the process multiple times for multiple points and noted any changes that needed to be made. As a new element for measuring light pollution, our team added a system of taking sky glow measurements. Another item added to the protocol was a system to create an inventory of all the lights located along the coast. The last addition to the protocol was a survey intended to gain insight into the degree to which community members understand the potential ecological impacts of light pollution in their neighborhood. It will also provide information on the opinions of community members on the lighting practices currently in place. This is a critical part of any assessment of coastal light pollution because without knowing the motivation behind community member lighting practices it will be difficult to enact change.

Our final Coastal Light Level Measuring Protocol consists of six chapters designed to allow the DRNA and JCA to study lighting practices in any coastal location. The protocol includes the following chapters:

1. Using the Photometer: This chapter outlines how to use a photometer to measure light trespass. This includes calibration methods, standard units of measurement, and instructions on how to take light level readings.
2. Quadrant System: This chapter describes the process of selecting data points every 100 meters using a Geographic Information System. These points serve as

anchors for a 10x10 meter quadrant system used to take light trespass and sky glow measurements.

3. Daytime and Nighttime Assessments: This chapter provides instructions on how to complete daytime and nighttime assessments at each point, using a Site Assessment Sheet to document geographic information including photographs and observations of each quadrant.
4. Performing Nighttime Measurements: This chapter provides detailed instructions for how and when to take light trespass and sky glow measurements and record the data using a Data Collection Sheet.
5. Creating an Inventory of Coastal Lights: This chapter outlines how to complete an inventory of coastal lights by assessing location, lighting use, shield type, bulb type, and type of shut off.
6. Survey to Gauge Perspectives of Community Members: This chapter provides a survey to be distributed in the studies location in order to gauge the perspectives of community members on light pollution and its impacts on these communities.

Our second objective was to use the protocol in the coastal community of Isla Verde to evaluate their current lighting practices. We measured sky glow and light trespass, completed an inventory of light fixtures along the coast, and administered a survey to the residents of Isla Verde.

First, we created a schedule of possible dates and times to complete our measurements, and six days were selected in November. The Management Program of the Coastal Zone of the Department of Natural and Environmental Resources identified points for our study using a GIS program to create an aerial map of Isla Verde. After taking our sky glow measurements the data was compared to a classification scheme for sky glow readings. Due to Isla Verde's location, our team hypothesized that the sky glow readings for the coast of Isla Verde would be consistent with typical readings of an urban neighborhood or bright suburb. Light trespass measurements were taken to determine if the levels were within acceptable range of a turtle nesting site, below 0.005 footcandles. The inventory was completed to make conclusions about lighting practices in Isla Verde and whether or not they effected light trespass measurements. The last step involved administering the survey using Qualtrics, an online survey platform, and in person to individuals in the area.

The sky glow measurements along the coast of Isla Verde had readings that all fell within the range that is typical of bright suburbs or urban areas where there is too much light for the Milky Way to be seen. There was a significant amount of variability in the light trespass data between quadrants as well as variability among the points of each quadrant. This was attributed to the practice of using a single or small set of luminaires to illuminate a very confined area around paths and for security. We found that only one out of 29 total quadrants had mean levels of illumination below the 0.005 foot-candle limit that is the maximum acceptable light for sea-turtle beaches. Even though the mean was below the 0.005 foot-candle limit, several points within the quadrant were above the limit. This was attributed to lights from hotels which were several hundred yards away.

After completing the inventory of the coast our team wanted to determine if there was any correlation in our data between coastal lighting practices and light trespass levels. We recorded a total of 336 lights. The number of lights per site ranged from 0-45 with the average number of lights per quadrant being 11.2. From the data, our team concluded that there was a positive correlation between number of lights surrounding a site and levels of light trespass. There was also a positive correlation between poor levels of shielding on a light and levels of light trespass. Fully shielded lighting resulted in lower levels of light trespass while areas with high levels of light trespass were surrounded by lighting with mostly partial, improper, or no shielding. After analyzing all of the classification data our team concluded that each property type requires lighting for different purposes and that lighting used for security and patio lighting were the most likely to have no shielding. Our final conclusion was that lighting habits have a direct effect on light trespass levels on the coast.

For our survey, although we had a large number of potential respondents, very few actually completed the survey. Due to the poor response rate, we concluded that the residents had an apparent lack of concern towards light pollution. While conducting surveys in person, many residents voiced concerns about safety and given the choice, would like to have more lights along the beach. The exception to this was a building administrator who had received education from the DRNA on the effects of light pollution and better lighting practices.

Recommendations

Our protocol results clearly indicated that Isla Verde has a light pollution problem, and that this stems directly from the area's poor lighting habits. Our team created technical recommendations to improve the protocol for future applications. In order to address poor lighting practices, our team decided to focus our efforts on creating community outreach programs to educate community members and help get them involved in making positive changes in Isla Verde. The programs are designed to be implemented in any region in order to promote discussion about lighting practices and get the community involved in making better lighting choices.

After applying the protocol in the coastal community of Isla Verde, our team was able to recommend improvements to certain aspects of the protocol. These protocol recommendations are designed to make the protocol more effective and allow greater critical analysis.

After concluding that the coast of Isla Verde has high light levels and low levels of concern for changing lighting practices, our team created a system to get community attention. While enforcement of local and state level regulation is pending for next year, the next best step is to hand out official notices to promote voluntary cooperation. We created a prototype for a Light Fixture Notice for recommendations on how to improve lighting habits. It does not include any legal repercussions if the light fixture recommendation is not completed.

The second part of our outreach plan includes a brochure that the DRNA and JCA can distribute to coastal regions in Puerto Rico to promote voluntary cooperation. The brochure provides information about the program as well as personalized data about a regions lighting practices and potential impacts on the ecosystem.

We also recommend that the DRNA and JCA coordinate a community outreach program in the form of a stargazing trip. The trip will include two components, an educational information session focusing on local lighting practices and a night sky tour. This program is intended for all community members in any coastal region where the protocol is carried out. However, the night sky tour will take place in a different location where it is dark and the light levels are not high enough to affect the appearance of the night sky. This tour will be used to attract the community members to participate in the program and used to help participants appreciate the result of a night sky in a dark location.

Lastly, we created a feedback form to allow community members to describe problematic light fixtures in their area and to request change. This is an excellent way for two-way communication to give the community members a voice in the process of changing lighting habits. The form will allow the DRNA and JCA to understand how community members feel about any bothersome light fixture and what their personal recommendations for improvement would be.

Conclusions

This project has the potential to improve coastal lighting practices in Puerto Rico. The final protocol can be used along the entire coast of Puerto Rico to measure light levels and evaluate lighting practices. Community outreach programs can educate residents about modifying their lighting practices to be in accordance with local lighting regulations. By using this system, the DRNA and the JCA can continue to take steps towards reducing light pollution in Puerto Rico.

Acknowledgements

- We would like the thank our advisors Professor Lauren Mathews and Professor Tina-Marie Ranalli for always pushing us to improve our project and guiding us through the IQP process
- José Alicea Pou for serving as our liaison and JCA contact
- Nitza Marrero Fontán and Miriam Ortiz Torres for accompanying us during our field work
- Paco López Mújica and Carlos Diez for proposing the project and trusting us to accomplish their goals
- Astrid J. Green Caceres and Hiram Cruz for serving as our DRNA contacts and introducing us to the program
- Professor Frederick Bianchi for allowing us to use his personal sky quality meters to complete our project

Table of Contents

List of Figures

List of Tables

1.0 Introduction

The International Dark Sky Association (2014), a non-profit member organization with the goal of preserving and protecting the night time sky by educating and promoting environmentally friendly lighting practices, defines light pollution as any adverse effect of artificial light, including sky glow, glare, light trespass and light clutter. Light is often overlooked as a form of environmental pollution, mainly because humans have long sought methods to illuminate the night sky (Longcore & Rich, 2004). The utilization of electricity for artificial lighting solved this problem but the vast increase of this technology has led to other issues. While the benefits of artificial lighting are clear, one cannot overlook the negative effects it can have on humans and ecological communities. The constant rise in global population has increased the need for artificial lighting. Artificial lighting has expanded into previously unlit areas and its density has intensified in developed areas. Two thirds of the world population in 2001 was living in an area where the night time sky had been deemed polluted by the First World Atlas of the Artificial Night Sky Brightness (Cinzano, 2001). The effects of light pollution have caused many countries, including the United States and Spain, to establish legislation in order to combat the rise of light pollution and its effects on ecosystems.

Currently in Puerto Rico, coastal light levels are rising due to increased tourism activity. Puerto Rico is starting an initiative to assess their coastal lighting practices and light pollution problems. Puerto Rico enacted the Light Pollution Control and Prevention Program Act (the Act), in 2008 in order to curb the effects of light pollution. The Act created regulations for reducing excess lighting. The Junta de Calidad Ambiental (Environmental Quality Board) or the JCA, in conjunction with the Departamento de Recursos Naturales y Ambientales (Department of Natural and Environmental Resources) or the DRNA, is placed in charge of enforcing the Act.

The purpose of this initiative is to determine if coastal regions are following best lighting practices as defined by national and international standards and requirements. One of the main areas of concern for the DRNA and JCA are coastal regions due to their tourism industry, which increases the use of artificial lighting. These artificial lights may have negative impacts on the natural coastal ecosystems. Given its location and convenience, the testing of the protocol will take place in the coastal community of Isla Verde within the city of Carolina. The Isla Verde beach is home to a coral reef marine reserve as well as turtle nesting sites, which makes it a prime candidate for a baseline study. The DRNA and JCA would like to develop and test a protocol to collect and organize a database on current light levels, different lighting practices by residents and businesses, as well as data on community member's perspectives on these lighting practices in coastal communities like Isla Verde. The data we collected allowed us to modify the current protocol which would reflect some of the most common lighting practices in coastal communities, like Isla Verde, as well as create a baseline for future studies.

The goal of this project was to assist the Departamento de Recursos Naturales y Ambientales and the Junta de Calidad Ambiental in developing a program to measure light levels and evaluate lighting practices for coastal communities in Puerto Rico. To accomplish this goal, we identified and classified all sources of nighttime light emissions that can be seen from the shore and measured ambient light levels along the coastline of Isla Verde, as a test site for the protocol. Our findings were organized into a database and analyzed to identify community lighting practices and possible improper use of exterior lighting that could contribute to light pollution in the form of light trespass on the coast. The next step was to gauge the perspective of community members by conducting surveys and interviews regarding exterior light issues and light pollution. The last step was to make recommendations to the DRNA and the Environmental Quality Board that included improvements to the protocol as well as a mitigation plan that will include fixture recommendations and an educational plan on best lighting practices. Our project will leave the JCA and DRNA with the tools to educate coastal communities on how to reduce nighttime light emissions, as well as a baseline for future studies of coastal light levels.

2.0 Background

The global population is constantly increasing, and as a result, the use of artificial light is increasing as well. Although artificial light has vastly improved the standard of living for many people, it has caused a new problem to arise: light pollution. Not all artificial light should be considered light pollution. That designation is reserved for outdoor lighting fixtures that are poorly designed and increase light in undesired locations. Around the world communities are taking steps to reduce light pollution and prevent the negative human and ecological effects associated with it. This project is specific to the island of Puerto Rico and the government's initiative to create a protocol for measuring coastal light levels.

This chapter will outline internationally accepted lighting practices and give the implications if these are not followed. It will also examine the potential ecological impacts connected with artificial lighting. To better understand light pollution around the world we discuss the steps other countries have taken to change their lighting habits. Our team is testing this protocol in the coastal community of Isla Verde.

2.1 Light Pollution

Not conforming to best lighting practices can lead to light pollution. Light pollution is a phenomenon of growing world-wide interest. In this section we clearly define light pollution and its major types, astronomical and ecological.

2.1.1 What is Light Pollution?

Light pollution is the encroachment of artificial light into unlit areas of the nighttime environment, which can cause changes in the spectral composition, duration and spatial patterns of light (Gaston, Davies, Bennie, & Hopkins, 2012). A more simple definition from the International Dark Sky Association (2014) considers that light pollution is any adverse effect of artificial light including changes in the spectral composition, duration and spatial patterns of light, and includes a number of different forms, which we discuss below. Each of these forms are similar but can be caused by different types of lighting. These effects have increased and spread around the globe due to the expansion of electric lighting to previously unlit areas as well as an increase in the density of lighting used in developed areas (Gaston et al., 2012). Figure 1 shows patterns of light emissions globally, which correlate with developed areas emitting more light compared to undeveloped areas. This figure also shows that light levels are so low in some regions of the world that the light doesn't even register on the satellite image.

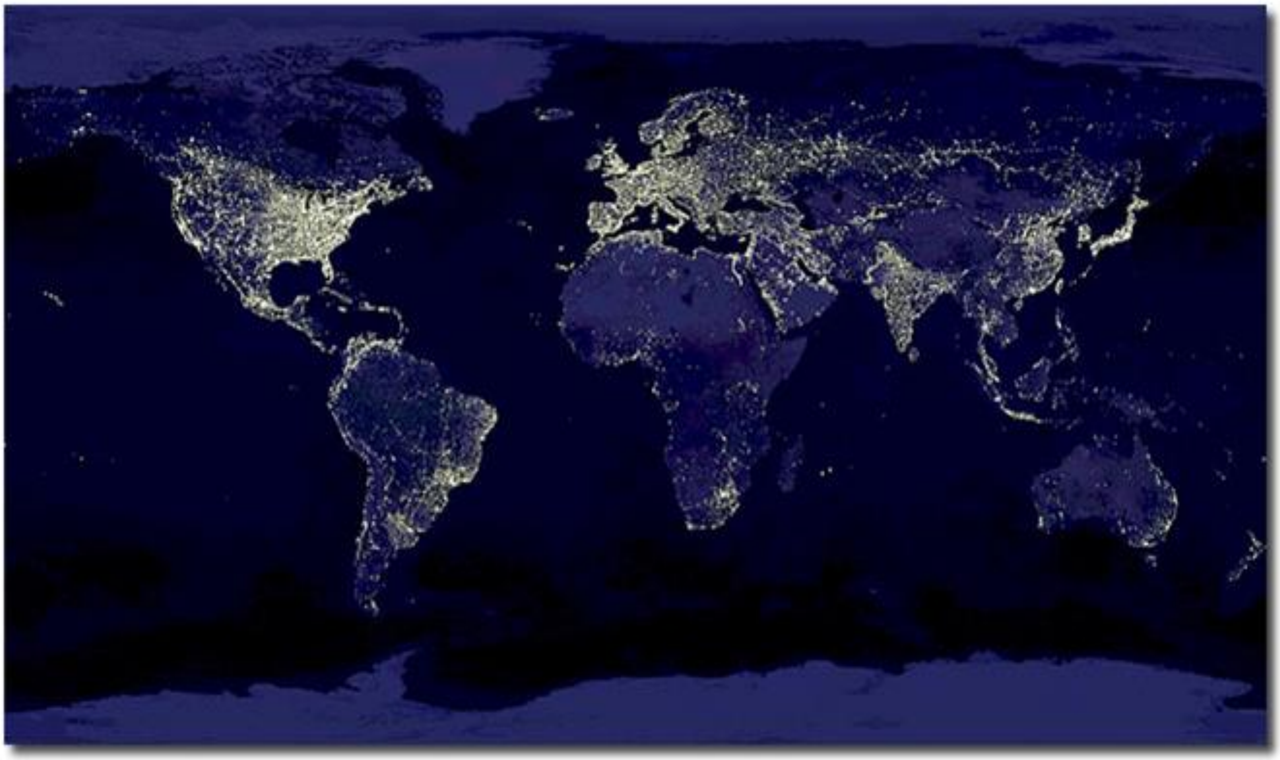


Figure 1: Satellite imagery showing global distribution of light emissions
http://environmentallysound.files.wordpress.com/2012/04/lightpollution5a.jpg

Light trespass is the most common form of light pollution and has varying spatial effects. Also referred to as spill light, or obtrusive light, light trespass occurs when light spills over its necessary boundaries into an area where light is unwanted or needed. A simple diagram of light trespass can be seen in Figure 2. Sky glow is a growing global phenomenon resulting from thousands of fixtures that each emits a portion of light directly upward into the sky where light scatters and cumulatively increases nighttime illumination. This scattering of light causes the brightening of the sky with an orange yellow glow which can be seen in Figure 3. Glare is any intense and blinding light that reduces visibility. In order to qualify as glare the light within the field of vision must be brighter than the eyes can adapt to (Figure 4). This is caused by poor lighting angles and shielding. Poor lighting techniques can also cause light clutter which, can be defined as an excessive grouping of lights well beyond what is required for necessary sight. All of these consequences result in decreased visibility at night and high amounts of energy waste (Longcore & Rich, 2004).

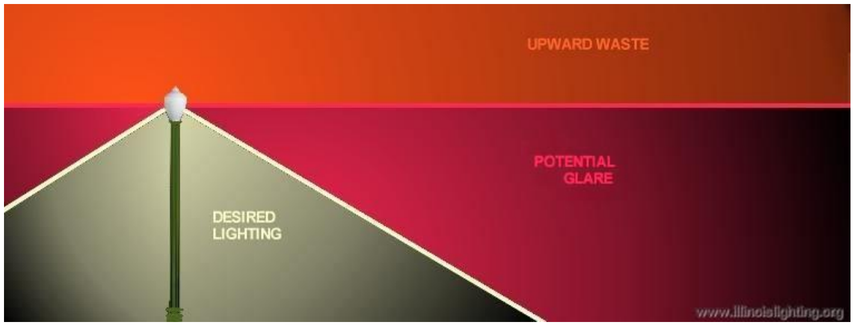


Figure 2: Diagram of light trespass. The section labeled "desired lighting" is the only beneficial light being emitted from the lamp. The purple area represents "potential glare" and the orange section represent "upward waste" which is a major contributor to sky glow. http://www.illinoislighting.org/fixture1.html

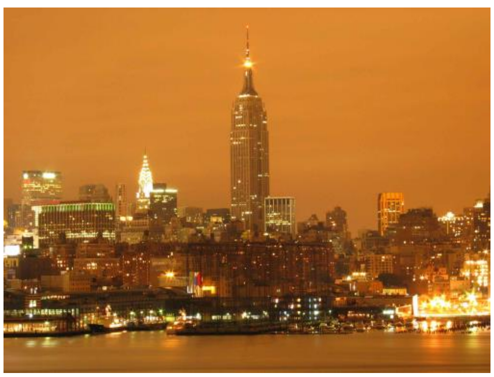


Figure 3: Sky glow


Figure 4: Glare

Astronomical light pollution was first discussed by astronomers due to the diffusion of urban sky glow impeding visual observation of dim celestial object near cities (Kuechly, 2012). Two elements of light pollution greatly affect astronomers above all others: sky glow and light trespass (Longcore et al., 2004). Sky glow is the scattering of light directly upward into the sky, as seen in Figure 5. This creates an orange-yellow glow above a city or town. The main concern with astronomical light pollution is that is can interfere with sensitive astronomical instruments that allow astronomers to see stars and other celestial bodies (Kuechly, 2012).

Figure 5: Diagram showing the causes and consequences of astronomical light pollution (Longcore & Rich, 2004)

Unlike astronomical light pollution, ecological pollution is a fairly new concept. It is lighting that alters natural light regimes in ecosystems, and is recognized as a major stressor for nocturnal organisms and a threat to biodiversity (Figure 5) (Kuechly et al., 2012). Ecological light pollution includes direct glare, chronically increased illumination and temporary unexpected fluctuations in lighting. Sources of ecological light pollution include but are not limited to lighted buildings and towers, streetlights, fishing boats, security lights, lights on vehicles, flares on offshore platforms, and light on undersea vessels (Longcore et al., 2004).

2.1.2 Measuring Light Levels

The best method for determining the ecological impact of light pollution is by measuring the illumination in an area. Illumination is the amount of light incident per unit area, which is the light that falls on a subject either directly or indirectly. Light incident is measured in photons per square meter per second. Illumination is often measured in lux because it is the standard used by most lighting designers. Unfortunately, lux measurements focus more on light that can be perceived by the human eye and less on those that humans perceive poorly. This also means that the using lux ignores biologically relevant information from different organisms. To monitor ecological light pollution it is important to consider how other organisms perceive light. The best way to do this is by measuring absolute illumination levels, as well as sudden and long term changes in illumination (Longcore et al., 2004).

There are multiple ways to describe the artificial light that we see all around us during the night (Figure 8). Luminous flux is the amount of light a fixture is emitting and is measured in candelas per square meter (lumens) (Danby et al., 2011). A candela is the luminous intensity, in a given direction, of a source that emits monochromatic radiation of frequency 540 x 1012 hertz and that has a radiant intensity in that direction of 1/683 watt per steradian (Thompson & Taylor, 2008). Luminous intensity measures the amount of light in certain directions once emitted from the fixture and is measured in candelas. Illuminance is the amount of light falling on a surface, and is measured in lux (lumen/m2) or foot-candles (lumen/ft2). Foot candles is the SI unit and 1 footcandle equals 10.8 lux. Luminance (cd/m^2) is the amount of light that the surface is reflecting (Danby et al., 2011).

Light follows what is known as the inverse-square law (Danby et al., 2011). For example, the flame from a candle will cause an illuminance of 1 lux on an object one meter way, but if this object is put two meters away it will only cause one fourth the amount of lux (Danby, et al., 2011). Figure 6 below is an excellent visual representation of this terminology.

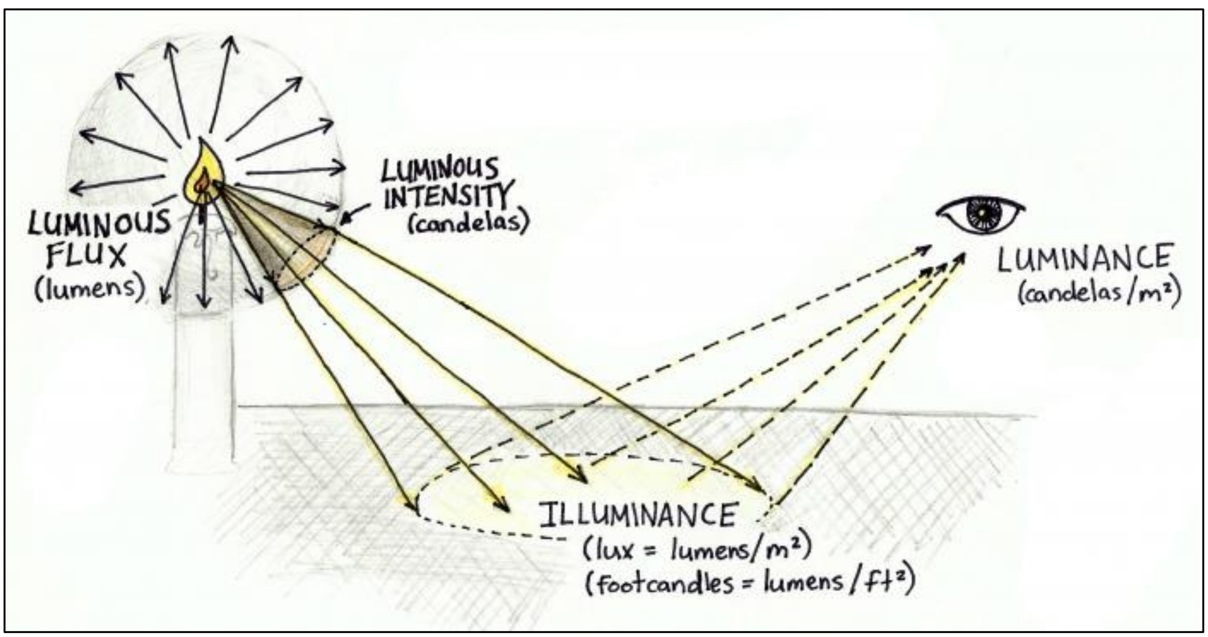


Figure 6: Basic metrics of light
http://sustainabilityworkshop.autodesk.com/buildings/measuring-light-levels

2.2 Internationally Accepted Lighting Practices

Overseen by the National Science Foundation, Globe at Night reports that the incidence of high magnitude light pollution has increased over the years 2006 through 2012 (Globe at Night, 2012). The data from these six years show an increase of night sky brightness and a reduced visibility of stars. Although light pollution is a global problem, regions such as the United States, Europe and Eastern Asia, are more severely affected. In the contiguous United States and Europe, as well as about two-thirds of the population in the world, 99% of the population are living in regions where the night sky has reached polluted status (Cinzano, 2001). These statistics are based on the level of artificial night sky brightness at sea level, which compares light pollution in various locations without taking their elevations into account, making the results more accurate. The comparisons of pollution levels across the globe are shown in Figure 7. In response to the increase of light levels around the world, international recommendations regarding acceptable lighting practices have been established by governmental and nongovernmental organizations. Some recommendations include properly directing light, using proper light sources and establishing curfews for outdoor lights.

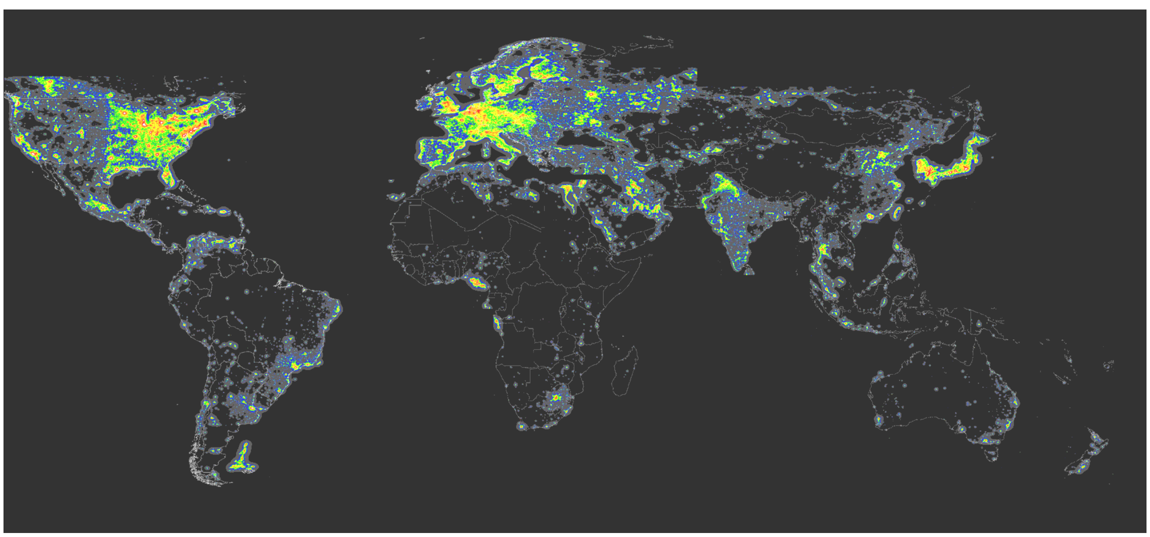


Figure 7: The brightest colors on this map of the world indicate where the highest levels of light pollution are. (Cinzano et al, 2001)

2.2.1 Shielding

In many poorly designed luminaires, light is not directed onto intended surfaces and is instead allowed to escape into the atmosphere. This brightens the night sky unnecessarily. A simple solution is to attach a device called a shield to block light shining in unwanted directions.

Shielding is classified by the degree to which it blocks excess light. "Full shielding" is defined when luminaires are prevented from allowing light to shine directly at or above the horizontal. This means that light should not be directed within the range of 0 to 45 degrees from the horizon plane (Falchi, 2011). A more restricting classification prevents light from being directed within zero to ten degrees below the horizon plane. This limitation is to control the reflection of light off the asphalt, which can increase the light levels considerably (Falchi, 2011).

2.1.2 Appropriate Bulb

After the light is properly directed towards the intended target, it is necessary to consider the characteristics of the light itself such as spectrum and brightness.

Spectrum is a crucial component to consider for effective lighting plans. Light Emitting Diodes for example are efficient light sources using half the power of an equivalently bright fluorescent bulb (Pathberiya, 2013). LED's used in outdoor applications often emit a cool light with a larger blue spectrum. This scatters more easily into the atmosphere, contributing more to light pollution than a warmer option such as a red or yellow light (Pathberiya, 2013). However red light also has drawbacks. Plants have a pigment called phytocrome that absorbs red light. This pigment is responsible for dormancy, seed germination and abscission. Plants that are exposed to extended exposure of lights with a predominantly red spectrum are put at an increased risk of natural weather phenomenon (Pathberiya, 2013).

Low-pressure sodium bulbs, or LPS bulbs, emit a yellow almost monochromatic light as can be seen in Figure 8 when compared to other common forms of lighting. The yellow wavelengths have less harmful effects than the blue or red wavelengths, which makes it ideal for lights such as street lights that will be on for most, if not all of the night. In addition, the monochromatic nature of LPS bulbs is a useful characteristic for astronomers as it is easier to filter out of astronomical observations than the complex spectrum emitted by fluorescent, incandescent, or metal-halide luminaires. Filtering light is a common practice in astronomy that is used to determine the conditions the light was emitted under. For example filtering out all light except for red and blue and examining the relative quantities of each color is used to calculate the temperature of a star (Luginbuhl, 2003). As long as astronomers do not need data from the spectrum that LPS light reside in, there is little to no interference with their studies.

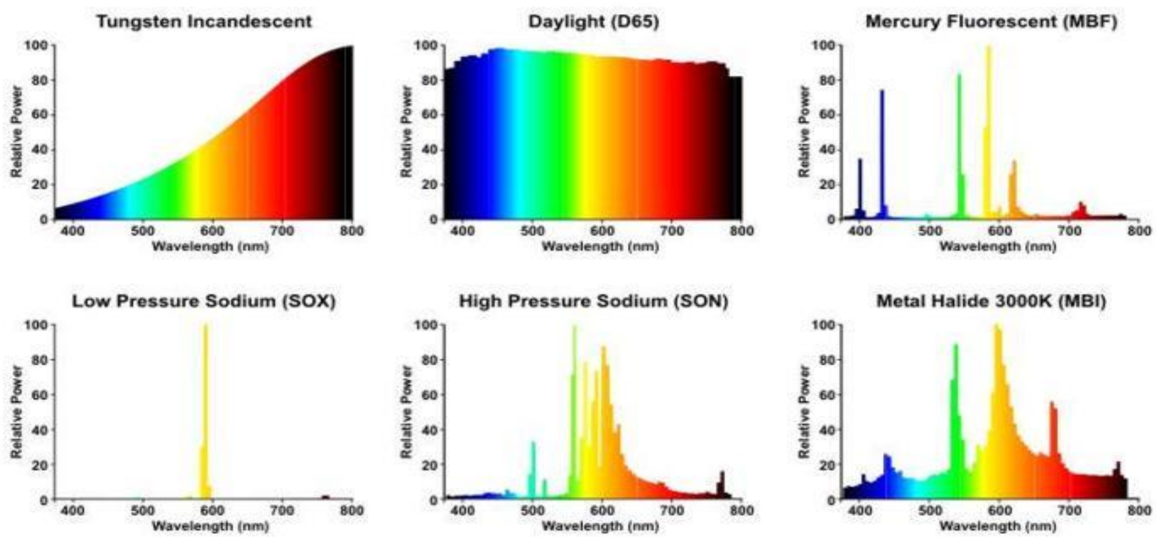


Figure 8: Spectrum and relative intensity of different bulbs and natural daylight http://www.lamptech.co.uk/Documents/SO%20Spectral.htm

Brightness is a more obvious consideration when selecting appropriate bulbs however this is a harder characteristic to provide recommendations for since there are numerous different situations that call for different levels of light. The Illuminating Engineering Society of North American (IESNA or simply IES) has created recommendation regarding light levels in footcandles of numerous situations. For example, the IES suggests that street lighting range 0.3 to 0.8 footcandles for lightly traveled roads, 0.6 to 1.6 footcandles for more heavily traveled roads and 0.6 to 1.3 footcandles for highways. These different recommendations with relatively large ranges illustrate how the application of lights influences the required brightness. This makes any specific overarching statement about necessary brightness difficult to impossible to make.

2.2.3 Curfew

Simply turning off unnecessary lights is the single most effective way to reduce light levels. Throughout the world, many businesses, sports facilities, and even parking lots keep their lights on for the majority of the night even if they are not conducting business during those hours. Many of these lights and advertisements are not necessary to have on from dusk to dawn. A curfew that sets a time when lights must be turned off will reduce the amount of light being wasted. Exceptions may be required if a light is used for safety and security or if it belongs to a business that operates after all other lights are required to be turned off (Mizon, 2012).

2.2.4 Mitigation Strategies

With the increase in light pollution levels, researchers have been exploring various ways to decrease light levels (Falchi, 2011). One conflict that arises when recommending different lighting methods is to ensure that the proposed lights do not harm the environment while satisfying societal demands (Falchi, 2011). The demands that are of most concern are to make sure that public safety will be maintained, as well as preventing the crime rate from increasing. The most popular methods that have been recognized as being environmentally friendly include “full shielding”, limiting the lit area, getting rid of over lighting, establishing a curfew, and reducing the growth of the installation of new lights.

The act of “full shielding” can be defined as preventing luminaires from allowing light to shine directly at or above the horizontal. This means that light should not be directed within the range of 0 to 45 degrees from the horizon plane (Falchi, 2011). Another restriction is to prevent light from being directed within zero to ten degrees below the horizon plane. This limitation is to control the reflection of light off the asphalt which can increase the light levels considerably (Falchi, 2011). Not only will “full shielding” reduce harm to the environment, but will also provide benefits to humans such as decreasing the amount of glare from streetlights which in turn will increase road safety.

Limiting the area that is being lit as well as eliminating the over lighting of an area both accomplish the goal of only lighting the intended area. The current light fixtures scatter light outwards where it is unnecessary but by if the light is carefully directed, less will be wasted. Not only will the amount of wasted light decrease but there will be less that can be reflected off of other surfaces like asphalt which will result in decreasing light levels (Falchi, 2011).

Throughout the world, many businesses, sports facilities, and even parking lots keep their lights on for the majority of the night even if they are not conducting business during those hours. Since many of these lights and advertisements are not necessary to have on from dusk to dawn, one solution is to establish a curfew. This idea involves setting a time when lights must be turned off which will also reduce the amount of light being wasted. There may be exceptions for light fixtures that are required for safety or security purposes, along with businesses that are open during the designated hours (Mizon, 2012).

Reducing the increase in installations of new lights is very important, as new lights are being put into use at a fast rate. Falchi's (2011) example on how to implement this idea is to allow a one percent increase in new light fixtures yearly. After this initial increase, the addition of light fixtures would be put to a stop and then there would be a decrease in the addition of new light fixtures. This decrease only means that if someone wanted to install a new light they would have to decrease the lighting from a preexisting fixture (Falchi, 2011).

Based on past research, implementing these techniques should lead to a significant reduction in light pollution. A study from a campaign of sky brightness showed that after analyzing six sites, 75% of sky brightness from artificial lights was produced by light directly from fixtures (Falchi, 2011). The other 25% of the sky brightness was a result of light being reflected off of surfaces. This data suggests that if all light fixtures were to be changed to the shielded version as previously described, then the sky brightness caused by artificial light could be reduced by as much as 25% of the current levels.

2.3 Initiatives Worldwide

In recent years, the International Dark Sky Association has had success in working with multiple cities in the United States to create light pollution laws. According to José A. Alicea Pou from the JCA, many people in Puerto Rico became interested in light pollution after realizing the success the United States was having (personal communication). In addition to multiple cities in the United States, the Canary Islands in Spain have established best lighting practices to reduce light levels.

2.3.1 Legislation in Mainland U.S. Cities

The San Diego County Code established in San Diego, California, includes a section called the Light Pollution Code which focuses on methods to reduce light pollution. According to Light Pollution News & Info (2011), it provides information on the types of luminaires (light fixtures) to be used for each zone, curfews for certain types of lights, and lights that are exempt from this code. San Diego used to have levels of light pollution so high that the stars were barely visible. Since the code's adoption in 2001, night sky visibility has improved as well as road safety due to reduced glare from streetlights. This Light Pollution Code also regulates "off-premise signs" which includes billboards. These regulations specify an appropriate number, size, height and location for each sign in order to improve traffic safety and the environment (Planning Division, 2013). As a result of this code, the poor quality of the night skies in Borrego Springs, a part of San Diego

County, has improved so much that the Milky Way is now visible on a regular basis (Dipping, 2008). Borrego Springs is also home to the Anza-Borrego Desert State Park which now has such clear skies that it has become a popular location for astronomers and is the reason why the public is trying to get Borrego recognized as a Dark Sky City (Dipping, 2008). This Light Pollution Code has gotten a lot of support from the community which is the main reason for the success in reducing light pollution in San Diego County.

The state of Arizona has adopted various ordinances regarding light pollution. In 2012 the city of Tucson, Arizona established a light ordinance to combat light pollution. Like the act in Puerto Rico, this law describes different lighting requirements depending on the type of zone the light is located in. However, the law in Tucson is much more detailed than that in Puerto Rico in terms of describing specific guidelines depending on the location of the lights, making the law much more straightforward and easy to understand. One of the sections in Tucson's light ordinance is called "Permits and Plan Submission Requirements". Within this section, there is a detailed description of the requirements for the permit submission including the plans of the location, the types of illuminating devices as well as photometric data (Services, 2012). The main reason that Tucson has seen success in mitigating light pollution can be credited to the fact that it is very specific and details exactly how to go about changing lights. Another city in Arizona that has had success in mitigating light pollution is Flagstaff. The lighting code here focuses on three main aspects similar to those in the previously mentioned laws. These aspects include the proper shielding of light fixtures, the spectrum of different light sources and the amount of light. By changing their current lighting situation to accommodate these laws, Flagstaff has been able to reduce their light pollution levels. In 2000, a study showed that the city of Flagstaff with a population of 55,000 emitted an amount of light that a city with a population of 40,000 in the United States would typically have (Portree, 2005). To ensure that the light pollution in Flagstaff does not increase, a group called the Flagstaff Dark Skies Coalition monitors the city by making sure lights are compliant with the law, and providing advice on what changes can be made to be compliant. As a result of this coalition and the law, Flagstaff has been recognized as the first International Dark-Sky City by the IDA.

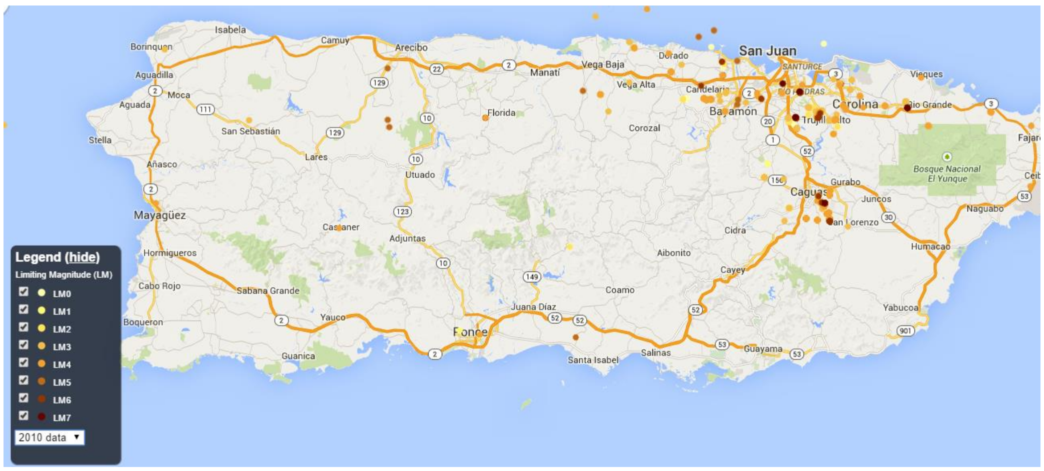
2.3.2 The Canary Islands: An Example of Regulatory Success

The Canary Islands, like Puerto Rico, enjoy a large tourist industry based on a pleasant climate and beautiful natural surroundings. There is a direct correlation between population density and artificial light levels, so it is not surprising that places like the Canary Islands and Puerto Rico are susceptible to increases in light pollution. One of the advertised tourist attractions of the islands used to be the quality of the night sky. As time progressed and the use of artificial light increased, the ability to see the stars decreased. This realization triggered the parliament of the Canary Islands to propose the Law for the Protection of the Astronomical Quality (Sky Law) of the Instituto de Astrofísica de Canarias (IAC) Observatories (IAC, 2014). This Sky Law (2014) was passed by the Spanish government on October 31, 1988 and has been regulated by the Sky Quality Protection Technical Office (OTPC) since 1992 (IAC, 2014). The regulations in the Sky Law that deal with light pollution target the islands of La Palma and Tenerife. For example, luminaires must not emit light towards the sky unless it is for emergency purposes, and certain types of lights such as mercury vapor are not allowed. The regulations were put in place in order to save energy, increase road safety by reducing glare, and improve the environment and visibility of the sky at night. In 2009, the Sky Law's success became evident when La Palma became the home of the world's largest ground-based optical telescope, Gran Telescopio Canarias (GTC, 2013). The site was chosen for superior night sky viewing conditions. This facility is considered one of the best astronomical observatories in the world (GTC, 2013).

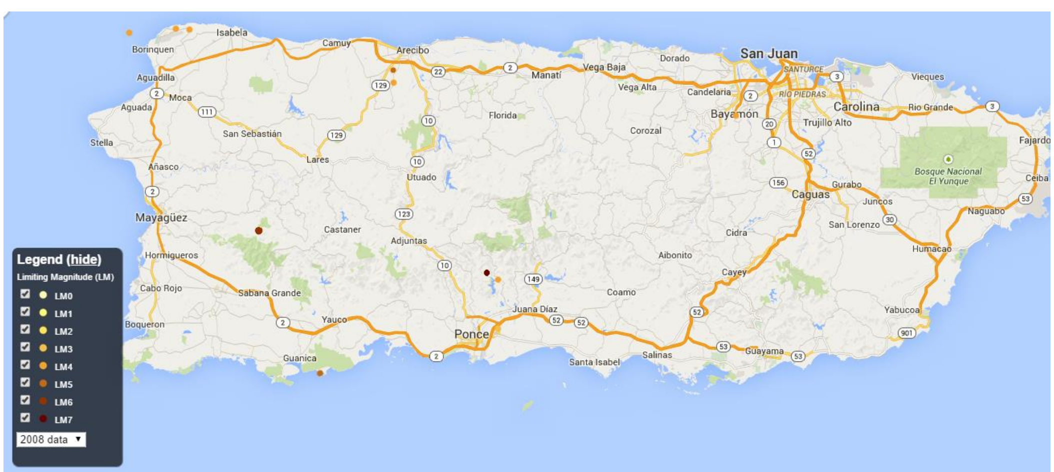
2.3.3 Worldwide Campaigns against Light Pollution

By educating the public on light pollution, the overall understanding about the importance of the issue and why change is necessary will improve. To increase knowledge on light pollution, many campaigns have begun attempting to increase the level of interest in the issue. Some of these campaigns are global while others pertain only to specific cities or regions. In either aspect, the end goal of improving the environment is the same.

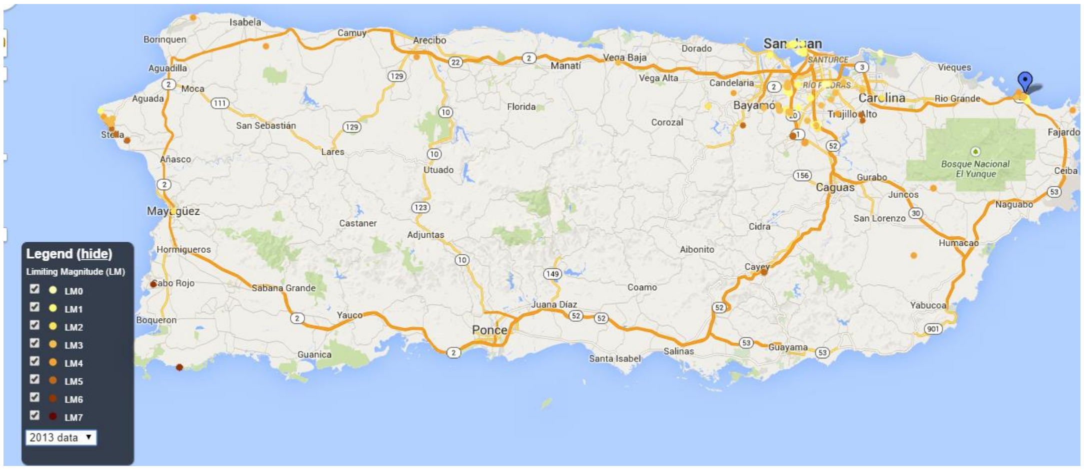
One of the most successful campaigns against light pollution is Globe at Night. Globe at Night is an international campaign with the goal of educating on the effects of light pollution. In order to raise awareness, this campaign allows anyone to help collect data by measuring their night sky brightness and then electronically submit their results (Globe at Night, 2012). People can measure night sky brightness by observing the night sky between 8pm-10pm and then matching those observations to one of the seven magnitude charts found on the Globe at Night website. In addition to these results, the amount of cloud cover, time, date, and location can then be recorded on the Globe at Night website. Since 2006, about 100,000 measurements from 115 countries have been recorded each winter and spring (Globe at Night, 2012). These measurements are then used to create an interactive map, which can be accessed by anyone, showing the light pollution levels worldwide. These levels are measured on a limiting magnitude scale from zero to seven with zero signifying the greatest levels of light pollution and seven signifying the least. Using this map to specifically analyze Puerto Rico, it is clear that light pollution has been increasing since 2006 especially along the coast (Figures 9 a-c).



(a)



(b)



(c)

Figure 9: The interactive data map showing the magnitude of light pollution in Puerto Rico in 2008 (a). These results show that the majority of cities reported light pollution at a limiting magnitude of five. Puerto Rico's light pollution levels in 2010 were mostly at a limiting magnitude of three (b). In 2013, the majority of Puerto Rico's light pollution levels had increased to a limiting magnitude of one (c). http://www.globeatnight.org/map/

Along with the interactive map, Globe at Night provides an analysis of the data that demonstrates the growth of light pollution globally during the past eight years. By involving everyone in their campaign, the interest level in light pollution has not only increased in Puerto Rico but in locations around the globe, making this campaign the most successful to date.

Aside from global campaigns, individual cities have also started campaigns to reduce light pollution. One contributing factor that causes light pollution is the growth of digital billboards. These produce a significant amount of light pollution because the light is not directed downward and is reflected up towards the sky by the surrounding buildings and asphalt. Ottawa, Canada is one specific location where the growth of digital billboards negatively impacted light pollution. After installing billboards in the city, a survey revealed that many found the light distracting and unnecessarily bright. The results of this survey led to the decrease of brightness of the billboards however, after a second round of surveys, it was evident that the billboards were still far too bright (Schepers, 2012). Eventually, after the third effort to reduce the brightness of the billboards, the goal of finding the balance between keeping the billboard bright while not distracting drivers or disturbing neighboring properties was accomplished. The level of brightness that was settled on was actually more than a factor of three lower than the Institute of Lighting Engineers' suggestions in the United Kingdom for maximum brightness proving that society does not always desire brighter lights (Schepers, 2012). This scenario is a good model of how campaigns that involve the communication of opinions are very effective in satisfying the demands of all involved in the situation. The billboard campaign in Ottawa is a perfect example of how even using tools like surveys are capable of identifying issues that may go unrecognized otherwise.

Using tools like the interactive data map or surveys may prove to be very useful in Puerto Rico. The interactive data map would be a helpful tool in providing quantitative data that can be used to monitor coastal light levels.

2.4 Ecological Impacts of Light Pollution

Increases in coastal populations and tourism along coastal regions has caused more artificial lighting to illuminate areas of attraction, and this causes changes in behavioral patterns of species in their natural habitats. The intrusion of artificial light sources has had noticeable effects on certain species in coastal regions such as sea turtles, zooplankton, bats and migrating birds. The effects described below mainly occur when these species are exposed to the artificial light in the wrong place, at the wrong intensity or during times of the night where they normally do not experience high light levels (Depledge, 2010). Behavioral patterns that are affected include orientation disruption, migration patterns, reproductive habits and interactions between species. All these consequences result from artificial lights that are improperly used by allowing light to shine upward toward the sky and illuminate areas that do not need to be illuminated (Klinkenborg, 2008).

2.4.1 Orientation Disruption

Orientation disruption occurs from artificial lighting causing confusion in visual cues that help animals navigate. Coastal lights are beginning to show a negative impact on hatching sea turtles that emerge onto beaches. When sea turtles hatch, nestlings must immediately get to the ocean. The visual cues they use to orient themselves come from the shadows created by bushes and grasses. The sea turtles use the shadows as a visual cue to move away from and the artificial light does not provide any dark shadows to trigger their movements (Depledge, 2010). With the artificial light illuminating a large area of the beach the sea turtles can become confused and may not make their way towards the ocean (Longcore et al., 2004). This is extremely dangerous due to an increase in the risks of dehydration and being attacked by a predator. An example of just how bad this problem has become can be seen in a case study where due to artificial light on a Turkish beach logger head turtle hatchlings reaching the ocean declined by 40% (Depledge, 2010).

2.4.2 Migration Patterns

Light has always been an important source of information for migrating birds, but artificial light has disrupted their daily and seasonal activities. Birds are able to determine day length by using patterns of light and darkness which controls daily activities as well as when to begin their migration (Gaston et al., 2012). Poot (2008) reports that nocturnally migrating birds who encounter artificial light tend to lose a lot of their energy due to light fixation, which can cause them to become confused and fly around points of illumination until they die from exhaustion. Another problem occurs when birds begin their migration too early. Migration is a specifically timed biological event and if they arrive at their nesting habitat too early the conditions for nesting will not be adequate (Gaston et al., 2012). Without conditions fit for nesting many birds' reproductive habits will suffer.

In addition to migrating birds, artificial light can impact zooplankton by not allowing them to migrate to the surface of the ocean during the nighttime. Zooplankton are simply heterotrophic plankton that drift with the currents of the sea. Zooplankton have important ecological roles in their communities. Artificial light that shines into the ocean can reach organisms that inhabit the lower levels. Zooplankton move from the lower levels of the ocean to the higher levels to feed on the algae and escape predators (Longcore et al., 2004). This daily migration from the lower levels of the ocean to the higher levels is known is diel vertical migration. During the day zooplankton can be found in the lower levels to escape predators and will eventually migrate to the surface at night. However, the artificial light does not allow for diel vertical migration to take place, because the increase in artificial light causes them to avoid these illuminated areas near the surface. This disruption in vertical migration may have significant impacts on the ecological community.

2.4.3 Disruption of Species Interactions

High nighttime light levels have been known to disrupt interactions between species, and through this mechanism it may have substantial effects in an ecological community. Longcore (2010) states that artificial light can be an influential force in shaping ecological communities by disrupting interactions between species. Toads and frogs are an example of species interactions being affected by artificial lighting. Toads and frogs have certain light levels they feel comfortable enough to hunt in during the night. The artificial light can intrude into much of their natural habitat and can cause certain species of toads and frogs, which prefer lower light levels to hunt in, to avoid well-lit areas (Longcore et al., 2004). This will favor predators that are more comfortable hunting in illuminated areas. Artificial lights are becoming an increasing factor in why species interactions are being affected in ecological communities.

In addition to amphibians, the relationship between insects and bats has become affected. Insects are attracted to higher powered lamps and cluster around them. Certain species of bats rely on these insects to be near streetlights. With an increasing amount of insects being attracted to the artificial light it is decreasing the food supply for bats who do not hunt near streetlights (Rydell, 1992). Klinkenborg (2008) reports that when some valleys in Switzerland put in streetlights the European lesser horseshoe bat began to suffer and decline in population due to a different species of bat taking more of the food supply (Klinkenborg, 2008).

2.4.4 Reproductive Habits

The reproductive habits of some species have become a point of concern due to artificial lighting causing an increase in predation risks. The artificial lighting illuminates large areas and during the night it constrains individual movement to and from mating areas. Sea turtles tend to nest on dark areas of the beach and with larger areas being illuminated are finding fewer and fewer spots to nest on. They have a tendency to avoid well-lit areas. In addition to sea turtles: toads, frogs, blackbirds and nightingales are experiencing light levels that are nowhere close to normal levels which are affecting their breeding habits by constricting their movement to and from mating areas (Klinkenborg, 2008).

2.5 Puerto Rico's Sea Turtles

Due to Isla Verde being a coastal region, there are several Sea Turtles that nest on their beaches. These turtles can suffer from the ecological impacts described above from high light levels at nighttime. Only leatherback turtles have been reported nesting in Isla Verde with nests ranging from 0 to 8 nests within a season. This is low compared to other areas in Puerto Rico, where there is no light pollution. Other areas nests ranges from 100 to 600 nests per beach (personal communication, Carlos E. Diez). In this section our team discusses the three main types of sea turtles that nest on Puerto Rico's beaches; the leatherback, green, and hawksbill sea turtle. We discuss their natural habitat, migratory processes, nesting habits, population threats, conservation efforts and regulatory actions.

2.5.1 Leatherback Sea Turtle

The leatherback sea turtle (Figure 10) is the largest turtle in the world. They are extremely migratory species but are known to forage in coastal waters on jellyfish and soft-bodied animals (NOAA, 2013). Females mate in waters adjacent to their nesting beaches and lay around 100 eggs, every 8-12 days, several times during their nesting season between February and July (NOAA, 2013). Many times these females lay their eggs on or near the vegetation line of the exact beach they themselves hatched (DNER, 2004). These nesting trends are hard to monitor due to their ability to maintain a core body temperature higher than that of the surrounding water, which allows them to tolerate colder water temperatures and increase the amount of places around the world that are suitable to mate and nest in (NOAA, 2013). Due to predators, scientists estimate that only 1% of all hatchling survive to adulthood (DNER, 2004). The leatherback sea turtle has been enlisted as an endangered species under the Endangered Species Act (ESA) in 1970 and have been nearly

Figure 10: Leatherback Sea Turtle
http://www.flickr.com/people/41464593@N02

driven to extinction in the Pacific Ocean. Their numbers worldwide have fallen from 115,000 to 25,000 in the last 30 years (Hayasaki, 2009).

In Puerto Rico, leatherbacks have been in danger from the US Navy, who has occupied the island of Vieques since 1941. The US Navy has been using the island for target practice and Ruiz (1999) states that countless ammunition shells have been found on the sites where leatherback turtles lay their eggs (Ruiz, 1999). Further threats include the harvesting of their eggs for consumption or commercial use, coastal development of critical turtle habitat, climate change and incidental capture in fishing gear (Wallace, Tiwari, & Girondot, 2013). There have been many regulatory efforts to protect this species. These regulations include the designated critical habitat along the U.S. West Coast in 2012, the designated critical habitat in the U.S. Virgin Islands in

1998, and regulations for fishing equipment to limit sea turtle interactions in fisheries (NOAA, 2013).

2.5.2 Green Sea Turtle

The green sea turtle (Figure 11), which is the largest of all the hard-shelled sea turtles, is another turtle that can be found nesting on the beaches of Puerto Rico. These turtles primarily can be found in tropical and subtropical waters and feed on sea grasses and algae (NOAA, 2014). Females return to the exact beach where they themselves hatched, every 2-4 years, to lay eggs during the months between June and September (NOAA, 2014). They have very complex migration patterns throughout the world.

Figure 11: Green Sea Turtle
https://sites.google.com/site/thebrockeninglory/

The Marine Turtle Red List Authority has analyzed population trends and concluded that there has been a decline in females nesting annually by 48-65% globally over the last 100 years (Seminoff, 2004). The newly hatched green turtles are in much danger from predators, incidental capture in fishing gear, degradation of nesting beach habitats and marine habitats, and disease, but one of their greatest threats is high light levels near beach sites that cause disorientation in hatchlings (NWF, 2012). These turtles are also vulnerable from eggs to adults due to anthropogenic impacts (Seminoff, 2004).

On January 7, 1994 a barge spilled 3.6 million liters of oil in San Juan, Puerto Rico and contaminated around 48 kilometers of Puerto Rico's north shore (Mignucci-Giannoni, 1999). The contamination led to the death of two green turtles. These turtles were enlisted as an endangered species under the ESA in 1978 and are protected by national and state laws (NWF, 2012). Regulations include the fixing of accidental capture by improving fishing gear modifications and practices, designation of critical habitat areas in coastal waters of Puerto Rico in 1998, inclusion of turtle excluder devices (TEDs) in shrimp trawl fisheries, encouragement of low pressure sodium lighting along beach nesting areas, and the regular monitoring of green turtle populations by the National Marine Fisheries Service (NWF, 2012).

2.5.3 Hawksbill Sea Turtle

The hawksbill sea turtle (Figure 12), which is not as large as the previous two turtles mentioned above, are found all over the world, including Puerto Rico, and can be mainly found near healthy coral reefs feeding on algae, sponges and other invertebrates (NOAA, 2014). Like the green turtle, the female hawksbill will return to the beach it was born at every 2-3 years, between April and November, to lay eggs every 14-16 days where there is little or no sand near the vegetation line (NOAA, 2014). They also have long migratory patterns similar to that of the green sea turtles where there is a large distance between nesting beaches and hunting areas.

Over the last three generations the hawksbill population has seen a decrease of 80% (Mortimer, & Donnelly, 2008). Hawksbill sea turtles face many threats, but its main threats to survival is habitat loss of coral reef communities and tortoiseshell trade. Hawksbill sea turtles rely on these reefs for their natural habitat and food resources, and due to human activity and global climate change, these reefs are becoming damaged and negatively impacted (NOAA, 2014).

Figure 12: Hawksbill Sea Turtle
http://www.dinosoria.com/tortue_mer.htm

They are important factors in contributing to marine and coastal food webs, and maintaining a healthy coral reef ecosystem (Mortimer et al., 2008). Other threats include harvesting of their eggs, slaughter for meat, hybridization with other species, oil pollution increase in recreational and commercial use of nesting beaches in the Pacific, demand for their shell and incidental capture in fishing gear (Mortimer et al., 2008). The hawksbill was listed as an endangered species under the ESA in 1970 and listed internationally as Critically Endangered by the International Union for Conservation of Nature and Natural Resources (NOAA, 2014). In 1998, the critical habitat for hawksbill sea turtles included the main areas of nesting in the U.S. These areas were the coastal waters of Mona and Monito Islands in Puerto Rico (NOAA, 2014).

2.5.4 Sea Turtle Regulation

All three sea turtles indigenous to Puerto Rico are listed by the International Union for Conservation of Nature (ICUN) as threatened. The leatherback is classified as vulnerable, the green as endangered and the hawksbill as critically endangered. In addition all are experiencing decreasing population trends (Donnelly and Mortimer 2008; Girondot et al., 2013; Seminoff, 2004). The international community has responded with conservation treaties and agreements however these are rarely comprehensive enough to fully protect sea turtles from the numerous artificial threats that threaten them in the wild. The problem arises from their amphibious and migratory nature. Sea turtles travel through four different legal regimes when nesting and after hatching. These are the terrestrial territory, territorial sea, exclusive economic zone and international waters and each has independent legislature governing it (Wold, 2002). For example, while in U.S. waters, sea turtles are protected by the National Marine Fisheries Service, however when they climb out of the water they come under the jurisdiction of the U.S. Fish and Wildlife Service (Sea Turtle Conservancy, 2014). Once sea turtles swim into international waters it becomes much more difficult to legally protect them. When in the high seas it is usually up to the State a vessel is flying its flag under to create legislature to protect sea turtles. The different legal jurisdictions encompassed in sea turtles range has resulted in many different conservation laws, however none provide protection for their full distribution. Here are a few examples of international conservation efforts.

The Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES) was drafted in 1963 and became enforceable in the U.S. on July 1, 1975. CITES is a voluntary international agreement between States to ensure that trade of plant and animal products do not threaten the survival of the species (CITES, 2014). This protects sea turtles from being exploited for international trade, which it does effectively (Wold, 2002). However CITES does nothing to protect sea turtles from other artificial threats such as loss of coastal habitat or incidental take which has been identified as the greatest threat facing sea turtle mortality.

This void was partially filled in the Americas by the Inter-American Convention for the Protection and Conservation of Sea Turtles (IAC), in 1996. This was the first international treaty specifically targeted towards the conservation of sea turtles. It complements CITES by banning domestic trade of sea turtle products, something CITES deliberately avoided. In addition it became the first treaty to promote Turtle Excluding Devices or TEDs. This was a major step in reducing sea turtle mortality from shrimp trawlers (Sea Turtle Conservatory, 2014). Although this is an improvement over CITES, it has no stipulations on habitat preservation (Wold, 2002). This absence is not unique to the IAC treaty. The Protocol Concerning Specially Protected Areas and Wildlife (SPAW) for the wider Caribbean range, the Memorandum of Understanding on the Conservation and Management of Marine Turtles and their Habitats of the Indian Ocean and South-East Asia, and the Memorandum of Understanding Concerning Conservation Measures for Marine Turtles of the Atlantic Coast of Africa all lack any provision protecting terrestrial sea turtle habitats. While these agreements have been effective at curtailing trade of sea turtle products there is still an international shortfall.

2.6 Applying the Protocol in Isla Verde

To test our protocol we will be using the community of Isla Verde. Isla Verde, like most Puerto Rican Coasts, is very unique. Although Isla Verde is a known tourist area it is also home to the Isla Verde Reef Marine Reserve and a sea turtle nesting habitat. In this section we will provide information about Isla Verde's location, industry and ecology.

2.6.1 Location and Industry

Isla Verde is a coastal community boarded by the Atlantic Ocean, located in the city of Carolina, Puerto Rico. Isla Verde was named after a small Island located off the coast of what is now known as "The Mid Point" which splits West and East Isla Verde. Isla Verdes location creates the perfect environment for a successful tourism Industry. The entire coast of Isla Verde is lined with businesses including numerous Hotels, Residences, Public Beaches and Clubs. The coast and the beaches are home to the Isla Verde Reef Marine Reserve and annual nesting site of sea turtles.

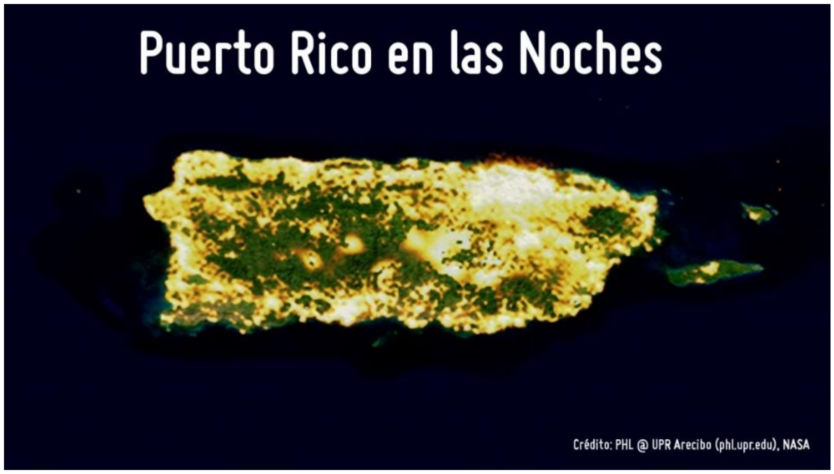


Figure 13: "Puerto Rico in the Night" is a strong visual representation of how much light is emitted daily. http://phl.upr.edu/library/media

2.6.2 Isla Verde Coral Reef Marine Reserve

The environmental variability found in marine ecosystems is unlike any other in the world. Unfortunately these systems are facing negative human impacts on a growing scale. The result of such a complex and diverse ecosystem creates a truly vulnerable interdependent natural system, one that is facing both natural and anthropogenic stresses (Sobel and Dahlgren, 2004). In order to protect these unique ecosystems marine reserves have been established.

In Puerto Rico there are a total of nine marine reserves. One of these marine reserves was created on September 26, 2012 on the coast of Isla Verde around a small island known as the Key Isla Verde in order to protect its ecosystem. Preserving this site was necessary due to the negative impacts from coastal developments, sedimentation, sanitary drainage overflow, overfishing, motor boats and jet skis. The coral reef within the reserve is home to numerous fish, invertebrates, crustaceans and sea grass (personal communication, Paco Lopez Mujica).

This urban hatchery for marine life has been threatened by both natural and human actions. The first concern of the coral reef is pollution. The source of this pollution comes from garbage being left on the beach as well as from the outflow of rain water drains which commonly contain litter. Litter in the water causes damage to both animals and marine life. The second concern is the outflow of contaminated water and sedimentation. Although this sedimentation comes from the Boca de Cangrejos Torrecilla Lagoon and can be perceived as natural, it is believed to be caused by the dredging of the Torrecillas Lagoon after the construction of the International Airport in 1950. Sedimentation is dangerous to coral reefs because the sediments will make the water cloudy which will reduce the amount of light that can reach the coral. (ESI, 2012) Without the necessary amount of light, the coral will not be able to perform photosynthesis. (ESI, 2012) In addition to these dangers, there are also manmade threats to the coral reef. Motor boats and jet skis are constantly damaging the reef because of the oil leaking into the water as well as scaring species living in the reef resulting in a reduction of the diversity of marine and plant life. (UNEP) The last and most damaging impact on the coral reef is overfishing. Overfishing is the practice of commercial or non-commercial fishing which reduces the fish population which can lead to there being not enough adult fish to breed and sustain their population. (Koster, 2011) Due to its unique location and diversity the coral reef was under heavy fishing pressure, and without protection, it was often subject to overfishing. The consistent damage to the coral reef inspired Paco Lopez Mujica, the president of Arrecifes Pro Ciudad Inc. and the director of the Isla Verde Reef Marine Reserve Management Board, to begin the process of establishing this site as a reserve.

According to Paco Lopez Mujica, the DRNA had to be convinced of the importance of this ecosystem in order for this site to be established as a marine reserve. The process for this site becoming a reserve took a total of seven years and was carried out by the Arrecifes Pro Ciudad Inc. In the first four years, underwater pictures of the coral reef were taken, species living in the reef were identified, and there were collaborations with scientists which helped form recommendations about how to preserve this reef. Using all of this information gathered on the coral reef, presentations were made about the merits of the coral reef and the urgency to protect this site. These presentations were then presented to the DRNA eventually convincing the organization to support the project. With this support, a reserve designation was organized by the Arrecifes Pro Ciudad Inc. In the first meeting of this designation, the specific sites to preserve were discussed because the designation wanted to include all reefs from San Juan to Piñones. During the second meeting, the committee decided to just focus on the reef in Isla Verde because the other idea was too ambitious. The reserve designation committee presented the project to a congresswoman who approved the project resulting in the establishment of the Isla Verde Marine Reserve. To date, this reserve is maintained through volunteer work from the users and neighbors of the Isla Verde, the DRNA, and the Arrecifes Pro Ciudad Inc (P. Lopez, personal communication)

2.6.3 Acceptable Light Levels in Puerto Rico

Under the Regulation for the Control and Prevention of Light Pollution created by the JCA on June 27, 2014, Rule 13 was established to classify outside areas based on their light characteristics. There are a total of 8 classes, each with an allowable level of nighttime illumination measured in footcandles that is acceptable for before and after 11 PM. A description of each classification can be seen below in Table 1. According to José A. Alicea Pou from the JCA, Isla Verde is classified as a Class 8 due to the possibility of sea turtle nesting (personal communication). If a beach is not adequately capable of having possible sea turtle nesting's, such as rocky beaches, then that beach will fall under Class 1 and not Class 8.

Table 1: Rule 13 of the Regulation for the Control and Prevention of Light Pollution – Outdoor and Special Area Classification

Outdoor and Special Area Classifications	Illuminance Value (foot-candles) Sunset to 11:00pm	Illuminance Value (foot-candles) 11:00pm to dawn
Class 1: Dark Tracts – Parkland and conservation areas, as well as rural, suburban and urban areas with little to no lighting	0.10	0.00
Class 2: Low Level Ambient Light – Residential rural and suburban areas	0.30	0.10
Class 3: Medium Level Ambient Light – Residential urban areas	0.80	0.30
Class 4: High Level Ambient Light – Residential or commercial urban areas	1.50	0.60
Class 5: Special Area for Vieques – Entire territorial area of the Island-Municipality of Vieques that seeks to protect the Mosquito Bioluminescent Bay	0.10	0.10
Class 6: Special Area for Parguera – Five mile radius around La Parguera Bioluminescent Bay	0.10	0.10
Class 7: Special Area for Las Cabezas De San Juan – Five mile radius around the Laguna Grande	0.01	0.01
Class 8: Special Beaches used by Sea Turtles Any beach where it is possible for sea turtles to lay eggs	0.00	0.00

3.0 Methodology and Results

The goal of this project is to assist the Departamento de Recursos Naturales y Ambientales and the Junta de Calidad Ambiental in developing a program to measure light levels and evaluate lighting practices for coastal communities in Puerto Rico. The program will involve a protocol for measuring light levels, creating an inventory of current light fixtures, and a survey to gauge the perspectives of community members on light pollution and its impacts on these communities. This data provided by the protocol will be used to evaluate coastal lighting practices. Our work will allow the DRNA and JCA to develop, promote and perform other projects around the coast using this protocol.

We worked on this project from October 26, 2014 to December 18, 2014, however the implementation of our suggestions will be carried out after our departure.

Our team fulfilled this goal through the following objectives:

- Develop a protocol for measuring light levels, creating an inventory of current light fixtures, and a survey to gauge the perspectives of community members on light pollution and its impacts on these communities
- Use the protocol in the coastal community of Isla Verde to evaluate current lighting practices

In this section, we present our methods and results organized by objective. Sections marked (a) indicate a description of our approaches, while sections marked (b) indicate our results for that approach.

3.1 Objective 1: Developing a Protocol

The protocol was designed to allow the JCA and DRNA to systematically analyze coastal light levels in order to gauge the severity of light pollution on Puerto Rico's beaches. In order to achieve a better understanding of lighting conditions on the beaches, two different forms of light pollution were measured, sky glow and light trespass. Sky glow is the result of many fixtures that each emit a portion of light directly upward into the sky, where light scatters and cumulatively increases nighttime illumination. Light trespass is a measure of local lights that shine directly onto a specific location and occurs when light spills over its necessary boundaries into an area where light is unwanted or needed. Both were measured to understand the immediate and widespread lighting practices of an area. An inventory was developed to be able to classify and analyze coastal light fixtures. The last step of the protocol is a survey that can be administered to coastal communities in Puerto Rico in order to gauge the perspectives of community members on light pollution and its impacts on these communities.

3.1.1.a Developing a System to Measure Sky Glow and Light Trespass

Sampling Schedule

To accurately measure the brightness of the sky without interference, measurements have to be taken after astronomical twilight and the moon has set (Carello et al., 2014). The moon is bright enough to interfere with light levels readings, therefore measurements cannot be taken until the moon has set. Astronomical twilight also interferes with light levels. Astronomical twilight, as illustrated in Figure 14, is the period when the sun is above a point 18 degrees below the horizon. During this time, the sun is illuminating the sky to some degree. Afterwards, the sky is only illuminated by the moon, stars, and artificial luminaires. When creating a sampling schedule, nights when the moon has set after astronomical twilight are selected so that it does not contribute to the overall brightness of the night sky.

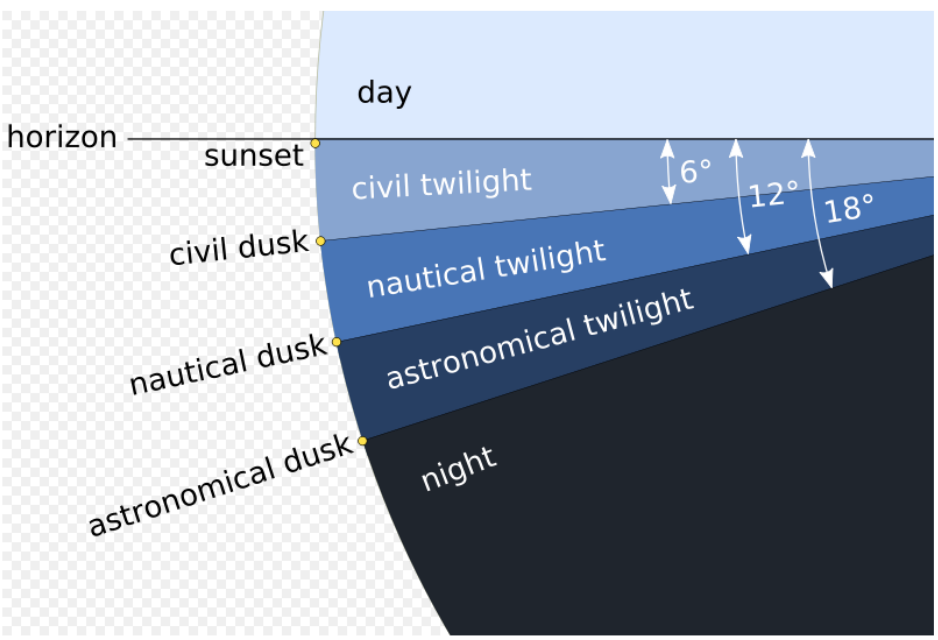


Figure 14: Twilight Sub-categories
Image Credit: "Twilight subcategories" by TW Carlson - Own work. Licensed under Creative Commons Attribution-Share Alike 3.0 via Wikimedia Commons

Selection of Data Points

In order to select data collection points for sky glow and light trespass along the coast our team used the system of the JCA. This group completed a project for the JCA measuring light trespass in Old San Juan. Their system, created with a GIS program, consisted of 100x100 meter squares that were broken up into 10x10 meter quadrants that were sampled. Our team evaluated this method for selecting data points for its usefulness in coastal regions and made modifications to arrive at a preferred method.

Measuring Sky Glow

Data is collected for sky glow by measuring the brightness of the nighttime sky using a Unihedron SQM-L meter (Appendix B for manual). These meters measure the brightness of the sky in magnitude per square arcsecond; high measurements correspond with darkness and low measurements with brightness. For example, a star that is magnitude 5 is brighter than a star that is magnitude 10 (Sky Quality Meter-FAQ). An arcsecond is a term used to divide the nighttime sky into equal sections. There are 360 degrees in a circle. Each degree is divided into 60 minutes, and each minute is divided into 60 seconds, therefore a square arcsecond has an angular area of one second by one second (Sky Quality Meter-FAQ) When combined, a magnitude per square arcsecond (mpss) means the brightness of an object measured in magnitudes spread out over a square arcsecond of the nighttime sky (Sky Quality Meter-FAQ). If the SQM-L meter gives a reading of 19.0 mpss it means that the brightness of a 19.0 magnitude star is spread out over one square arcsecond of the nighttime sky.

Our team decided to create a process for measuring sky glow using the SQM-L meter that would account for any potential variability for sky glow readings above each data point. Therefore, our process involved taking three measurements in the center of each quadrant. This process was tested in the field and any problems and limitations were noted.

Measuring Light Trespass

Based off the current system used by the JCA for measuring light trespass, our team used a trial and error system to determine if any changes needed to be made for the protocol of measuring light trespass along the coast. To measure light trespass, a quadrant system is used and involves a 10x10 meter square with points marked off every 2.5 meters (Figure 15).

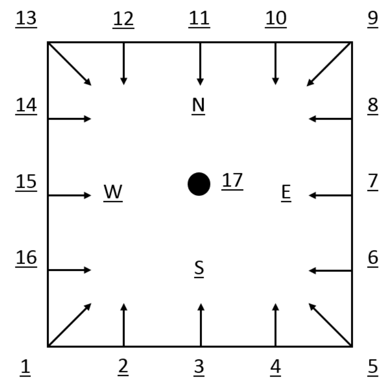


Figure 15: Diagram of quadrant system setup

This allows multiple measurements to be taken around the perimeter of the 10x10 meter quadrant. Our team began by testing the process for setting up the 10x10 meter quadrant using the materials and protocol described by the previous protocol. To test this system, the process of initial preparation and perimeter set up was completed in the field. The second part of the protocol involved creating daytime and nighttime site assessments. Our team decided to test the same site assessment sheets used in the previous protocol, which included geographical and observational data, to determine if any changes needed to be made for our protocol. This was done by going to the site and completing a pilot test for both the daytime and nighttime assessments and noting any changes that needed to be made for the process. To measure light trespass, our team tested the same method previously used to see if any problems or limitations arose. To complete this, our team went to the coast and completed the process multiple times for multiple points and noted any changes that needed to be made. For our project, our team had access to two photometers to complete light trespass measurement, the Konica Minolta T-10A (specifications in Appendix A) and the Extech Heavy Duty Model 407026 light meter. Both light meters measure luminance in lux and footcandles. The Konica Minolta T-10A has a range of 0.01-29,900.000 footcandles.

3.1.1.b A System to Measure Sky Glow and Light Trespass

This section describes the results of testing the methods for selecting data points, creating a quadrant system, completing site assessments, taking sky glow and light trespass measurements and presents our protocol.

When applying the JCAs system for selecting data points, the system was not effective for sampling a coast. The coast is a much smaller area and when the 100x100 meter square system was first used much of the square was in the water. To accommodate this, our team decided that a point system along the coast was better suited than a 100x100 meter square system. Still using the GIS program single points were selected to be the center point of each 10x10 meter quadrant rather than dividing the entire coast into 100x100 meter squares than again into 10x10 meter quadrants. Seen below in Figure 16 the aerial map marks a green point every 100 meters along the desired coast. Each point has corresponding coordinates of latitude and longitude. The coast may be divided into multiple phases depending on the location. The purpose of dividing the coast into phases is to establish spatial priority to account for time constraints.

Figure 16: Example Aerial Map of Selected Data Points along a Coastal Region

The system for preparing and establishing the quadrant initially used caution tape and cones to create the perimeter of the quadrant. This proved to be problematic due to the wind and sand on the beach. The caution tape was not held in place by the cones and moved whenever there was a gust of wind. To fix this problem, our team decided to develop a new system that would be structurally capable of withstanding the conditions at the beach. The system our team developed used ropes and stakes to prepare and establish the perimeter of the quadrant. After testing the initial preparation, the process for finding the corner points of the perimeter proved to be slow and inefficient. Our team developed a new strategy which included a diagonal rope that allowed our team to mark of the northwest and southeast corners of the quadrant Figures 17, 18 and 19. After these two corners were marked, the northeast corner could be found by connecting two 10 meter ropes, one to the northwest and one to southeast corners. Both 10 meter ropes were stretched out and where the ends met was the northeast corner. This same process was done to find the southwest corner. This system proved to be very effective and was very time efficient.

Figure 17: Place the center of the diagonal rope on the center

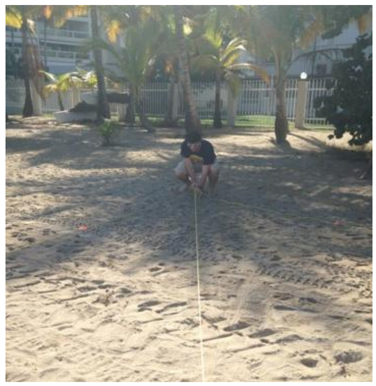


Figure 18: Mark off the northwest and southeast corners

Figure 19: Mark off the northeast and southwest corners

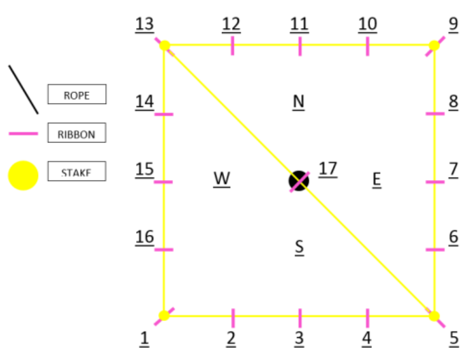


Figure 20: Final Quadrant Setup Diagram

After testing the daytime and nighttime assessment process established by (Devries et. al., 2013), our team decided that this system was effective in coastal areas and could be used for the protocol. Each site assessment sheet includes a section to record site number, date, time, latitude, longitude and location. These categories were selected to keep track of when and where site assessments were completed. Apart from geographical data, the site assessments sheets allowed our team to record observations in each cardinal direction in case there was a correlation of what our team observed and the light trespass measurements recorded. It is important to record any observations of light fixtures that can be seen from the center point of the quadrant for this purpose. It is also important to record any environmental observations such as the presence of vegetation, types of buildings (hotel, residential), and structures such as walls or huts. This is done to gain a better understanding of the environment surrounding each point. We encountered multiple points that were inaccessible. If the point is inaccessible due to high tide or physical location such as private property and cannot be moved 5 meters in any direction to make the point accessible, the site assessments cannot be completed and should be excluded from the phase. This also includes taking sky glow and light trespass measurements.

After testing the process for measuring sky glow, the process for taking three measurements in the center point proved to be an effective way of creating an average sky glow reading for each point. While in the field, the following factors were discovered that could potentially affect sky glow readings. The list below describes these factors and how to adjust to them if encountered.

- Trees or buildings that could block the sensor and cause excessively high (dark) readings. If the center point is shaded by a tree or building, the point needs to be moved 5 meters away from the obstruction.
- Lighted objects (such as street lamps or the moon) that could hit the sensor at an angle and cause excessively low (bright) readings. If the center point is near a lighted object that could possibly affect our readings, the point needs to be moved 5 meters in any direction until the object is no longer a threat. All sky glow readings need to be taken after the moon has set to avoid any interference.
- Weather conditions (rain, clouds, fog, and mist) could reflect light back down to the earth, causing artificially bright readings. If any of these weather conditions are present, the sky glow measurement needs to be postponed to a later date when the sky is clear.

The process for measuring light trespass proved to be effective. Light trespass measurements were taken every 2.5 meters along the perimeter of the quadrant. The only change our team made was to incorporate the Extech Heavy Duty Model 407026 Light Meter due to the request of our liaison. The Extech model gives a maximum footcandles reading over a 30 second interval, because the Konica Minolta uses a continuous reading system both reading were recorded after a 30 second period on the Data Collection Sheet which can be seen in chapter 4 of the protocol below.

The system to measure sky glow and light trespass can be seen in the following chapters from the protocol. These chapters are intended to be used by anyone attempting to measure sky glow and light trespass in a coastal region and therefore are written as a set of instructions to be followed. To be clear we did not develop this entire protocol it was modified from a previous IQP project (Devries et. al., 2013). Chapter 1 Using the Photometer was not changed, Chapters 2: Quadrant System, 3: Daytime and Nighttime Assessments and 4: Measuring Light Trespass and Sky Glow all had significant alterations. Chapters 5: Creating an Inventory and 6: Administering a Survey were completely new additions to the protocol.

CHAPTER 1
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 typed 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.

CHAPTER 2

QUADRANT SYSTEM

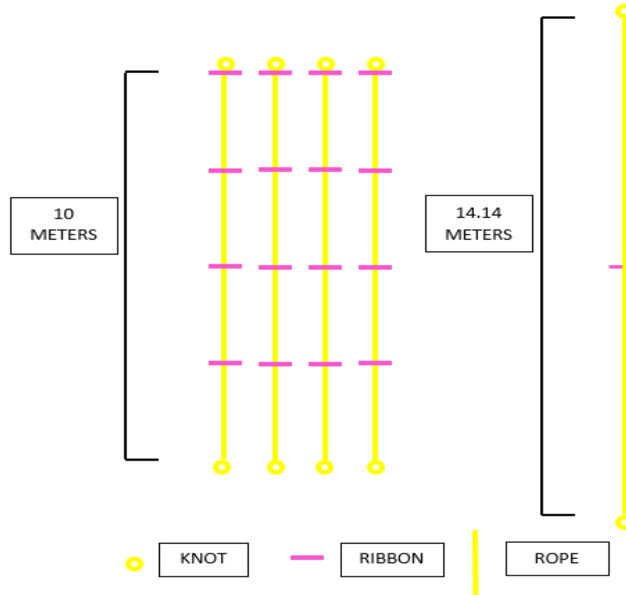
A GIS program needs to be used to create an aerial map of the desired location. The map marks a point every 100 meters along the desired coast. Each point should have corresponding coordinates of latitude and longitude. The coast may be divided into multiple phases depending on the location. The purpose of dividing the coast into phases is to establish spatial priority to account for time constraints. To find the point use a handheld GPS and input the coordinates of the point, which are typically given in meters north and meters east. This point will become the center point of the 10x10 meter quadrant. To form the quadrant follow the steps below:

Materials

1	60-meter piece of rope (if you need to use more than one piece of rope, ensure you can have 4 pieces approximately 11 meters long and 1 piece approximately 15 meters long)
5	Stakes
1	Compass
13	Pieces of ribbon

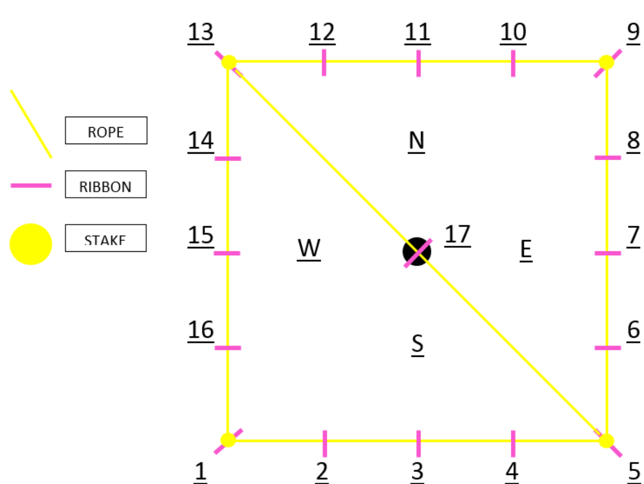
Initial preparation

1. Cut four pieces of rope that are 10 meters long plus some slack to tie loops at each end.
2. Cut a fifth piece of rope that is 14.14 meters long plus some slack to tie loops at each end. This will stretch from one corner diagonally to the opposite corner.
3. Tie loops at the end of each rope. These loops should fit around the stake tightly.
4. Mark the 10-meter ropes every 2.5 meters starting at a loop. Use something that will be visible in the dark to make the marks. We used neon ribbon.
5. Mark the center point of the 14.14 meter rope



Setting up the quadrant

1. Place a stake in the center of the quadrant.
2. Take the 14.14-meter rope and align the center point on the rope with the center of the quadrant.
3. Using a compass, place one end in the northwest corner of the quadrant and the other end in the southeast corner. Stake each end into the ground.
4. Loop two 10-meter ropes around each of the two stakes you just put into the ground. All four 10-meter ropes should now have one loop around a stake.
5. Take the other ends of the 10-meter ropes to the approximate locations of the northeast and southwest corners of the quadrant. Now there should be two loops in each of these corners.
6. Put a stake through these two loops. Pull the ropes taut and put the stake into the ground.



CHAPTER 3

DAYTIME AND NIGHTTIME SITE ASSESSMENTS

Once a quadrant has been located using the GPS unit, the team must make observations about the site. Full assessment of each quadrant requires one daytime and one nighttime visit. The daytime and nighttime assessment includes geographical data and visual observations. The nighttime site assessment must be completed right before light level measurements are taken, which is described in Chapter 4. If the point is inaccessible for any reason and cannot be moved 5 meters in any direction to make the point accessible, the site assessments cannot be completed and the point should be excluded from the phase.

Daytime and Nighttime Assessment using Site Assessment Sheet seen below:

- Locate point using GPS
- Note the number of the site, the date and time, the coordinates of the site
- Take a photograph of site assessment sheet (in order to keep track of which photographs correspond to which quadrant) and then photographs in cardinal directions from the center point using a compass
- Record observations of light fixtures in the cardinal directions from the center point using a compass. These fixtures may include hotel lights, street lights, residential lights, ground level beach lights, lights mounted in trees, or other light sources.
- Record environmental observations. These include the presence of vegetation, types of buildings (hotel, residential), and structures such as walls or huts.

Site Assessment Sheet

SITE NUMBER	DATE	TIME	LATITUDE	LONGITUDE	LOCATION

	OBSERVATIONS	PHOTOGRAPHS
NORTH		
EAST		
SOUTH		
WEST		
EXTRA		

CHAPTER 4

PERFORMING NIGHTTIME MEASUREMENTS

All measurements must be taken after astronomical twilight and the moon has set so that the sun and moon do not affect the light measurements by adding extra light. Astronomical twilight is the time when the sun's altitude is above a point 18º below the western horizon and 18º below the Eastern horizon. The start and end of astronomical twilight as well as times for moonrise and moonset can be found on the "astronomy" section of the Naval Observatory website (http://www.usno.navy.mil/USNO). Once astronomical twilight has ended, begin by establishing the measurement quadrant as described in chapter 2. The list below describes any factors that could potential affect sky glow readings and how to adjust to them if encountered.

- Trees or buildings that could block the sensor and cause excessively high (dark) readings. If the center point is shaded by a tree or building, the point needs to be moved 5 meters away from the obstruction.
- If the weather is cloudy or partly cloudy above the center point, sky glow measurements with the SQM-L meter cannot be taken and step 4 must be skipped and completed at a later time when the sky is clear. Overcast skies will give a higher reading than clear skies and therefore will increase the variability of our results
- Lighted objects (such as street lamps or the moon) that could hit the sensor at an angle and cause excessively low (bright) readings. If the center point is near a lighted object that could possibly affect our readings, the point needs to be moved 5 meters in any direction until the object is no longer a threat. All sky glow readings need to be taken after the moon has set to avoid any interference.
- Weather conditions (rain, clouds, fog, and mist) could reflect light back down to the earth, causing artificially bright readings. If any of these weather conditions are present, the sky glow measurement needs to be postponed to a later date when the sky is clear.

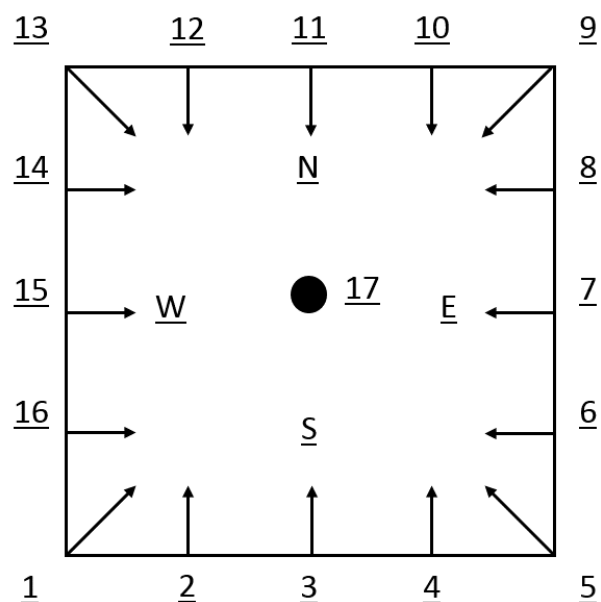
Nighttime Measurements using Data Collection Sheets

Materials

1	Unihedron SQM-L
1	Konica/Minolta T-10A
1	1.5-meter stick
1	Camera
1	Compass
1	Timer
1	Site Assessment Sheet
1	Data Collection Sheet

Directions

1. Start in the center of the quadrant.
2. Using the compass and the camera, take 4 pictures in the cardinal directions.
3. Record how many lights are visible in the Site Assessment Sheet (for nighttime site assessment).
4. If the weather is clear hold the SQM-L over your head straight up and hold down the ‘start’ button. Record the reading in the Data Collection Sheet.
5. Go to the southwest corner of the quadrant with the 1.5-meter stick and the T-10A (shown as point 1 in the diagram below).
6. Place the 1.5-meter stick next to the stake at the corner.
7. Take the receptor diffuser window cap off and turn the T-10A on. The T-10A zeros itself automatically.
8. Place the center of the window next to the end of the 1.5-meter stick facing the center point of the quadrant.
9. Hold the T-10A facing the center point of the quadrant for 30 seconds using the timer to determine when to stop.
10. At the end of the 30-second period press the large button above the power switch on the side of the T-10A.
11. Record the measurement in the Data Collection Sheet.
12. Press the same button again to zero the T-10A.
13. Move east 2.5 meters along the rope to the next point (shown as point 2 in the diagram below).
14. Repeat steps 6-13 until all points along the perimeter of the quadrant have been measured.



Data Collection Sheet

SITE NUMBER	DATE	TIME	WEATHER	TEMP	LATITUDE	LONGITUDE	LOCATION

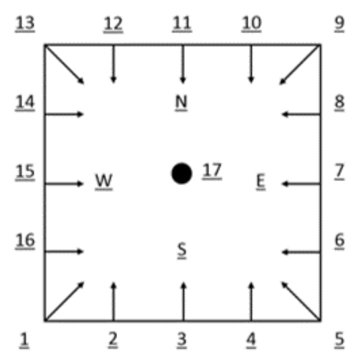
Konica Minolta Measurements

	Konica Minolta
1	
2	
3	
4	

	Konica Minolta
5	
6	
7	
8	

	Konica Minolta
9	
10	
11	
12	

	Konica Minolta
13	
14	
15	
16	



Sky Quality Meter Measurements

DATE	TIME	WEATHER	TEMP

17			

SAFETY CHECKLIST

SAFETY ITEMS	CHECKOFF
BUGSPRAY	
SUNSCREEN (DAYTIME)	
FLASHLIGHT	
SAFETY VEST	

3.1.2.a Creating an Inventory System

Our team created an inventory system to catalog all the luminaires along the coast independent of the quadrant system. The purpose of the inventory was to assess the current lighting practices along the coast. Our team wanted to know who was contributing the most light and why, as well as if lighting habits had an effect on light level readings. To determine the contributors of the most lighting, our team decided on a classification system. The classification determined the type of property the luminaire was on and its purpose. The location of each luminaire is important to determine where the greatest contributors of light are. Knowing the purpose of each luminaire is important because it may affect other characteristics and features of the luminaire. Our team decided that the three factors that could affect light level readings are level of shielding, bulb type and if any automatic shutoff is present. The level of shielding and bulb type on a luminaire can greatly impact the amount of light trespass in an area. The presence of an automatic shutoff was chosen because if a luminaire is not on it cannot contribute to light trespass levels. Therefore, if a luminaire is not being used it can be controlled by using an automatic shutoff.

3.1.2.b Inventory System

An inventory of luminaires was created to analyze the current lighting practices affecting the coast. The inventory provides a detailed description of each luminaire along the coast, establishing a baseline against which to evaluate any future change in lighting practices. The key features for completing the inventory are classification, level of shielding, type of bulb used, and whether any automatic shutoff device is present.

The two levels of classifications include what type of property the luminaire is located on and its use on that property. Our team selected residential, commercial, industrial and public property as options for the first classification because these types of properties are most likely to be located along the coast. Residential properties were identified as a houses, apartment buildings, and condominiums. Commercial properties were identified as any business serving the public such as a hotel, restaurant, or bar. Industrial properties were business such as a manufacturing plants or factories. Public property was identified as being either located on roadways or entryways onto the beach. The second level of classifications were similarly chosen because the following uses are most likely to be seen along the coastal area: street/roadway, pathway/entryway, parking lot/garage, security, scenic, signage, patio, sports, park/playground and entertainment.

Each luminaire has different levels of shielding and therefore recording the type of shielding is necessary. The shields were classified as full shields, partial shields, improper shields and no shield, example pictures of each type of shielding can be seen below in chapter 5 of the protocol. A full shield fully encompasses the bulb preventing light from traveling above the horizontal. A partial shield does not fully encompass the entire bulb and does not completely prevent light from traveling above the horizontal. An improper shield fully encompasses the bulb but does not prevent light from traveling above the horizontal. A classification of no shield means that there is no shield present on the luminaire to prevent light from traveling above the horizontal. In all cases that our team encountered, the luminaire was visible and the type of shielding could always be identified.

For the bulb classification, we provided a list for some common bulb types that may be encountered. This is a partial list and there are more possibilities. In order to identify the bulb, it is necessary to visually inspect the luminaire. Although some bulbs such as fluorescents are easy to identify, many bulbs look very similar with few if any features to distinguish them. If the luminaire is inside an inaccessible area and a visual inspection cannot be completed, then the owner of the luminaire must be contacted for details on the bulb.

Similar to bulb type, it may be difficult to know what form of automatic shutoff, if any, a luminaire has. If when repeatedly approached, a light turns on and then off after leaving the area, it may have a motion detector. If, over the course of many nights, a luminaire, or set of luminaires, turn off at the same time, it may be concluded that these lights have a timer. Again, it may be necessary to inquire with the owner as to what kind of shutoff device is utilized for a full inventory. If a luminaire is in an inaccessible area and the above methods cannot be completed for identifying if any automatic shutoff is present, then the owner of the luminaire must be contacted for details.

The system to create an inventory of luminaires can be seen below in chapter 5 from the protocol. It includes detailed descriptions on the types of classifications, level of shielding, bulb types and types of automatic shutoffs.

CHAPTER 5

CREATING AN INVENTORY OF COASTAL LIGHTS

The inventory of lights is completed at night but separately from the night time assessments. An assessment should be completed for every light located on the coast. A luminaire may not be directly on the beach but angled towards the beach or close enough to contribute to the brightness of the beach and should therefore be included in the inventory.

Step one is to photograph the luminaire and add corresponding identification number

Step two is to record the location of the luminaire

Step three is to classify the luminaire as:

- Residential: Any exterior light on the property of a residence such as a house, apartment, condominium, etc.
- Commercial: Any exterior light on the property of a business serving the public such as a hotel, restaurant, bar, etc.
- Industrial: Any exterior light on the property of a business such as a manufacturing plant, factory, etc.
- Public: Any exterior light on public property such as street lights

The second part of step three is to classify the light fixture as:

- Street/Roadway: Lighting used to illuminate a street or roadway
- Pathway/Entryway: Lighting used to illuminate a pathway or entryway
- Parking lot/garage: Lighting used to illuminate a parking lot or garage
- Security: Lighting used for security purposes, such as lights that illuminate areas outside of property boundaries and often point away from properties
- Scenic: Lighting used for a landscape, terrain, beach etc.
- Signage: Lighting used with a sign such as a promotional sign
- Patio lighting: Lighting used to illuminate outdoor patios such as restaurants or hotels
- Sports lighting: Lighting used to illuminate sports facilities such as volleyball or basketball courts
- Park/Playground: Lighting used to illuminate park or playground areas
- Entertainment: Lighting used for outdoor theaters, concerts, etc.

Step four is to classify the level of shielding:

- Fully Shielded: Shield fully encompasses the bulb preventing light from traveling above the horizontal

- Partially Shielded: Shield does not fully encompass the entire bulb and does not completely prevent light from traveling above the horizontal

- Improper Shielding: Shield fully encompasses the bulb but does not prevent light from traveling above the horizontal due to the angle

- Not Shielded: No shield present

Step five is to identify the type of bulb. If the luminaire is inside an inaccessible area and a visual inspection cannot be completed, then the owner of the luminaire must be contacted for details on the bulb.

- Low pressure sodium
  - Mostly used for street lighting and industrial light
  - Outdoor lighting and security lighting
  - Produce monochromatic yellow color

- Very efficient bulb
- Powerful bulb for large areas

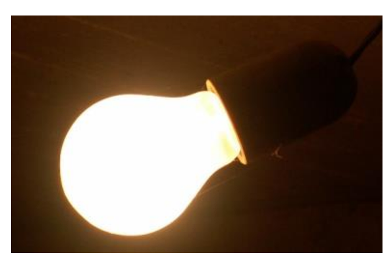
- High pressure sodium
  - Good efficiency
  - Produce bright yellow color
  - Smaller size than LPS or fluorescent
  - Can fit into many fixture types
  - Greater bulb light than LPS
  - Outdoor, municipal and home yard lighting

- Fluorescent
  - Made up of long glass tubes
  - Can become noisy after long use (clicking sounds)
  - Produce a very bright blue/white light
  - Can have sensors for presence or daylight detection
  - Useful for indoor lighting of large areas
  - Contains small amount of mercury
  - Less heat produced and longer life than Incandescent

- LED
  - Produce white light
  - Can produce red, green or blue light
  - Does not emit light in all directions
  - Useful for specified area lighting
  - More efficient than Fluorescent and Incandescent
  - Higher cost
  - Low light output, need multiple LED's for a lamp

- Halogen
  - Need to have a shield due to high glare
  - Need to be properly directed due to high glare
  - Good for general lighting in living spaces
  - Produce a soft white light
  - Useful for outdoor floodlights and display lighting
  - Produces a lot of heat

- Incandescent
  - Work well for lighting small areas
  - Low cost
  - No toxic materials
  - Not very efficient
  - Low lifespan
  - Produce yellow light color



Step six is to determine what type of automatic shutoff, if any, is present. If the luminaire is inside an inaccessible area and the methods for determining if any automatic shutoff is present cannot be completed, then the owner of the luminaire must be contacted for details on the bulb.

- Motion detector: Light is activated by the detection of motion, or turns out due to the absence of motion
- Timer: Light is activated and deactivated in accordance with a set schedule
- None: Lights are manually operated

Example Inventory Collection Sheet

Photo Identification Number	Location	Light Fixture Classification	Shield	Bulb	Automatic Shutoff	Notes

3.1.3.a Developing a Survey

In order to research how much people know about the effects of lighting practices in their community and its contribution to light pollution in the area where they live, we developed a survey. This survey is to gain insight into the degree to which community members understand the potential ecological impacts of light pollution in their neighborhood. It will also provide information on the opinions of community members on the lighting practices currently in place. The results from this survey can be analyzed by correlating certain responses with the light measurements previously taken as well as data from the inventory. The analysis results can then be used to form the brochure along with other recommendations.

In addition to demographic information, the main categories of information requested in this survey involve lighting outside the respondents' residence, respondents' actions in response to light levels, knowledge on light pollution, and examples of lighting practices in Isla Verde and other communities. Demographic questions should be included to know whether the respondent was a resident of the specified location and if opinions differ as a result of demographic factors such as age and gender. Questions regarding light outside of the respondents' residence are helpful in understanding how the community members feel about the current light levels surrounding their home. Asking respondents about actions that they may or may not have taken in response to the current light levels will determine whether or not the community members are combatting the issue on their own and if so, what they have done. Including questions about the forms and effects of light pollution are important to gauge how much is already known throughout the community. The last category about examples of lighting practices in Isla Verde and other communities will help understand the kinds of lighting practices that members of the community have noticed along the coast of Isla Verde and overall how it compares to other coastal communities. Combined, all of these categories will provide data that can be used to help form better recommendations to improve the current lighting practices along any coastal region.

This survey is intended to be self-administered and the respondents are to be sought on the beach or door-to-door. Even though this survey is intended to be administered in person, the respondents will have the option to complete a hard copy or given a link to an electronic version. If there are surveys completed in writing, those responses can be input into an online survey platform so that all of the data will be stored in one location. The design of the survey and possibly the outcome of the responses were affected by the decision of whether to administer the survey in person (on the beach or door-to-door) or electronically. We reasoned that a survey administered in person should be kept shorter so it does not take a long time to finish. This is because most people will not want to stop and fill out a survey that takes more than a few minutes to complete. Since there is also an electronic version, the design does include open-ended questions to gather more information and explanations but these questions were limited in order to make the survey fast to finish.

Approaching respondents in person could affect the outcome in a few ways. For example, there may be a difference in the number of responses by each gender or age group compared to the number of responses we may have obtained through administering the survey electronically. This is because whoever is administering the survey may only approach a certain group of people depending on who they are comfortable talking to. Another factor that could affect the outcome is that if respondents decide to complete the survey while on the beach, their responses could be based more on what they can observe rather than their usual opinions.

The responses from the questions regarding lighting outside of respondents' residences can be used to gather data on how much light is outside respondents' residences and in the community, their feelings about those lights, how those lights compare to other communities and what their ideal amount of light is. This information can help the DRNA and JCA to understand the community members' satisfaction with the current light levels and whether or not they desire change. To understand the degree of the respondents' opinions, the response option should be on a scale of 1-5. The questions about respondents' actions in response to light levels will be used to determine what the respondents have done personally to reduce light levels, how they feel about changing their lighting habits, and whether or not the current amount of light affects what they do. These responses will provide insight on how the light levels affect respondents' daily lives. For these questions a mixture of multiple choice, open-ended, and ranking questions can be used so that each respondent can elaborate on what actions they have taken or why they feel a certain way. For the next category about light pollution knowledge, it is important to discover the information that respondents know and to what extent so that it is clear what the community needs to be educated on. These questions focus on the different forms of light pollution as well as different ecological effects of light pollution. This category also uses a variety of question types for the same reason as in the third category questions. The last category is intended to provide data on the different kinds of lighting that respondents have noticed along the coast and how it compares to other coastal communities. Since these answers are straightforward, multiple choice and multiple selection type questions can be used.

When analyzing the data from the first category of questions, the responses can be separated into residents and non-residents to understand the difference in their opinions. By analyzing the results for residents, the data can be used to understand what recommendations should be made to the specified community where the survey is administered. The second and third categories of questions can be analyzed against inventory data like the amount of shielding or the number of lights there were by classification. By correlating this data, conclusions can be made about the reasons why respondents feel a certain way about the number or amount of lighting. The fourth and fifth categories of questions can be compared to all of the light measurements taken and the inventory results and then used to provide statistical data in the brochure. Both aspects of the survey and all of the measurements are necessary because the survey responses can provide insight into why there are certain light types or why there is the amount of lights that there is along the coast. Using both sets of results, it will be easier to conclude what lighting should be changed in order to reduce light pollution as well as satisfy the community.

3.1.3.b Survey to Gauge Perspectives and Opinions of Community Members on Light Pollution and its Impacts on Coastal Communities

In our survey, there are a total of 21 questions: 11 multiple choice/multiple selection, 6 scale, and 4 open-ended. Our team created all of these questions with the exception of question numbers: 8, 11, 13, and 18-21. These specific questions were added by the JCA. The survey that can be used in coastal communities in Puerto Rico can be seen below in Chapter 6 of the protocol.

CHAPTER 6

SURVEY TO GAUGE PERSPECTIVES OF COMMUNITY MEMBERS

To gain insight into the degree to which community members understand the potential ecological impacts of light pollution in their neighborhood and their views on current lighting practices it is necessary to administer this survey. This survey can be distributed by either Qualtrics, an online survey platform, or hard copies.

[Current Location] Light Survey

The purpose of the following questions is to understand your opinion on the use of lights and luminaires, as well as the outdoor lighting practices in your community. This questionnaire is voluntary and all of the responses will be anonymous.

1. Gender:
   - ❍ Male
   - ❍ Female

2. What age group do you belong to?
   - ❍ Under 18
   - ❍ 18-30
   - ❍ 31-44
   - ❍ 45-59
   - ❍ Over 60

3. How would you describe your role in the [Current Location] community? Select as many that apply.

- ❑ Business Owner
- ❑ Resident
- ❑ Employee
- ❑ Tourist/ Visitor
- ❑ Other

4. How would you describe the levels of outdoor artificial light in the community around your residence at night?

Insufficient [1] [2] [3] [4] [5] Excessive

5. How much do you feel affected or bothered by light levels in your community?

It doesn't bother me at all [1] [2] [3] [4] [5] It is irritating

6. If you are bothered, are you able to reduce the light that enters your residence at night? Explain what you have done to reduce the light if anything.

7. What do you believe the ideal level of light to be outside of your residence at night?

Totally dark (no visibility) [1] [2] [3] [4] [5] The most light as possible (as if it were daytime)

8. Have you considered moving to another place because of the light level outside your residence?

- ❍ Yes
- ❍ No

9. How would you describe the lighting at night in the community around your residence?

Totally dark (no visibility) [1] [2] [3] [4] [5] Very bright (as if it were day)

10. Do you know what light pollution is?

Not at all [1] [2] [3] [4] [5] Very familiar

11. What do you think you can do to help the light pollution problem in Puerto Rico? Explain

12. Have you noticed any of the following in the area of [Current Location]? Select all that apply

- ❑ Glare: any intense and blinding light that reduces visibility
- ❑ Sky glow: brightening of the night sky with an orange-yellow glow
- ❑ Light Trespass: light in an unwanted or needed area
- ❑ Light Clutter: an excessive grouping of lights

13. Please explain your answer to the previous question. You can use examples, but please do not identify any business by name or location.

14. Do you think changing your outdoor lighting habits would negatively affect your business or style of life?

- ❍ Yes
- ❍ No

15. In relation to public lighting in your community, how do you feel walking alone on the beach in [Current Location] at night?

I do not feel safe [1] [2] [3] [4] [5] I feel very safe

16. How does the lighting of businesses and residences surrounding the beach in [Current Location] at night compare to lighting at other beaches that you have visited in Puerto Rico or other countries?

- ❍ Worse
- ❍ The same
- ❍ Better

17. From the list, select all that you think are ecological effects of light pollution because of excessive or unnecessary outdoor lighting.

- ❑ Migration patterns of birds
- ❑ Disorientation of sea turtle migration to the sea
- ❑ Nighttime exposure of many organisms to predators and other dangers
- ❑ The loss of the use of the habitat
- ❑ Death of insects or other organisms because of luminaires that generate heat
- ❑ Change in circadian cycles of the organisms (with nighttime activity when there shouldn't be)
- ❑ None of the above, therefore light pollution does not cause harm

18. Do you know any example of these effects on organisms or animals that are inhabitants or visit the beach in [Current Location]?

- ❍ Yes
- ❍ No

19. Explain your previous answer.

20. In relation to the outdoor lighting in residential and commercial properties that surround [Current Location] beach, what are the outdoor light uses that you have seen?

- ❍ Lighting in gardens
- ❍ Lighting on gates and entrances
- ❍ Public post lighting
- ❍ Lighting for signs and outdoor public announcements
- ❍ Lighting for sidewalks, paths in businesses or residences
- ❍ Lighting for pools
- ❍ Lighting on the water or the sand
- ❍ Lighting using lasers or lights that move
- ❍ None of the above

21. With respect to the use of outdoor lighting that reaches the sand on the [Current Location] beach, what do you believe applies the most?

- ❍ It should light the entire coast so that the beach can be used at night at any hour.
- ❍ The control and management of outdoor lighting of some businesses or residential properties should be improved.
- ❍ As it is now is good, it is not necessary to change the outdoor lighting in this zone at all.

3.2 Using the Protocol in the Coastal Community of Isla Verde to Evaluate Current Lighting Practices

Once the protocol was developed it was used in the coastal community of Isla Verde to begin the process of evaluating coastal lighting practices. Our team measured sky glow and light trespass, completed an inventory of light fixtures along the coast, and administered a survey to the residents of Isla Verde.

3.2.1a Measuring Sky Glow and Light Trespass in Isla Verde

Sampling Schedule

To develop a sampling schedule for our application of the protocol to Isla Verde, we consulted the United States Naval Observatory (USNO) on moon rise and set times for the year 2014 to show when measurements were taken and compiled information on appropriate times to take light trespass and sky glow measurements as seen in Table 2. For the first week of November, excluding 10 minutes on November 5, the moon was out from the end of astronomical twilight to the beginning the next morning, which is why those slots were left blank.

On November 14, there was a blank time slot for the end of the measurement period. This is because the moon did not rise until 0035 the following morning, and this was deemed too late to take measurements on this day. The start and end times were on different days until November 30. Table 3 below shows the dates that our team went to the field to take measurements.

Table 2: Available field times corresponding with moonset and astronomical twilight for the month of November

Day	November					
	Measurement Time		Moon		Astronomical Twilight	
	Begin	End	Rise	Set	Begin	End
1			1357	105	510	1906
2			1444	204	510	1905
3			1530	303	511	1905
4			1616	402	511	1905
5	501	511	1703	501	511	1905
6			1751	600	512	1904
7			1841	659	512	1904
8			1933	756	513	1904
9	1904	2024	2024	850	513	1904
10	1904	2116	2116	942	513	1903
11	1903	2207	2207	1031	514	1903
12	1903	2258	2258	1116	514	1903
13	1903	2347	2347	1158	515	1903
14	1903			1238	515	1903
15	1903	35	35	1316	515	1903
16	1903	123	123	1353	516	1903
17	1902	211	211	1431	516	1902
18	1902	300	300	1509	517	1902
19	1902	350	350	1550	517	1902
20	1902	442	442	1633	518	1902
21	1902	518	537	1719	518	1902
22	1902	519	633	1810	519	1902
23	1904	519	730	1904	519	1903
24	2001	520	827	2001	520	1903
25	2101	520	923	2101	520	1903
26	2201	521	1017	2201	521	1903
27	2300	521	1108	2300	521	1903
28	2359	522	1156	2359	522	1903
29		522	1242		522	1903
30	57	523	1327	57	523	1904

Table 3: Sampling Schedule

Date	Start Time	End Time	Point Assessed
November 13, 2014	7:05 PM	7:30 PM	42
November 17, 2014	7:05 PM	9:30 PM	33-38
November 18, 2014	7:05 PM	9:00 PM	39-41, 28
November 19, 2014	7:05 PM	9:30 PM	22-27
November 20, 2014	7:05 PM	9:00 PM	16-21
November 24, 2014	8:01 PM	10:00 PM	9-15

Selection of Points

The Management Program of the Coastal Zone of the Department of Natural and Environmental Resources identified points for our study using a GIS program to mark an aerial map of Isla Verde. The map marks a point every 100 meters along the coast, resulting in a total of 46 points. Figure 21 below shows the entirety of Isla Verdes coast followed.

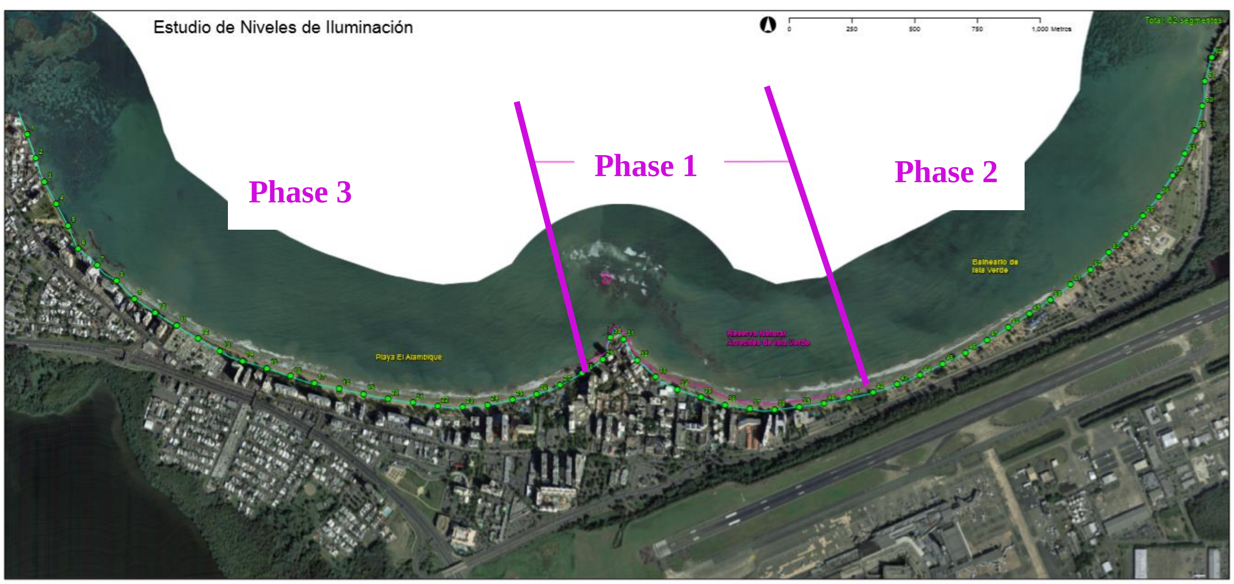


Figure 21: Aerial map of selected data points on coast of Isla Verde. Phase 1 is located between the purple lines, Phase 2 is to the right of the purple lines and Phase 3 is to the left of the purple line

The coast was divided into three sections resulting in three phases for data collection. The purpose of dividing the coast into phases was to establish spatial priority to account for time constraints. Phase 1 and 3 were the primary focus. Phase 1 was the primary focus of the DRNA and JCA because of the Isla Verde Coral Reef Marine Reserve which stretched from points 28-42. Phase 2 was located on the coast of Balneario which ranged from points 43-58. Phase 3 originally had least priority due to its size being twice as large as Phase 2, however Phase 2 was less developed than Phase 3 which consisted of points 9-27 along the Alambique Beach. Data from a more developed area was of higher priority for the DRNA and JCA, therefore we conducted our protocol in Phases 1 and 3.

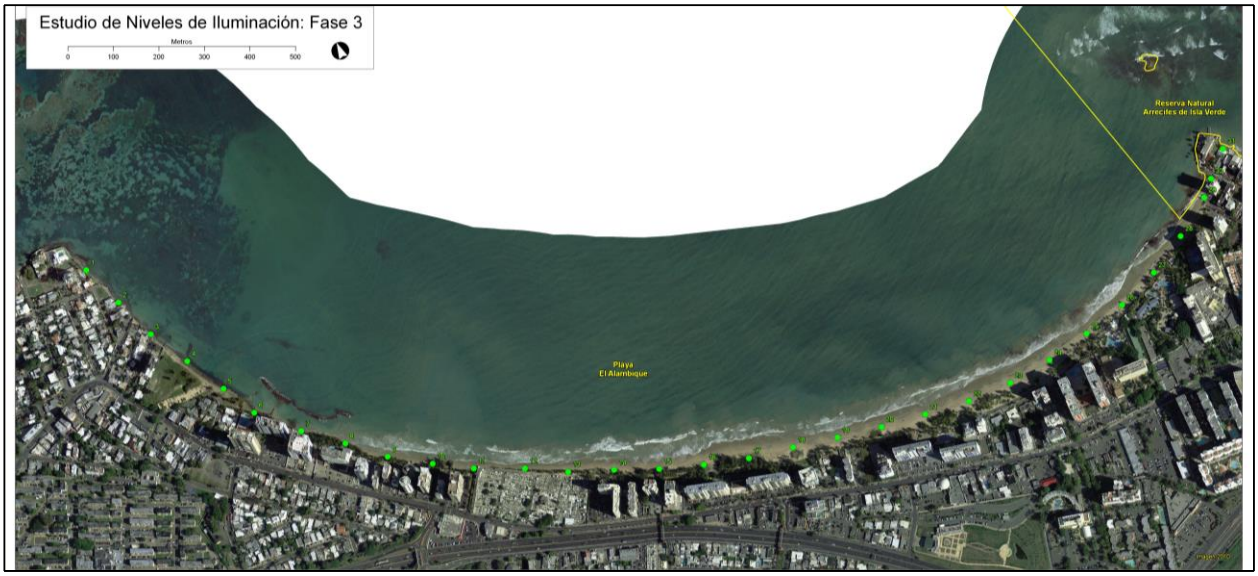


Figure 21a: Aerial Map of Phase 3, Site Numbers 1-27

Figure 21b: Aerial Map of Phase 1, Site Numbers 28-42

Figure 21c: Aerial Map of Phase 2, Site Numbers 43-58

Sky Glow

Table 4 shows the classification scheme for sky glow created by Flanders (2008). We used this scheme to analyze the numbers recorded from the sky glow measurements. Table 3 consists of six ranges of sky glow measurements with corresponding descriptions of typical locations with these readings. High measurements, such as 20.5 mpss and above, correspond with dark skies and low measurements, such as 18.8 mpss and below, correspond with bright skies. Isla Verde is in the city of Carolina, and is bordered to the west by the neighborhood of Condado in San Juan, to the south by the neighborhood of Santurce in San Juan, and to the east by other parts of Carolina. All three are suburbs of the capital city of San Juan. Due to Isla Verde's location, our team hypothesized that the sky glow readings for phases 1 and 3 would be consistent with typical readings of an urban neighborhood or bright suburb, which ranges from 18.0-18.8 mpss.

Table 4: Sky Glow Level Classification Chart (modified from Flanders, 2008)

Light Level in Magnitude per Arcsecond (mpss)	Light Level Description
21.2-22.0	This is often assumed to be the average brightness of a moonless night sky that's completely free of artificial light pollution. The Milky Way is extremely visible and shows an intricate network of tiny dark lines
20.5-21.2	This is typical for a rural area in the eastern U.S., with a medium-sized city not far away. It's comparable to the glow of the brightest section of the northern Milky Way, from Cygnus through Perseus. The Milky Way is obvious and shows a large number of dark lanes
19.8-20.5	This is typical for the outer suburbs of a major metropolis. The summer Milky Way is readily visible but severely washed out
18.8-19.8	Typical for a suburb with widely spaced single-family homes. The Milky Way is never noticeable until it is very high in the sky on summer nights.
18.0-18.8	Bright suburb or urban neighborhood. The Milky Way is invisible.
<18.0	Typical near the center of a major city such as New York or Boston.

Light Trespass

Light trespass measurements were taken in accordance with the procedure from chapters 1-4 of the Coastal Light Level Measuring Protocol. In some cases it was unclear whether the quadrant would fit in a selected site. In these cases, the ropes of the fully assembled quadrant would be pulled taut and the system would be roughly oriented to determine if there was room between the natural and artificial obstacles found on the beach such as retaining walls and the ocean. The quadrant was moved if a more appropriate site was within five meters, otherwise the site was discarded. This procedure was used to reject the quadrant 29 site; all other quadrants were successfully sampled.

Another problem that was occasionally encountered while taking measurements was weather. Although this did not interfere light trespass readings, the meters could be damaged by precipitation. During the few occasions that it did rain lightly, the meter was tucked in a poncho or rain jacket with only the lens protruding.

To analyze the data, the mean light trespass measurement of all sixteen points within a quadrant was taken for each site. This average was then plotted in bar graphs with error bars of one standard error to visualize the range and variability of the data collected. Any major outliers that were outside the outer fences of the data set were excluded from the graph so that darker sites could be represented with greater detail. A value that is outside an outer fence is more than three times the length of the interquartile range away from either end of the interquartile range. The interquartile range is from a point with 25% of all measurements below it, to another point with 25% of all measurements above it. The excluded sites were then analyzed using the nighttime assessment photos to determine the cause of the especially high measurements. Nighttime assessment photos were also used in order to explain the unusually high standard errors of certain sites.

The data set, with the exclusion of the major outliers, was then analyzed using the light trespass measurements. Nighttime assessment photos were not utilized since the camera used to take pictures was not ideal for especially dark conditions. The darkest sites were than plotted in a bar graph with error bars of one standard error and compared to the 0.005 foot-candle acceptable limit for a beach that could support sea turtle nesting.

3.2.1b Sky Glow and Light Trespass Data and Analysis

This section includes the data and analysis of our measurements taken while performing the protocol in Isla Verde.

Sky Glow Data and Analysis

After completing the sky glow readings two values stood out from the rest of the sky glow measurements, 17.58 mpss at point 9 and 17.32 mpss at point 33. These measurements were consistent with sky glow readings typical at the center of a major city such as New York or Boston (Flanders, 2008). This level of sky glow was inconsistent with our hypothesis, therefore the team referred back to the site assessment sheets and inventory data to see if there was a potential explanation. For both site numbers 9 and 33, luminaires (Figure 22 and Figure 23) were discovered to be in close proximity to the center point where the measurement was taken. Mentioned earlier, lighted objects such as street lights could potentially hit the sensor of the sky quality meter at an angle and cause excessively low (bright) readings. Our team concluded that these two luminaires were the cause of such low readings.

Figure 22: Luminaire in Quadrant 9

Figure 23: Luminaire in Quadrant 33

Figure 24 shows the average sky glow measurements taken at each site number which are highlighted on the aerial map in Figure 25.

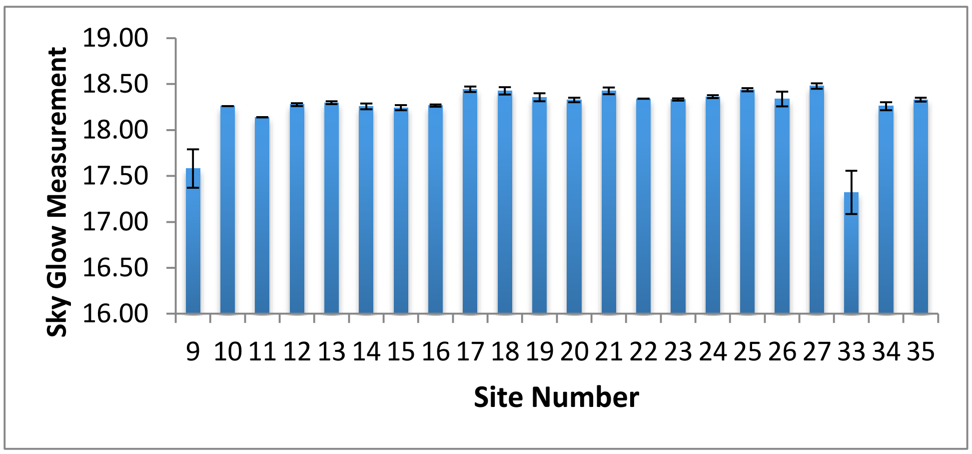


Figure 24: Average Sky Glow Measurement by Site Number
Error bars are one standard deviation

Figure 25: Data points 9-35 corresponding with sky glow measurements

Excluding those two quadrants, the readings ranged between 18.14-18.44 mpss and had an average reading of 18.33 mpss. These readings are consistent with a bright suburb or urban neighborhood where the Milky Way is invisible. This is the level of sky glow our team expected for the urban area of Isla Verde. Phase 1 had a range of values from 18.26 to 18.33 mpss with an average sky glow reading of 18.295 mpss. Phase 3 had a range of 18.14 to 18.48 mpss with an average sky glow reading of 18.335 mpss. Our team concluded that there was no variation of sky glow readings for Phases 1 and 3. This was expected because both phases were highly developed regions.

Light Trespass Data and Analysis

The levels of illumination varied greatly between the different sites, and different points along the perimeter of the sites. The light measurements were taken across almost three kilometers of beach, which changed drastically from high-rise hotels and condominiums to dense vegetation, as can be in Figure 26.

Figure 26: Local environment of sites 33-42

In addition, we observed a considerable amount of variability in the distance to the nearest luminaire. Figure 27 shows the mean for the 16 readings per quadrant and depicts the scope of the variability. The change in local environment and distance the nearest luminaire contributed to data that ranged from a mean illumination of 0.881 foot-candles in quadrant 9 to 0.003 foot-candles in quadrant 42.

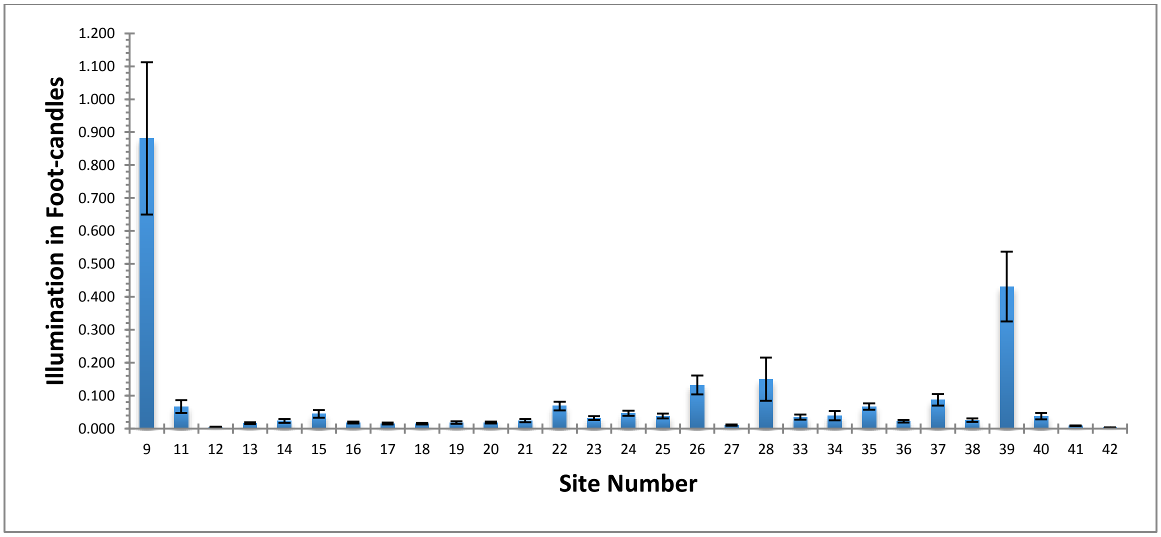


Figure 27: Mean light trespass per site
Error bars are one standard error

This large range makes it difficult to visualize the data. In order to draw any useful conclusions it was necessary to remove the major outliers from this data set. This data set has an upper outer fence of 0.213. Quadrants 9 and 39 both had mean light trespass values above this fence of 0.881 and 0.431 foot-candles respectively. These quadrants are still valuable data points, however due to the degree to which the average illumination levels are above the outer fence, these quadrants were excluded from Figure 28 to better illustrate the data acquired.

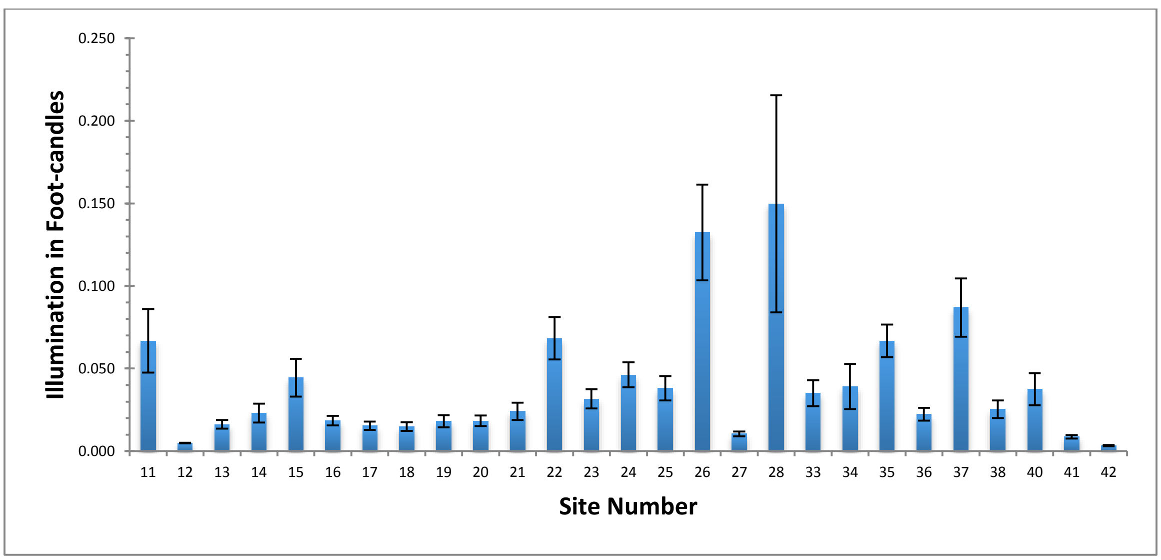


Figure 28: Mean light trespass per quadrant, excluding sites 9 and 39
Error bars are one standard error

With the exclusion of the major outliers, it is easier to note there is high variability both between and within sites, even at darker light levels. Along the beach, there would often be a single or small group of very bright luminaires beside a path or for security around a building. This would significantly raise the average levels of illumination in the quadrant. An example of this practice was in quadrant 28, shown in Figure 29. With the exclusion of the two highest points, the ambient light level is 0.057 foot-candles. When point 1 and 10, which had light levels of 0.850 foot-candles and 0.750 foot-candles respectively, are included, the average for this quadrant increases 2.6 times to 0.150 foot-candles. This accounts for the unusually high standard error between light trespass measurements of 0.263.

Figure 29: East nighttime assessment photo of site 28

A single or small set of bright luminaires also accounts for the variability between adjacent sites. The beach to the east of the luminaire in Figure 29 is relatively dark and is sparsely developed. Higher light levels are usually proportional to more human activity, however the coast of Isla Verde is dotted with these exceptionally bright luminaires in otherwise dark regions.

Quadrant 9 is another example of a single bright luminaire contributing to higher than normal measurements. This was the brightest quadrant on average and had the single brightest point of 4.100 foot-candles in the northeast-facing corner. This quadrant, shown in Figure 30 was almost directly beneath a very bright luminaire.

Figure 30: South nighttime assessment photo of site 9

The yellow line in the bottom left of Figure 30 is the stake used to mark off the corners of each quadrant. The proximity of the luminaire to the quadrant is responsible for the 4.100 foot-candle measurement. Although it cannot be seen due to glare, this luminaire is only partially shielded.

The quadrant with the next highest light measurements was taken directly outside of a hotel's open-air restaurant. The restaurant can be seen in Figure 31.

Figure 31: South nighttime assessment photo of site 39

This quadrant has an average level of illumination 17 times higher than the adjacent quadrant to the west and 11.5 times higher than the adjacent quadrant to the east. The highest reading in this quadrant was 1.268 foot-candles, which is 6.4 times higher than the outer fence of the entire data set. Figure 32 was taken from quadrant 38 and shows quadrant 39 in the distance. This image illustrates the stark difference between the light emitted from this restaurant and the ambient lighting.

Figure 32: East nighttime assessment photo of site 38

Since this beach has the potential to support sea turtle nesting, it is considered a sea turtle nesting beach. Accordingly, no point along the beach should have a level of illumination above 0.00 foot-candles. The photometer used for this study could measure down to 0.001 foot-candles. We opted to use standard rounding rules, such that any value between 0.005 and 0.009 was rounded to 0.01, and any value below was rounded to 0.00. Therefore any quadrant that had an average level of illumination of 0.005 or above was considered unacceptable and anything below 0.005 was considered acceptable for the designation of this beach.

The darkest three quadrants are shown in Figure 33. There are only three quadrants displayed to show one quadrant below, one above and one almost at the 0.005 limit. The only site that had average level of illumination below the 0.005 foot-candle threshold was quadrant 42 with an average level of illumination of 0.003 foot-candles. Quadrant 12 had an average level of illumination of 0.0049 however this is rounded up to 0.005 when significant figures are accounted for.

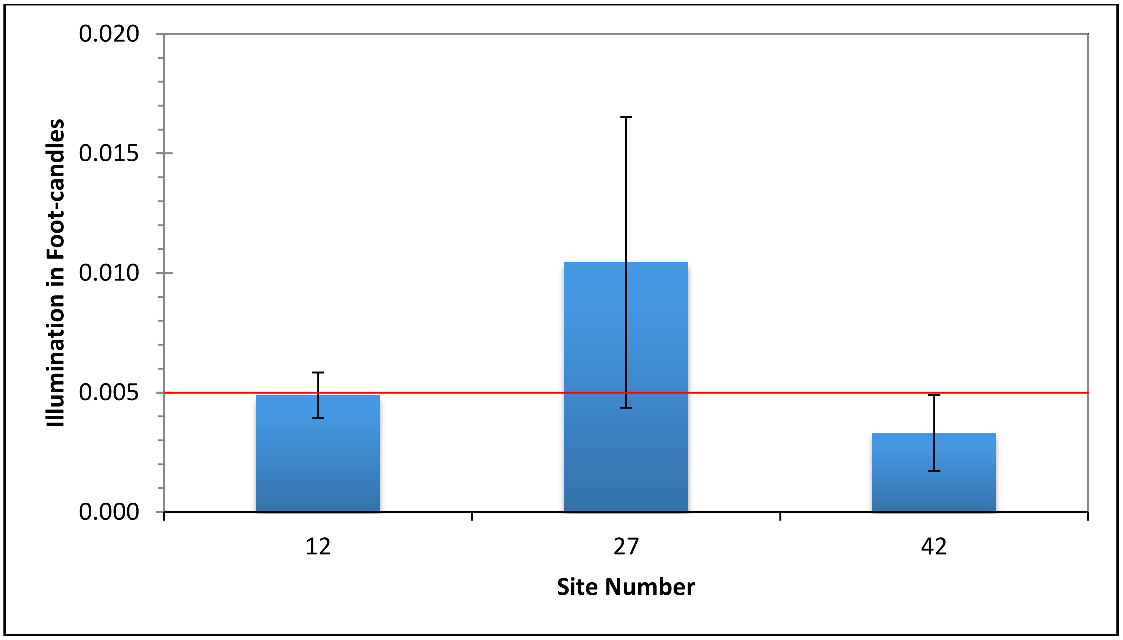


Figure 33: The three darkest sites with 0.005 limit in red
Error bars are one standard deviation

Although on average quadrant 42 was below the 0.005 acceptable limit, three out of the sixteen measurements were above. Although this is better than the rest of the beach, it is still not ideal. The points that were above the acceptable limit were facing west and southwest. The photometer was most likely picking up the brightly illuminated hotels to the west, the nearest of which is over three hundred meters away. If this is the case then the light from these hotels have an impact on the coast for several hundred meters.

3.2.2.a Completing the Inventory in Isla Verde

The inventory was completed for Phase 1 on November 25th from 6:30 pm to 8:30 pm, the inventory for Phase 3 was completed on November 30th from 7:00 pm to 9:00 pm. The completed Inventory Collection Sheets can be found in Appendix F. As predicted when creating the protocol our team ran into difficulties when trying to determine the bulb type and automatic turn off type of each luminaire. Our team outlined these potential problems in Chapter 5 of the protocol and possible alternatives for finding this information. For the purpose of our project and due to time constraints our team chose to focus on the data we recorded about light classification and level of shielding.

The inventory sheets contain a large amount of data, therefore before completing our analysis our team thought of some key questions we wanted to answer. The first thing we wanted to know was if there was a correlation between the number of lights surrounding a quadrant and the corresponding light trespass measurements, as well as if the level of shielding on lights surrounding a quadrant had an effect on the light trespass measurements of a particular quadrant. This was done by comparing the numerical data from the Inventory Collection Sheets and the average light trespass measurements by quadrant. We used SPSS to carry out a correlation analysis and report Pearson's correlation coefficient. Our second question was whether different what lighting practices associated with each classification. Specifically, we wanted to know what classification has the largest amount of light trespass and what the lighting is used for in order to determine the purpose of lights on the beach. This was done by using bar graphs and pie charts to compare lighting by use and classification type. Lastly our team wanted to determine whether there was any relationship between the usage of the lights and the probability that they would be properly shielded. Are lights with no shield usually for security uses because there is a perceived "need" to light up larger areas? Likewise, are scenic lights more shielded in order to prevent glare from affecting the view? This was done by comparing the level of shielding by light use though bar graphs and pie charts.

3.2.2.b Inventory Data and Analysis

The inventory was completed from quadrant 9-42, excluding sites 29-32 due to their location not being accessible. Phase 1 had a total of 125 lights while Phase 3 had a total of 211 lights making the total number of lights on the coast of Isla Verde 336. The number of lights per quadrant ranged from 0-45 with the average number of lights per quadrant being 11.2. The exact number of lights per quadrant can be seen below in Figure 34.

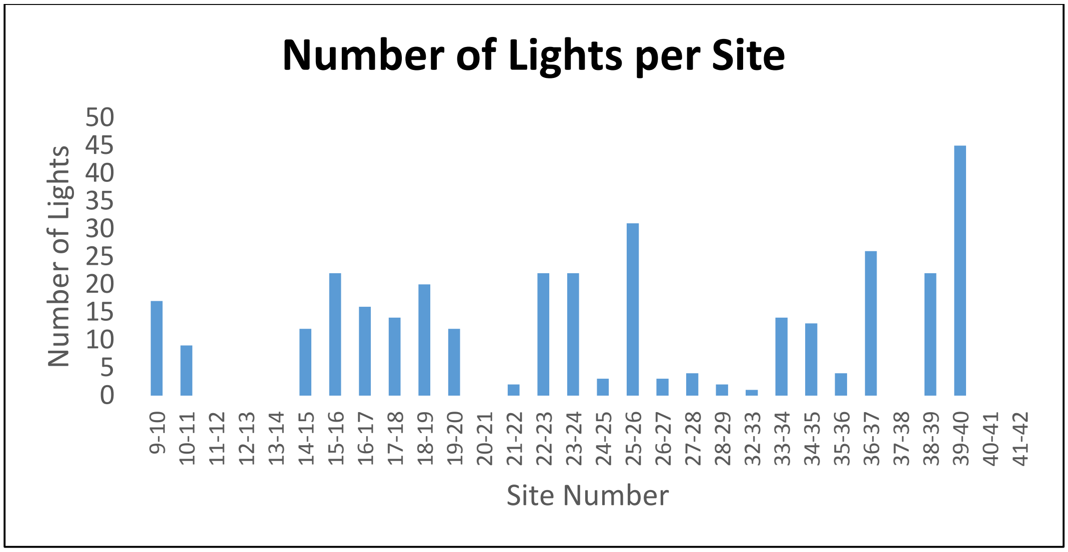


Figure 34: Lights by Site Number

To determine if the level of shielding on a light fixture had an effect on the level of light trespass, a Pearson's correlation was completed in a Statistical Package for the Social Sciences program, a sftware package used for statistical analysis. The SPSS was used to determine if there was a correlation between poor shileding and high light trespass values. This was done by using the average light tespass measurements per site calculated during the light trespass analysis and comapring them to the number of poorly shielded light fixtures found while doing the inventory.

Due to the process of completing the inventory, lights were measured from one site to another, for example 9-10 and then 10-11, and this included a large amount of space that technically falls between site numbers. In order to do the correlation analysis we needed one number for each site number. To do this we divided the number of lights between site number and attributed half to each site number. This analysis excluded sites 9, 28 and 39 which were outliers as well as sites that had no light trespass data. The analysis indicated a weak positive correlation between poor shielding and the readings for light trespass (Table 5 correlation coefficient=.276, df=26, p-value=.173).

Table 5: Light Trespass and Poor Shielding Correlation

		Light Trespass	Poor Shielding
Light Trespass	Pearson Correlation	1	.276
	Sig. (2-tailed)		.173
	N	26	26
Poor Shielding	Pearson Correlation	.276	1
	Sig. (2-tailed)	.173	
	N	26	26

Figure 35 below visually shows the correlation between light trespass level and number of poorly shielded lights by using a best fit line of the correlation.

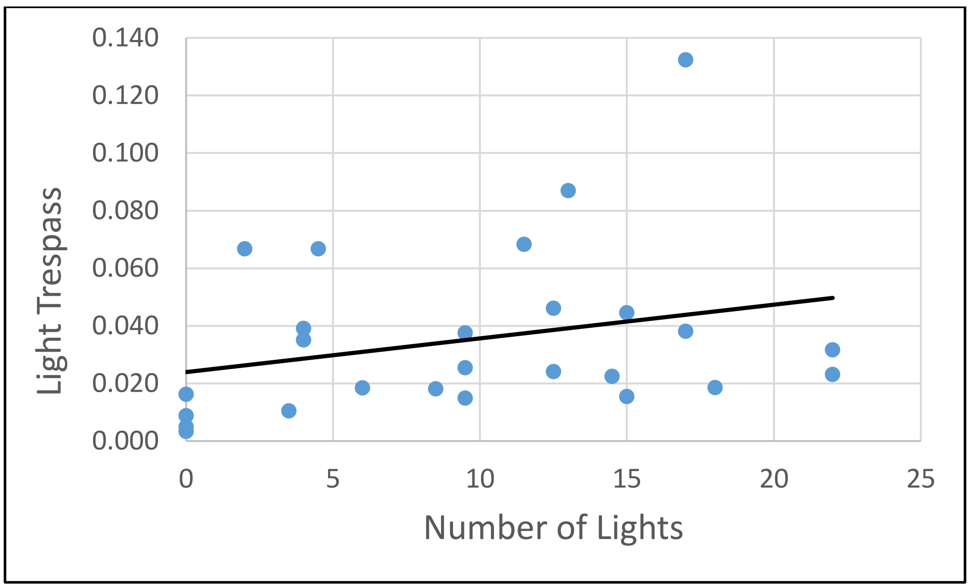


Figure 35: Light trespass vs. number of poorly shielded lights per site

The next step in seeing if there was a correleation between level of shielding and light trespass levels was to test the correlation between fully shielded lights and average light trespass. Using a Pearsons correlation, we determined there was no correlation between the number of fully shielded lights and average light trespass levels (Table 6 correlation coefficient= -.011, df=26 p-value=.959).

Table 6: Light Trespass and Full Shielding Correlation

		Light Trespass	Full Shield
Light Trespass	Pearson Correlation	1	-.011
	Sig. (2-tailed)		.959
	N	26	26
Full Shield	Pearson Correlation	-.011	1
	Sig. (2-tailed)	.959	
	N	26	26

Figure 36 below visually shows the correlation between light trespass level and number of fully shielded lights by using a best fit line of the correlation.

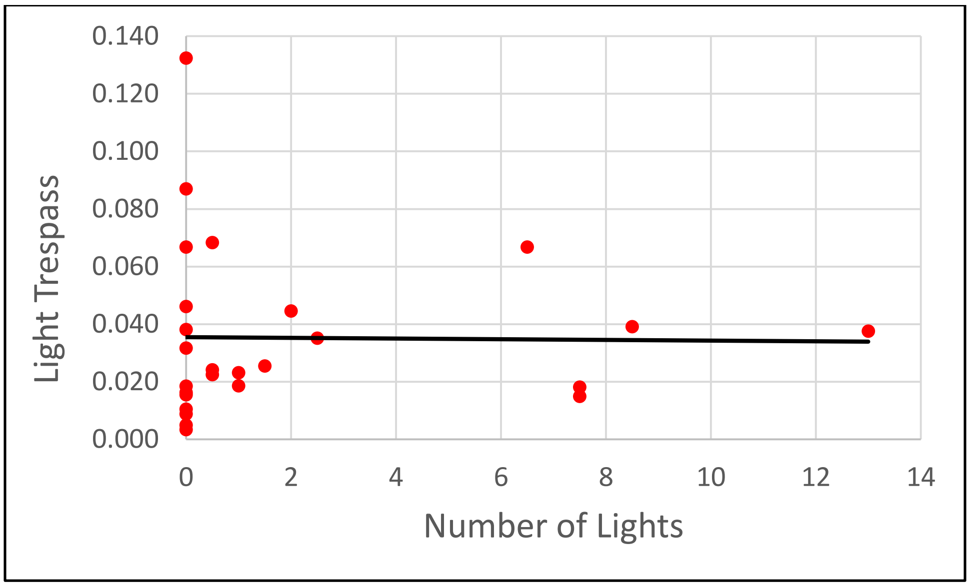


Figure 36: Light trespass vs fully shielded lights

Due to there only being a weak correlation between the number of poorly shielded lights and high light trespass levels we could not conclude with certianly that the level of shielding had an inpact on light trespass levels. Our team then decided to test if the number of lights surrouding a site, regardless of shielding level, had an effect on light trespass levels. The analysis indicated a significant correlation between the number of lights and the readings for light trespass (Table 7; correlation coefficient= .324, df=26, p-value=.107).

Table 7: Light trespass and Total Number of Lights per site Correlation

		Light Trespass	Number of Lights
Light Trespass	Pearson Correlation	1	.324
	Sig. (2-tailed)		.107
	N	26	26
Number of Lights	Pearson Correlation	.324	1
	Sig. (2-tailed)	.107	
	N	26	26

This shows that there is a moderate positive correlation between the number of lights surrounding a site and light trespass levels. Figure 37 below visually shows the correlation between light trespass level and number of lights surrounding a site by using a best fit line of the correlation.

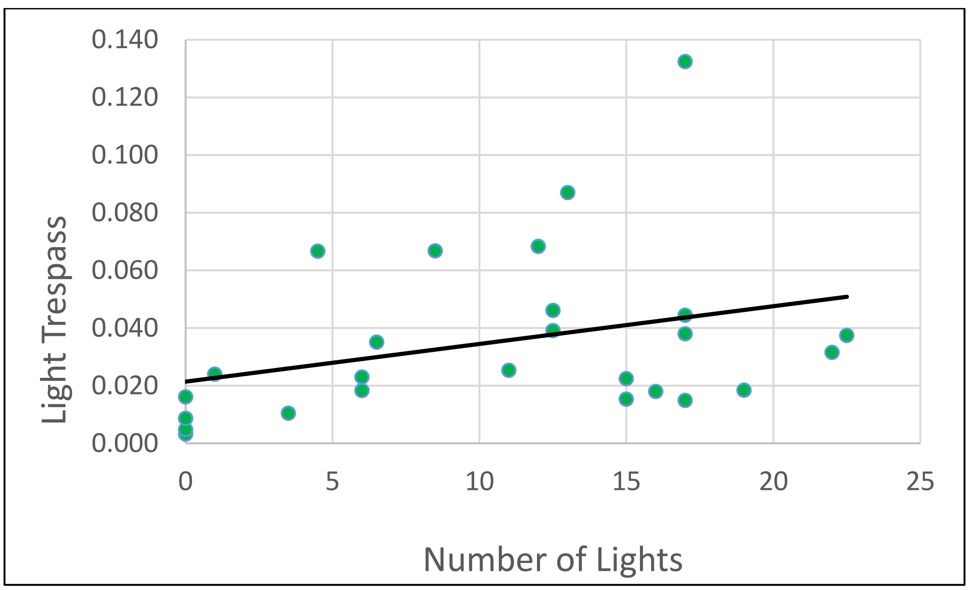


Figure 37: Light trespass vs. total number of lights per site

The next thing our team wanted to determine was what lightening practices are used in each classification. That way we can determine what purpose lighting serves for residential, commercial, industrial and industrial properties. Figure 38 shows the percentage of lights found in residential, commercial and public properties along the coast of Isla Verde. The majority of lights were either residential or commercial with a small percentage being public and no industrial.

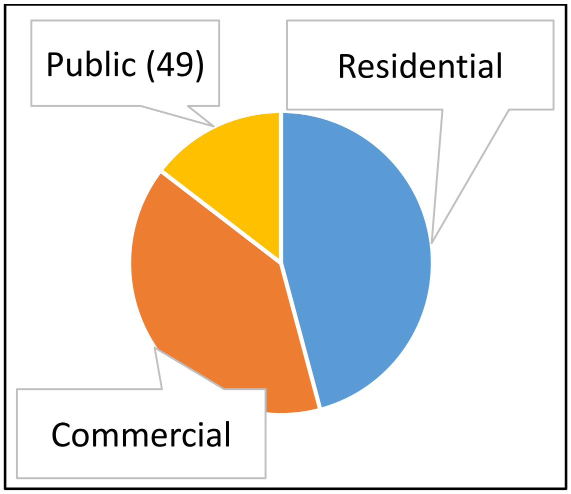


Figure 38: Percentage of lights by property location

Figures 39, 40, and 41 show the distributions of light use by location type. We recorded no lights that were classified as sports, or entertainment lighting, therefore these classifications were excluded from the graph. Our team made some key conclusions from Figure 39, Figure 40 and Figure 41, the first being that residential, commercial and public properties may have different needs when it comes to lighting.

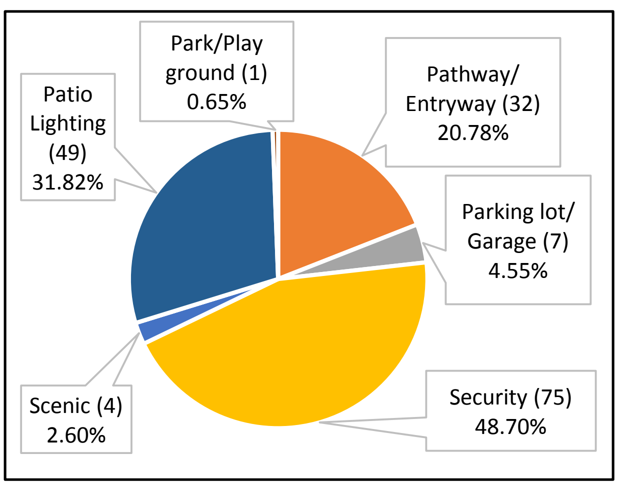


Figure 39: Light use by residential property

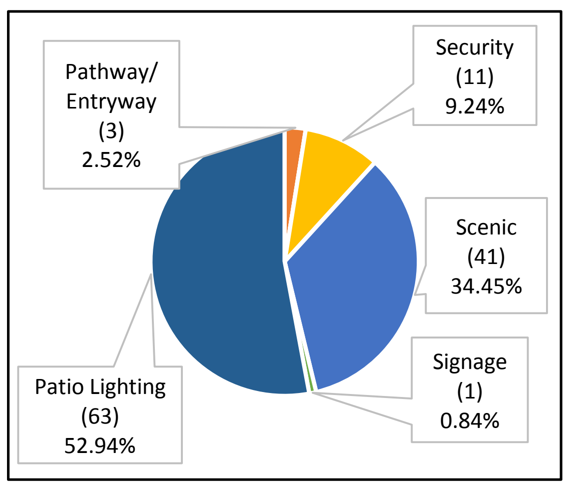


Figure 40: Light use by commercial property

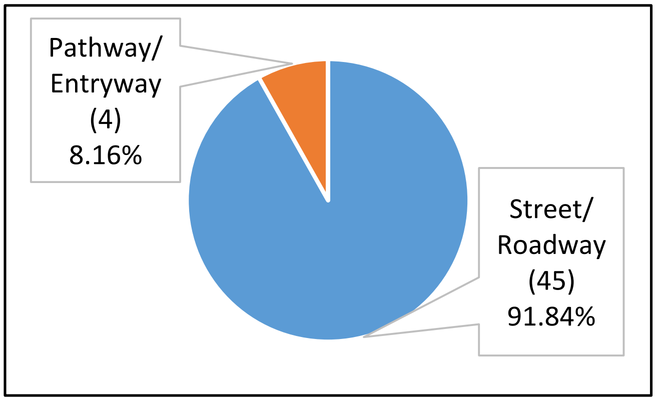


Figure 41: Light use by public property

Public lighting was solely used for street and roadway lighting as well entryways to the beach. From the data provided by Figure 39 we can conclude that the majority of residents use lighting for the purpose of either security or patio lighting. During our assessments our team observed that the residences along the coast consisted of large apartment buildings that each had a portion of land between the buildings and the beach fenced off with a patio area located inside. Although the patio areas were heavily lighted, often the lights used for security were located on the exterior fences pointed toward the beach, not even illuminating the residential property. The high percentage of lights used for security lighting on residential properties led us to conclude that there is either a perceived or real issue of safety for the residents living on the coast of Isla Verde. The analysis on commercial light use was completed using Figure 40 to residential properties, commercial properties had a high percentage of patio lighting; however they had a much higher percentage of scenic lighting and a much lower percentage of security lighting. This data allowed us to conclude that due to the tourism industry, commercial properties cater to the needs of tourists which often include outdoor lighting near the beach. This explains the high use of patio and scenic lighting. After analyzing all of the classifications it became clear that each property type requires lighting for different purposes which could potentially impact the amount of light trespass emitted by each property.

We wanted to determine if there was a pattern in the level of shielding on a luminaire depending on what the luminaire is used for, because the light use might affect the level of shielding. Conclusions were drawn from the data by using Figure 42, which displays the number of lights at each level of shielding by use.

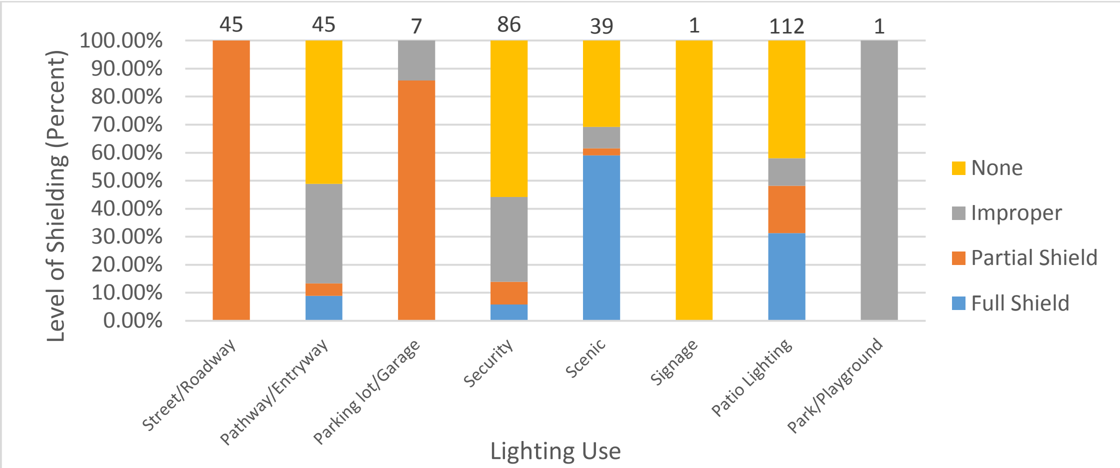


Figure 42: Level of shielding by light use for commercial, residential, public and industrial properties

Considering that all of the street and roadway lights recorded were located on public property, our team concluded that public property often uses similar luminaires for all street/roadway lighting. This may be due to the suppliers of public lighting for Isla Verde, this would explain why all the light fixtures are the same level of shielding. The lighting for pathway/entryways and security lighting had similar shielding distributions, with most lights having either no shield or improper shielding. Therefore our team concluded that pathway/entryways are lacking sufficient shielding because they increase the lighting in potentially unsafe areas where people may be walking, entering or exiting areas of the beach. Although these areas may be unsafe, the light is still reaching the beach and therefore contributes to light trespass. The majority of scenic lighting had fully shielded luminaires and we determined that this was most likely done by both residential and commercial patrons to avoid the glare caused by improper and partial shielding. If such lights were anything but fully shielded they would interfere with one’s ability to see the beach. Therefore, we concluded that these luminaires were selected with more attention to the amount of light emitted and the direction of the luminaire than level of shielding. The level of shielding used for patio lighting although mostly shield less, has a high percentage of fully shielded lights as well. It seemed odd to our team that the level of shielding differed so much for patio lighting, 31.25% of patio lights were fully shielded while 41.96% had no shielding. In order to find an explanation for this contrast, our team wanted to break down the level of shielding by classification, hoping that we could explain the difference if we knew the property type of these lights.

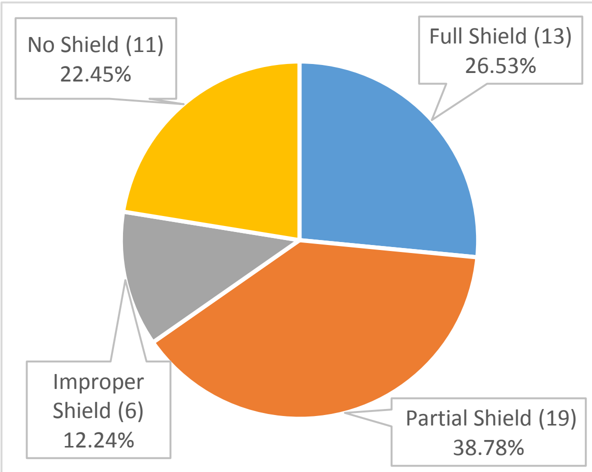


Figure 43: Percentage of Shielded Residential Patio Lighting

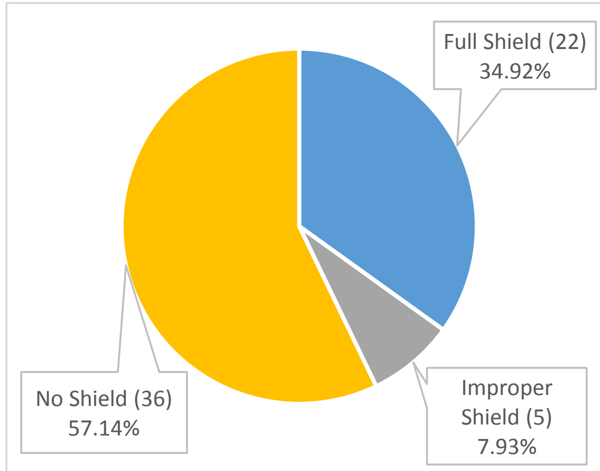


Figure 44: Percentage of Shielded Commercial Patio Lighting

Figures 43 and 44 showed that 57.14% of all commercial patio lighting was unshielded while only 22.45% of residential patio lighting was unshielded. We suggest that the difference can be attributed to the fact that a lot of commercial patios are either for outdoor restaurants or bars. Such places were partially enclosed, such as in Figure 45, and consequently unshielded indoor lighting was often used, explaining the high number of unshielded patio lights. This was most likely due to the restaurants and bars wanting to provide a high amount of light for dining purposes. Likewise, the number of residential patio lights that use full shielding can be explained by their function: these lights are to enhance the experience of residents and patrons on the beach rather than hinder it.

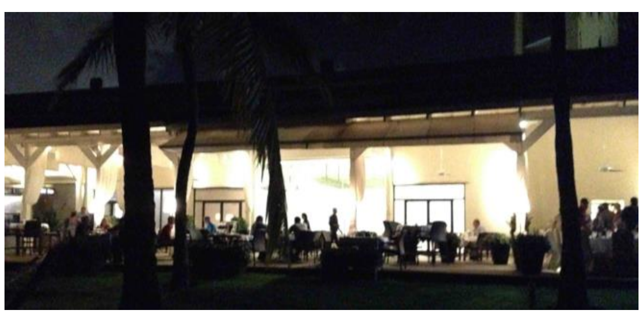


Figure 45: Partially enclosed patio, demonstrates the type of partially enclosed patio seen on many commercial properties

3.2.3.a Administering a Survey in Isla Verde

In order to reach the most potential respondents, we initially visited the numerous high-rise condominiums that line the coast of Isla Verde. This was later supplemented by walking along the beach to get more responses. We began this process at 10 am on December 11, and were accompanied by Nitza Marrero Fontán and Miriam Ortiz Torres, who are employees of the JCA.

The first building we encountered had 300 residents. We spoke with a representative of the building's administration office, who agreed to email the Qualtrics survey link to the residents' email list. A similar situation occurred at the next building with the administration agreeing to send the survey out to another 150 residents. We attempted to continue this process with the rest of the condominiums along the coast, however these were the only two buildings that this was possible. Out of the 450 possible respondents, only 18 had completed the survey three days later.

We encountered significant problems in our attempts to seek responses by approaching individual buildings. It was rare to find a dedicated administration office within a condominium complex. Typically there was a call box that was attached to a fence or wall that completely enclosed that complex. In these cases, we attempted to attempt to call the administration, however this either did not go through or we were told to come back during their limited office hours. In a few buildings, we were able to visit an administration office, but discovered that they do not maintain a list of resident email addresses. One property manager informed us that many of the residents are retired and probably do not use email. We were not allowed to distribute the survey door to door in any buildings due to private property restrictions.

After attempting to contact the residents in the condominiums we decided to seek more respondents by approaching people on the beach. This was partially successful and 11 people completed the survey, however, we had a low participation rate. Many people that we approached seemed to not want their time on the beach interrupted by a lengthy survey. In some cases we had the opportunity to explain who we were and the purpose of the survey, but usually we were dismissed before we could.

3.2.3.b Survey Data and Analysis

Two days after the survey had been administered there were only 29 responses. This includes the 11 people who were directly approached on the beach. The other 18 responses were from a pool of 450 potential respondents. This low response rate of 4% led our team to conclude that the community members were indifferent to the light pollution problem in the area. This response rate was calculated under the assumption that all residents received the email. It is possible that the mailing list was not up to date, or that some addresses were entered incorrectly. Alternatively, it is possible that only one of the building administrations successfully sent the survey to its residents. If this was the case then the response rate would actually be 6% or 12% depending on which building received the survey.

The difficulty our team encountered accessing residential complexes may reflect how the community feels about their safety. Tall fences or walls completely surrounded all of the buildings we visited, many of which were topped with sharp spikes. Our conversations with the residents on the beach reinforced the idea that there was clearly a perceived sense of danger. Many residents talked about the crime at the beach due to the residents from a nearby-subsidized housing project coming to the beach at night. When we asked these residents about how the safety situation could be improved along the beach, nearly all suggested adding more lighting to the coast.

While going to administrative departments in residential buildings, we were able to conduct a survey with a building administrator for a condominium complex that was located directly on the beach. This building administrator told us he had attended a local information session on light pollution held by the DRNA and JCA. In this session, he learned better lighting practices for light fixtures that were impacting the coast. After attending the session, the building administrator took action and replaced all the metal halide bulbs with LEDs that produce a softer white light and are more efficient. All the light fixtures were also angled away from the beach and focused on the property within the fence for security reasons.

The building administrator made these changes to the buildings lighting practices because of his education on the consequences of poor lighting practices. He said he could personally reduce light pollution by educating the residents. This suggests that a strategy that focuses on outreach to building administrators might have a large impact on the severity of light pollution in Isla Verde.

Once all survey responses were gathered, there were a total of 29, 23 (80%) by residents and six (20%) by non-residents. This information will help understand the opinions of the residents specifically which can be used to make recommendations on how to educate the community and encourage voluntary cooperation.

One of the main results from our survey was that there was a high concern for safety in the area. According to verbal responses from conversations on the beach, the respondents indicated that safety was a concern due to crime and the fact that many people from the nearby government project housing complex go to the beach at night. For these reasons, respondents desire more light along the coast. In comparison, no non-residents reported feeling unsafe on the Isla Verde beach at night. Since only non-residents feel safe in the area, we concluded that residents may perceive there to be a larger safety problem in Isla Verde then there actually is. However, due to the small amount of responses, this is not considered to be a strong conclusion.

For question 15, the responses indicated that 14 residents (61% of residents) did not feel safe on the beach in Isla Verde at night. Out of these 14 residents, six (43 %) were male and eight (57 %) were female. Since there were no interesting relationships between the sense of safety and gender of the respondent, we broke down the responses by the age group of each respondent, shown in Figure 46. We decided to analyze this relationship to determine which groups felt safer and overall what the sense of security was like in the community. Each colored bar in the graph indicates a different age group while the scale of 1-5 along the x-axis represents the sense of security with 1 being not safe and 5 being very safe. Using Figure 46 we concluded that as the number on the scale decreased, the number of respondents increased. This means that overall the sense of security was low throughout the community especially for those in older age groups.

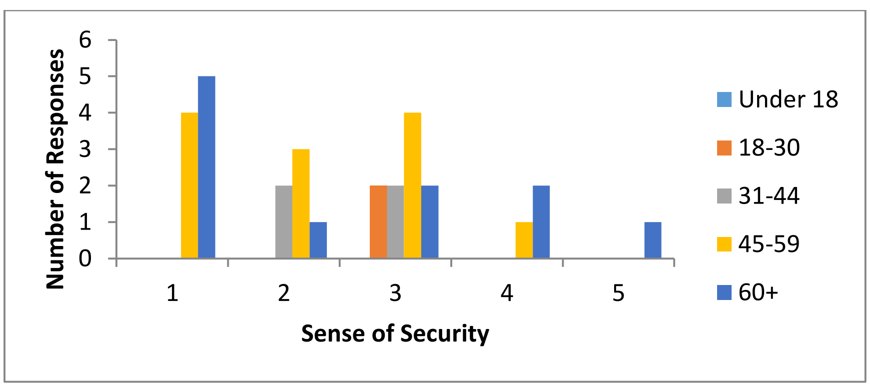


Figure 46: Relationship between the sense of security and number of responses for each age group. This graph represents the number of responses by age group for each value on the scale of 1-5. The value of 1 signified that the respondent did not feel safe and 5 signified that they felt very safe.

Another important result from these survey responses was that there was a lack of knowledge about the effects of light pollution. Out of 29 respondents, 20 (69%) of them answered that they knew what light pollution was (question 10) but when asked to identify all the effects that it could have (question 17), only six people were able to answer correctly. We then organized these six responses by what age group each respondent belongs to in order to determine which groups have the most understanding about light pollution. This data is represented below in Figure 47. Using Figure 47 we were able to conclude that it is especially important to start educating the younger age groups about light pollution. This is so that there can be more of a balance in the number of people for each age group who are knowledgeable about the topic.

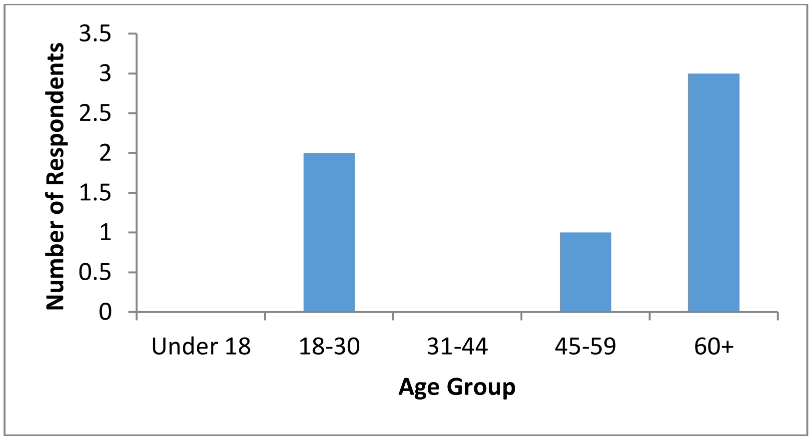


Figure 47: Relationship between age groups and their knowledge of light pollution. This graph represents the number of respondents for each age group who knew what light pollution was and its effects.

Our team wanted to determine what kinds of lights should be changed in order to achieve the ideal level of brightness for the residents of Isla Verde. The results of question #7, which asked what the respondent believed the ideal level of light to be outside of their residence at night, showed that 5 (22% of residents) residents answered a 4 or 5, showing that the majority do not want there to be an excessive amount of light in the area. We then wanted to determine which uses of lighting residents had noticed along the coast which is shown in Figure 48. The top three lighting uses that have been noticed by residents are: lighting on gates and entrances, lighting in gardens, and public post lighting. Since these are the most noticed among residents, we inferred that these are probably the most distracting for them and would be the most appropriate to change first in order to achieve their ideal level of light. However, the other options also had high response rates with the exception of lighting that uses lasers, indicating most of these light uses along the coast are overused and require modification.

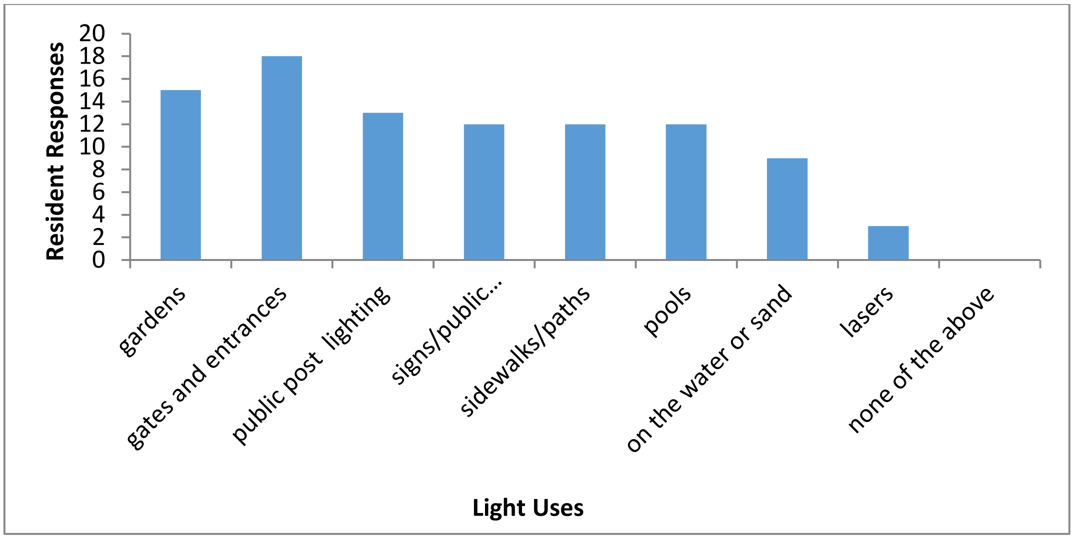


Figure 48: Different types of light uses noticed by residents of Isla Verde

We also analyzed the questions focused on feelings about modifying lighting habits to determine whether or not community members were willing to change. Out of all responses, 23 (85%) said that they did not feel as though changing their outdoor lighting habits would negatively affect their business or lifestyle. Out of these responses, 100% were residents. From this question we concluded that overall, the residents of Isla Verde would probably be willing to change their lighting habits since they did not feel as though it would impact their lives negatively.

Lastly, we wanted to determine if there was a difference in opinion between males and females about how bothered they felt by the current light levels and whether or not the lighting practices along the coast should be improved. In response to question 5 which asked how affected/bothered by light levels the respondent felt, 77% of females and 56% of males did not feel bothered by the current light levels. In response to question 21 which asked how much improvement the respondent thought the lighting on the beach needed, 58% of females and 81% of males felt that the lighting should be improved. Although the majority of people did not feel bothered by the light levels, they still felt that it should be improved which also shows the willingness to change the lighting habits in the community.

4.0 Recommendations

Based off of our results we made a series of recommendations for the DRNA and the JCA. The implementation of our suggestions will be carried out after our departure. The technical recommendations include improvements for future applications of the protocol. The community outreach programs are recommendations to encourage voluntary cooperation to improve community lighting practices.

4.1 Protocol Recommendation

After applying the protocol in the coastal community of Isla Verde, our team was able to recommend improvements to certain aspects of the protocol. These protocol recommendations are designed to make the protocol more effective and allow greater critical analysis.

Selection of Data Points

The method we used to select data collection points for sky glow and light trespass measurements was effective for our purposes however, there are drawbacks. It is a very technical approach for a relatively simple problem. We needed to select points that were 100 meters apart. To do this we used GIS software to identify these points. Then we used a GPS device to find the sites that were previously identified and decide whether these sites were appropriate for evaluation. The aerial photo that was used to select our points had been taken at low tide. When we went to perform our daytime assessment, many of these sites were underwater. When the sites were selected farther inland, several were under tree cover. It took several iterations to select the coordinates for our data collection.

It would have been simpler to select the data collection points first, then record the coordinates. For this, a rope would have sufficed. This method could only be used on relatively level ground with little change in elevation since the rope would measure the hypotenuse between points rather than the horizontal distance. The difference is negligible if the elevation is constant. The GPS device we used was accurate to 5 meters. This meant that the distance between points could be anywhere from 90 to 110 meters apart. There would need to be an elevation change of over 40 feet for the rope to be this inaccurate. There should also be little vegetation or other obstacles for this method to be effective. Although Isla Verde is a large sandy beach with few such obstacles, other beaches may not be as suitable for the use of a rope for site selection.

Inventory

When our team completed the inventory along the coast, we did not record which light fixtures were contributing light trespass to each site. Our team stated which points the light fixture was located between, but this made it difficult to make accurate correlations between light fixture features and light trespass levels. Therefore, our team recommends that when completing the inventory along the coast, the halfway point between each site number should be recorded. Any light fixture 50 meters on each side of a site will be attributed to that site number. The light fixtures affecting the light trespass measurements can be analyzed in a more effective way by understanding which light fixtures contribute light to each site. This will allow for a more effective correlation analysis.

Sky Glow

When taking sky glow measurements our team encountered problems with light fixtures that were in close proximity to the center of each site. If the light fixture was high enough, the light emitted would reach the sky glow meter and cause the meter to measure unwanted light. This caused readings to be inaccurate and much lower than expected. Our team recommends attaching the sky quality meter to a pole that can be raised higher when taking sky glow measurements. The higher the meter is, the less likely it is to be affected by any light fixture. This will reduce the risk of any unwanted light making contact with the sky quality meter producing inaccurate readings.

Survey

When administering the survey along the beach, our team found it difficult to engage citizens to fill out a 21 question survey. The survey was long and had multiple questions that provided no significant information. Therefore, our team recommends shortening the survey and having it focus more on questions about safety and how it can be improved, light pollution and lighting habits around their residence or business. Our team recommends removing questions 11 and 18-21. These questions provide no significant conclusions and do not help us assess the level of knowledge on light pollution, the level of safety community members feel or lighting habits around their residence or business.

4.2 Mitigation Plan

The data obtained from the protocol clearly indicated that Isla Verde has a light pollution problem, stemming directly from poor lighting habits. To help address these habits, our team decided that community outreach programs that educate community members should be implemented. The programs are designed to be executed in any region in order to promote discussion about lighting practices and get the community involved in making better lighting choices.

Notifications to residents

After concluding that the coast of Isla Verde has high light levels and a lack of concern for changing lighting practices, our team created a system to get community member attention. Since the enforcement process of the local pollution regulations is planned to start next year, we reasoned that handing out notices in coastal communities could be used to promote voluntary cooperation. The Light Fixture Recommendation Form seen in Appendix C does not include any legal repercussions if the light fixture recommendation is not completed, however the hope is that it will promote change. Many light fixtures are located inside of private properties and cannot be accessed without contacting the owner. The notice will allow the resident or business to become aware of a problematic light fixture, while promoting better lighting practices.

Informational Brochure

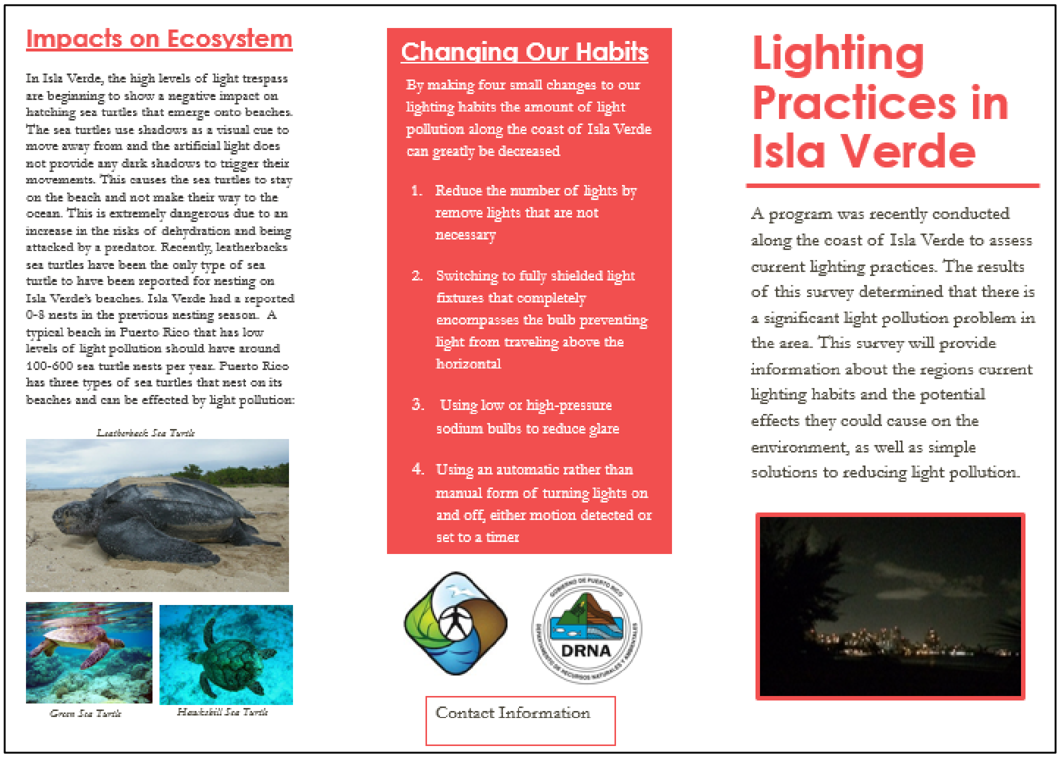
The purpose of the brochure is to provide personalized data about a region's lighting practices and to make the reader think about, and hopefully change their lighting habits. The brochure was created for Isla Verde using the data after conducting the light measurement program. The brochure can serve as a model for similar material to be distributed in another coastal location that has been surveyed for lighting practices using our protocol. Like our other forms of community outreach the brochure was created to act as a persuasive form of education to help promote voluntary cooperation with local lighting regulations.

For any coastal location, we recommend that the content for these three sections stay the same; "Lighting Practices in [Region]" (title page), "Light Pollution in [Region]", and "Changing Our Habits". The remaining sections "Lighting Practices in [Region]", "Resident Survey" and "Impacts on Ecosystem" will be created using specific information from each individual region and therefore will change from region to region. For convenience, we will describe the contents of the brochure in the order the columns appear in the figures below rather than the way the information would appear in person.

The first section seen in column one of Figure 49a is “Impacts on Ecosystem”. This section should describe the particular impacts caused in the specific region to the ecosystem due to their lighting practices. The potential ecological effects are included in the brochure to make the reader truly think about the potential implications of their actions. These impacts can include examples of disruption in orientation, migration patterns, species interactions and reproductive habits. For Isla Verde, this section included the orientation disruption of nesting sea turtles. In Isla Verde there is a very sympathetic feeling towards sea turtles. Our hope is that by understanding their lighting habits could harm sea turtles will inspire community members to change their current lighting practices to those suggested in the brochure.

In column two of Figure 49a is “Changing Our Habits”, a short section that describes four ways to decrease light pollution; removing excess lighting, using fully shielded light fixtures, switching to eco-friendly bulbs such as low and high-pressure sodium bulbs, and installing a form of automatic shut off on all lighting fixtures. After this section, all brochures will provide contact information for the DRNA and JCA if the reader has any comments or questions.

The title page “Lighting Practices in Isla Verde” explains that a program to measure light levels was completed in a certain area and identifies whether or not the region was determined to have a light pollution problem. This title page should be applied to all regions simply by changing the name of the region.



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

Contact Information

Lighting Practices in Isla Verde

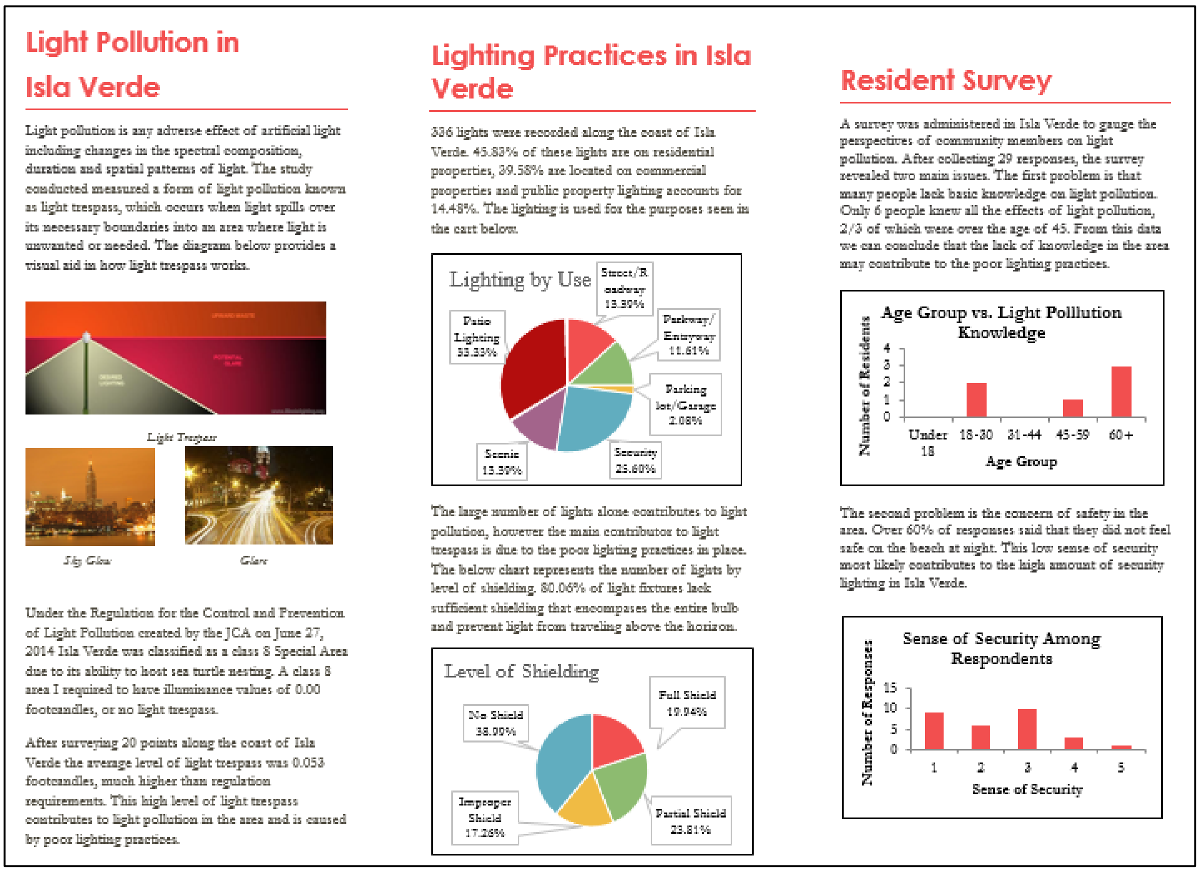
A program was recently conducted along the coast of Isla Verde to assess current lighting practices. The results of this survey determined that there is a significant light pollution problem in the area. This survey will provide information about the regions current lighting habits and the potential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

Figure 49a: Isla Verde Light Pollution Brochure (page one)

On page two of the brochure, seen in Figure 49b, there are three sections. Column one is "Light Pollution in Isla Verde". This section describes what light pollution is and the regulations in the Light Pollution Control and Prevention Program created by the JCA regarding appropriate illumination values for particular areas depending on the classification. For example, Isla Verde was a Class 8 beach. This section can be catered to any region by changing the title and classification to match the particular region. The classification of the region and corresponding regulated illumination levels can be seen at the bottom of the first column in Figure 49b. The average light trespass level found for each region while conducting the protocol should also be indicated here. The level of light trespass will either be within the range of the regulated illumination values and therefore considered to not have a light pollution problem, or the levels will be higher than the illumination value and therefore the region has a light pollution problem. Including this number is important because it uses quantitative data that clearly indicates whether or not a region is within the specified levels of light trespass as required by the DRNA and JCA.

The next section "Lighting Practices in [Region]", uses inventory data to describe the region's current lighting habits. This section should include data from the most pertinent findings either from classification type, level of shielding, bulb type or automatic shut-off and use simple visual aids to help reiterate the findings. For example, in Isla Verde the data included in the brochure is the classification of lights as well as the level of shielding used. The purpose for lighting is included in order to make the reader think about how they contribute to the total light levels in their community. The level of shielding data is included because our results showed that Isla Verde had a correlation between shielding and light levels, therefore their lack of shielded lights greatly increased the amount of light trespass in the region.

Lastly in column three of page two is the "Resident Survey" section. This section should include the most important conclusions drawn after analyzing the survey results collected during the protocol. For Isla Verde this included our two conclusions about the lack of knowledge in the area about light pollution, as well as the low sense of security levels that most likely contribute to high uses of security lighting.



Light Pollution in Isla Verde

Light pollution is any adverse effect of artificial light including changes in the spectral composition, duration and spatial patterns of light. The study conducted measured a form of light pollution known as light trespass, which occurs when light spills over its necessary boundaries into an area where light is unwanted or needed. The diagram below provides a visual aid in how light trespass works.

Light Trespass

Sky Glow

Glare

Under the Regulation for the Control and Prevention of Light Pollution created by the JCA on June 27, 2014 Isla Verde was classified as a class 8 Special Area due to its ability to host sea turtle nesting. A class 8 area I required to have illuminance values of 0.00 footcandles, or no light trespass.

After surveying 20 points along the coast of Isla Verde the average level of light trespass was 0.053 footcandles, much higher than regulation requirements. This high level of light trespass contributes to light pollution in the area and is caused by poor lighting practices.

Lighting Practices in Isla Verde

336 lights were recorded along the coast of Isla Verde. 45.83% of these lights are on residential properties, 39.58% are located on commercial properties and public property lighting accounts for 14.48%. The lighting is used for the purposes seen in the cart below.

Lighting by Use
Street/Roadway 13.39%
Parkway/Entryway 11.61%
Parking lot/Garage 2.08%
Security 25.60%
Scenic 13.39%
Patio Lighting 35.33%

The large number of lights alone contributes to light pollution, however the main contributor to light trespass is due to the poor lighting practices in place. The below chart represents the number of lights by level of shielding. 80.06% of light fixtures lack sufficient shielding that encompases the entire bulb and prevent light from traveling above the horizon.

Level of Shielding
Full Shield 19.94%
Partial Shield 23.81%
Improper Shield 17.26%
No Shield 38.99%

Resident Survey

A survey was administered in Isla Verde to gauge the perspectives of community members on light pollution. After collecting 29 responses, the survey revealed two main issues. The first problem is that many people lack basic knowledge on light pollution. Only 6 people knew all the effects of light pollution, 2/3 of which were over the age of 45. From this data we can conclude that the lack of knowledge in the area may contribute to the poor lighting practices.

Age Group vs. Light Polllution Knowledge
Number of Residents
0 1 2 3 4
Under 18, 18-30, 31-44, 45-59, 60+
Age Group

The second problem is the concern of safety in the area. Over 60% of responses said that they did not feel safe on the beach at night. This low sense of security most likely contributes to the high amount of security lighting in Isla Verde.

Sense of Security Among Respondents
Number of Responses
0 5 10 15
1 2 3 4 5
Sense of Security

Figure 49b: Isla Verde Light Pollution Brochure (page two)

Educational Session and Star Gazing Tour

As a suggestion for a community outreach program, we recommend a stargazing tour. The trip would include two components, an educational information session and a night sky tour at a location with darker skies. This program could be used for any coastal region where the protocol had been carried out, and is intended for all community members in that region. The tour would be used to attract community members to participate in the program and would help participants appreciate the benefits of a dark night sky. The sky of the darker location would be compared to the location that the protocol was applied to, so residents can realize the difference proper lighting practices can make. The organizers of such a tour would have to take into account the distance the chosen location is to the target residents. Therefore, it is not feasible for us to predict appropriate sites that would be suitable for all locations that this protocol was applied at.

The tour would begin with an information session that educates the community on light pollution, its effects, as well as measures individuals can take to reduce it in their area.   The session would start with an explanation of the purpose of the tour and then expand upon the other facets of the protocol. After the introduction, light pollution would be defined and the attributed effects it can have on the ecosystem would be described. This should focus on effects that are specific to the particular location the program had been applied to. If the local coastlines cannot support sea turtle nesting, it would be unproductive to go into depth on the hardships sea turtles experience due to light pollution. The community members are more likely to respond favorably to effects that are experienced in their region. Once the members of the community have a working understanding of light pollution and its effects, the results of the program will be presented. This will add personal context to their recently acquired knowledge. The last section of the information session would be dedicated to teaching the community strategies and practices they can implement to reduce light pollution. This should include the benefits of proper shielding and bulb use as well as emphasis on simple steps such as turning off lights that are not being used.

The content of the information session should be appealing for all age groups. Specific methods to reduce light pollution will most likely be uninteresting to children that have no control over such measures. We recommend leaving information that is targeted at a specific demographic for the end to keep the attention of the group as a whole. The results that have been gathered from the light measurements should be presented in a simple format that is easy for all to understand. This also applies to the information regarding light pollution.

The stargazing portion of the tour will take place in a location with night skies superior to those where the protocol was applied. This will hopefully impress upon the community the significance of better lighting practices. Excessive lighting will cease to be an inconsequential form of pollution, and become something the community strives to reduce.

Feedback Form

A feedback form was created to allow community members to describe problematic light fixtures in their area and request change. Our team wanted to be able to educate community members on features of light fixtures. We asked questions about shielding, type of bulb, and automatic shutoff, and then provided examples of how to classify and recognize each. Our team also wanted to know if the light fixture was allowing light trespass onto the beach. This allows the DRNA and JCA to know whether or not this light fixture is contributing to orientation disruption of sea turtles. This form allows for two-way communication and gives the community members a voice in the process of changing lighting habits. The form will allow the DRNA and JCA to understand how community members feel about any bothersome light fixture and what their personal recommendations for improvement would be. As a result of community members completing the feedback form, the DRNA and JCA will be able to take appropriate action. As the community members fill out this form, it will educate them on how to recognize and classify ideal lighting practices. The DRNA and JCA can use the feedback forms to create a record of light fixtures that community members have requested change for. This will speed up the process of fixing each light fixture to accommodate the community. An electronic Light Fixture Feedback Forms was created and can be found in Appendix D. The DRNA and JCA could hand out flyers to administration offices and business owners to advertise the feedback form and promote two way communication.

4.3 Conclusions

Our team believes that if the DRNA and the JCA follow these technical recommendations after our departure, they will be able to successfully repeat our protocol in other locations allowing them to evaluate all lighting practices along coastal regions of Puerto Rico. The implementation of our community outreach programs can educate communities on light pollution and better lighting practices.

5.0 Bibliography

American University Washington College of Law. (2014). International Environmental Law and Policy - Sea Turtles. Retrieved November 6, 2014 from http://www.wcl.american.edu/environment/iel/sup5.cfm.

Anonymous (2010). LED Downlight Boasts Twice the Efficiency of a CFL. (2010, May 24). Retrieved November 3, 2014, from http://search.proquest.com.ezproxy.wpi.edu/docview/324652847/abstract?accountid=29120

Asamblea Legislativa de Puerto Rico. (2008). Ley Num. 218. Retrieved from http://www.oslpr.org/download/en/2008/A-0218-2008.pdf

Berg, R. (2009). Getting Serious about Light Pollution. *Journal of Environmental Health, 71*(9), 46-48.

Cinzano, P. (2000). The Night Sky in the World. Retrieved September 10, 2014 from http://www.inquinamentoluminoso.it/worldatlas/pages/fig1.htm

Cinzano, P., Falchi, F., & Elvidge, C. D. (2001). The first world atlas of the artificial night sky brightness. *Monthly Notices of the Royal Astronomical Society. 328(3).* 689-707.

Danby, D., Menter, A., & Faludi, J. (2011, January 1). Measuring Light Level. Retrieved October 3, 2014 from http://sustainabilityworkshop.autodesk.com/buildings/measuring-light-levels

Department of Natural and Environmental Resources (DNER). (2004). Proyecto Tinglado Isla de Culebra. Retrieved from http://www.coralations.org/turtles

Depledge, M. H., Godard-Codding, C. A., & Bowen, R. E. (2010). Light Pollution in the Sea. *Marine Pollution Bulletin, 60*(9), 1383-1385.

Devries, J.F., Giambrone, M.D., Haring, A.P., & Penrose, M.H. (2013). *Puerto Rico Light Pollution* (Undergraduate Interactive Qualifying Project No. E-project-121813-083238). Retrieved from Worcester Polytechnic Institute Electronic Projects Collection: http://www.wpi.edu/Pubs/E-project/Available/E-project-121813-083238/

ESI. (2012). *Coral Reefs.* Retrieved December 17, 2014 from http://www.endangeredspeciesinternational.org/coralreefs7.html

Falchi, F., Cinzano, P., Elvidge, C. D., Keith, D. M., & Haim, A. (2011). Limiting the Impact of Light Pollution on Human Health, Environment and Stellar Visibility. *Journal of Environmental Management, 92*(10), 2714-2722.

Flanders, T. (2008, December 5). Rate Your Skyglow. Retrieved November 22, 2014 from http://www.skyandtelescope.com/astronomy-resources/rate-your-skyglow

Gaston, K. J., Davies, T. W., Bennie, J., & Hopkins, J. (2012). Review: Reducing the Ecological Consequences of Nighttime Light Pollution: Options and Developments. *Journal of Applied Ecology, 49*(6), 1256-1266.

Globe at Night - 2012 General Analysis. (2012). Retrieved September 5, 2014 from http://www.globeatnight.org/gen-an-2012.php

The Gran Telescopio Canarias (2013). Introducing the Gran Telescopio Canarias. Retrieved September 15, 2014 from http://www.gtc.iac.es/gtc/gtc.php

Hayasaki, E. (2009, October 1). NYC Students Seek Kinship with Puerto Rico's Endangered Leatherbacks. Retrieved November 6, 2014 from http://vault.sierraclub.org/sierra/200909/puertorico.aspx

Instituto de Astrofísica de Canarias. (2014). Sky Quality. Retrieved September 16, 2014 from http://www.iac.es/servicios.php?op1=28&op2=69&lang=en

Klinkenborg, V. (2008). Our Vanishing Night *National Geographic, 214*(5), 102-123.

Koster, Pepijn. (2011, Feb. 11). *Overfishing basics.* Retrieved December 17, 2014 from http://overfishing.org/pages/what_is_overfishing.php

Kuechly, H. U., Kyba, C. C., Ruhtz, T., Lindemann, C., Wolter, C., Fischer, J., & Hölker, F. (2012). Aerial Survey and Spatial Analysis of Sources of Light Pollution in Berlin, Germany. *Remote Sensing of Environment, 126*, 39-50.

Longcore, T., & Rich, C. (2004). Ecological Light Pollution. *Frontiers in Ecology and the Environment, 2*(4), 191-198.

Luginbuhl, C. B. (2003). *Why Astronomy Needs LPS Lighting*. Retrieved September 10, 2014 from http://www.nofs.navy.mil/about_NOFS/staff/cbl/LPSnet/whyastronomyneedsLPS.pdf

Mignucci-Giannoni, A. A. (1999). Assessment and Rehabilitation of Wildlife Affected by an Oil Spill in Puerto Rico. *Environmental Pollution,* 104(2), 323-333.

Mizon, B., (2012). *Light pollution: Responses and Remedies*. New York: Springer.

Mortimer, J.A & Donnelly, M. (IUCN SSC Marine Turtle Specialist Group) 2008. *Eretmochelys imbricata*. The IUCN Red List of Threatened Species. Version 2014.2.Retrieved November 6, 2014 from http://www.iucnredlist.org/details/8005/0

National Oceanic and Atmospheric Administration (NOAA). (2014, October 30) Hawksbill Turtle (Eretmochelys Imbricata), Green Turtle (Chelonia Mydas). Retrieved November 6, 2014 from http://www.nmfs.noaa.gov/pr/species/turtles/.htm

National Oceanic and Atmospheric Administration (NOAA). (2013, June 23) Leatherback Turtle (Dermochelys Coriacea). Retrieved November 6, 2014 from http://www.nmfs.noaa.gov/pr/species/turtles/leatherback.htm

National Wildlife Federation (NWF). (2012). Green Sea Turtle. Retrieved November 6, 2014 from http://www.nwf.org/wildlife/wildlife-library/amphibians-reptiles-and-fish/sea-turtles/green-sea-turtle.asp

Pathberiya, S. (2013, September 1). Lights Out! Too Many Bulbs Actually Put Us in the Dark. Retrieved November 3, 2014 from http://www.readperiodicals.com/201309/3095867421.html

Poot, H. (2008). Green Light for Nocturnally Migrating Birds. *Ecology and Society, 13*(2), 1-14.

Portree, D. S. (2005). Flagstaff's Battle for Dark Skies - Flagstaff Dark Skies Coalition. Retrieved September 10, 2014 from http://www.flagstaffdarkskies.org/international-dark-sky-city/flagstaffs-battle-for-dark-skies/

Ruiz, C. (1999, 1999 Fall). Environmental Tragedy in Vieques. *Earth Island Journal*, 14, 19.

San Diego Astronomy Association (2011. Light Pollution News & Info. Retrieved November 10, 2014 from http://www.sdaa.org/lightpollution.htm

Schepers, N. (2012, September 14). *Permanent Signs on Private Property - Amendments to Permit Digital Billboard Signage*. Retrieved December 17, 2014 from http://www.scribd.com/doc/106176825/Digital-Billboard-Executive-Summary-and-Report-Panneaux-d-information-numeriques-Resume#scribd

Sea Turtle Conservancy (2014). Information About Sea Turtles: Conservation Strategies. Retrieved November 6, 2014 from http://www.conserveturtles.org/seaturtleinformation.php?page=conservation

Seminoff, J.A. (Southwest Fisheries Science Center, U.S.) 2004. *Chelonia mydas*. The IUCN Red List of Threatened Species. Version 2014.2.

Services, P. C. D. (2012). *2012 City of Tucson/Pima County Outdoor Liighting Code* Retrieved September 23, 2014 from http://webcms.pima.gov/UserFiles/Servers/Server_6/File/Government/Development%20Services/Building/OLC.pdf

Sky Quality Metere- FAQ. (n.d.) Unihedron. Retrieved November 24, 2014 from http://www.unihedron.com/projects/darksky/faq.php

Smith, A. O. (2004). Billboards = Light Pollution: Sooner Edition. *Pittsburgh Post - Gazette*, p. C.10.

Sobel, J., Dahlgren, C. (2004). *Marine Reserves: A Guide to Science, Design, and Use*. Washington: Shearwater Books [Imprint].

Thompson, A. & Taylor, B. N. (2008). *Guide for the Use of the International System of Units (SI).* National Institutes of Standards and Technology Special Publication 811.

UNEP, (n.d.). *Tourism's Impact on Reefs.* Retrieved December 17, 2014 from http://www.unep.org/resourceefficiency/Business/SectoralActivities/Tourism/Activities/WorkThematicAreas/EcosystemManagement/CoralReefs/TourismsImpactonReefs/tabid/78799/Default.aspx

Waldron, T., Navis, C., & Fisher, G. (2013). Explaining Differences in Firms' Responses to Activism. *Academy of Management Review, Vol. 38*, 397-417.

Wallace, B.P., Tiwari, M. & Girondot, M. 2013. *Dermochelys coriacea*. The IUCN Red List of Threatened Species. Version 2014.2 Retrieved November 6, 2014 from http://www.iucnredlist.org/details/6494/0

What is CITES? (n.d.). Retrieved November 7, 2014, from http://www.cites.org/eng/disc/what.php

Wold, C. (2002, January 1). *The Status of Sea Turtles under International Environmental Law and International Environmental Agreements.* Retrieved November 6, 2014, from http://cmbc.ucsd.edu/content/1/docs/wold.pdf

Appendix A – Konica Minolta T-10A Manual

For simple but accurate illuminance measurements. Makes creating illuminance measurement systems such as multi-point measurement systems easy!

Reliable, worry-free illuminance meters that conform to JIS AA Class and DIN Class B

Illuminance Meters T-10A and T-10MA conform to Class AA of JIS C 1609-1: 2006 "Illuminance meters Part 1: General measuring instruments" and DIN 5032 Part 7 Class-B " Photometry; classification of illuminance meters and luminance meters" requirements to provide high-accuracy, high-reliability, worry-free measurements.

Illuminance meters conforming to these standards are required for measurements of general illumination light sources, white LED lamps for illumination, etc. in a variety of industrial fields.

Easy, inexpensive multi-point measurement (2 to 30 points).

Illuminance distribution of a projector etc. can be easily measured with a single instrument and several receptors.

Compatible with PWM-controlled lighting. Enables measurements of next-generation light sources.

Conventional illuminance meters often cannot accurately measure PWM-controlled light sources, but the T-10A series of illuminance meters can be used to accurately measure even such light sources.

Removable receptor

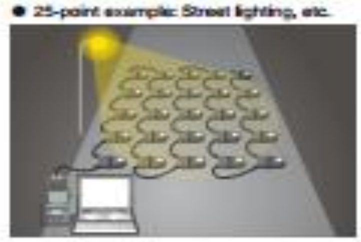
The receptor and main body can be detached from each other and then connected using a LAN cable, making it easy to install as part of an inspection system.

Multi-point illuminance measuring system

- 5-point example: Architectural lighting, etc.

- 9-point example: Projectors, etc.

- 25-point example: Street lighting, etc.



Main applications

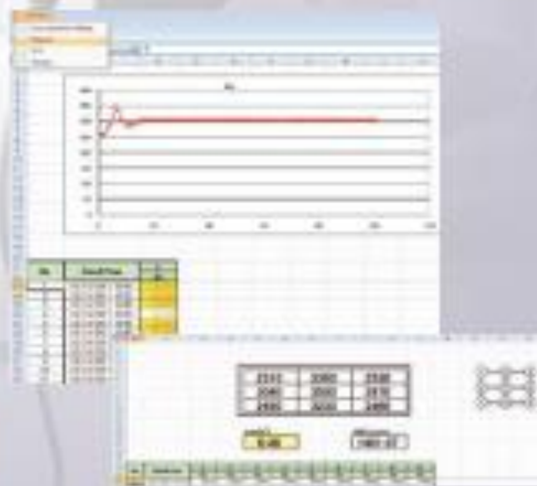
- Government testing organizations
- Research/inspection at illumination equipment makers
- Maintenance at factories, offices, hospitals, etc.
- Illuminance control of security lighting, street lighting, etc.
- Checking light sources for construction

- Lighting control at LED-lit factory farms
- As sensor for equipment measuring total flux or light-distribution characteristics, etc.

Data Management Software T-S10w (Optional accessory)

Convenient, easy-to-use Excel® add-in software

Reads measurement data from T-10 series Illuminance Meters directly into Excel®. Further processing of data can then be performed easily using the various functions of Excel®.



Data transfer using buttons on main body

When using T-S10w, measurements can be taken and data sent to Excel® by using not only the computer keys but also by using the buttons on the T-10A main body.

Multi-point measurement and CCF calibration possible

Measurements of up to 30 points can be controlled. A CCF (Color Correction Factor) function is also provided to enable calibration to user standards.

Main specifications of Data Management Software T-S10w

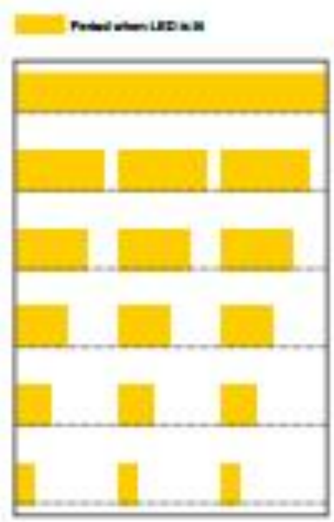
Type	Add-in for Excel® (Excel® is required to use this add-in.)
Operating environment	One of the following environments with Excel® installed: * Languages in parenthesis ( ) are the OS language. Windows® XP + Excel® 2003 (English, Japanese, or Simplified Chinese) Windows® 7 + Excel® 2010 (English, Japanese, or Simplified Chinese) * For details on system requirements for above versions of Windows® and/or Excel®, refer to their respective specifications.
Compatible instruments	T-10A, T-10MA, T-10WsA, T-10WLA, T-10, T-10M, T-10Ws, T-10W.

About PWM-controlled lighting

PWM is the abbreviation of Pulse Width Modulation, and refers to the method of controlling signal intensity by controlling the ratio between the ON period and OFF period of a pulse signal.

A pulse signal is a signal which repeatedly alternates between ON and OFF, and the percentage of ON period during a single cycle is referred to as the "duty cycle".

PWM-controlled lighting is a method for controlling the brightness of a lamp by controlling the duty cycle (lit time) of light from a pulse-emission source. As the lit time becomes longer, the light becomes brighter, and conversely, as the lit time becomes shorter the light becomes darker.



<Standard receptor>

T-10A

<Mini receptor>

T-10MA/T-10WsA/T-10WLA

T-10A

Conforms to JIS AA Class and DIN class B

Can be used for general measurements of illuminance.

T-10MA (Cord length: 1 m)

Conforms to JIS AA Class and DIN class B

Enables illuminance measurements of small areas.

Can be used for illuminance measurements in narrow spaces where the standard receptor won't fit. It can also be easily installed on various kinds of equipment or jigs for measuring light levels such as illumination.

T-10WsA (Cord length: 5 m)
T-10WLA (Cord length: 10 m)

Conforms to JIS requirements for special illuminance meters

Waterproof | Custom order

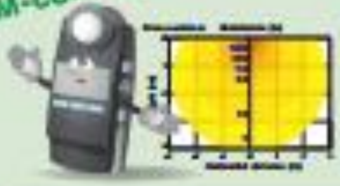
The mini receptor and cord are both waterproof, so they can be used for measurements in water.
They can be used for illuminance control for fishery-related applications (such as fish farming, etc.) or for measuring outdoor illuminance on rainy days.

Konica Minolta Sensing's Illuminance Measurement Trio

Konica Minolta Sensing's line of instruments for measuring illuminance includes not only the Illuminance Meter T-10A which can measure PWM-controlled light sources, but also the Chroma Meter CL-200A which can measure color temperature and the Illuminance Spectrophotometer CL-500A which can measure color-rendering properties.

Illuminance meter that can handle PWM-controlled lighting

Illuminance Meter T-10A



Conforms to DIN Class B and JIS AA Class.

Capable of accurately measuring next-generation lamps including PWM-controlled lighting.

Multiple receptors can be used for easy, low-priced, multi-point measurement, and a miniature receptor model is also available for easily measuring illuminance in narrow spaces.

Measures color temperature

Chroma Meter CL-200A

A de facto industry standard for color-temperature measurement.

Can also perform illuminance measurements (JIS AA Class).

Compact and lightweight with removable receptor connectable with extension cables.

Includes simple, convenient PC software as standard accessory.

Measures color-rendering properties

Illuminance Spectrophotometer CL-500A

The first illuminance spectrophotometer to conform to both JIS AA Class and DIN Class B requirements.

Compact, handheld type can easily be installed in inspection equipment and is ideal for evaluating color-rendering properties.

Includes simple, convenient PC software as a standard accessory.

Illuminance-modified Spectroradiometer CS-2000A

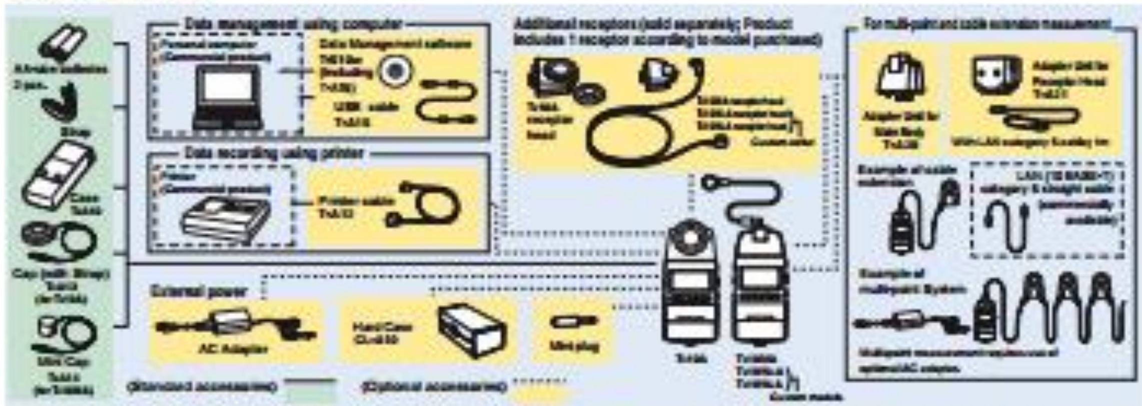
Measurements of spectral irradiance are made possible by using the illuminance adapter. This makes it ideal for illuminance evaluation of projectors and LED or EL lighting.

This single instrument can be used for measuring both spectral radiance and spectral irradiance.

Our top-of-the-line CS-2000 is used for measuring various types of high-definition displays, and received the 13th Advanced Display of the Year 2008 Grand Prize in the Display Testing Equipment Category.

Spectral bandwidth: 5 nm or less (half bandwidth)
Measurable illuminance range:
1° measuring angle: 0.01 to 75,000 lx
0.1° measuring angle: 1.00 to 7,500,000 lx

System diagram

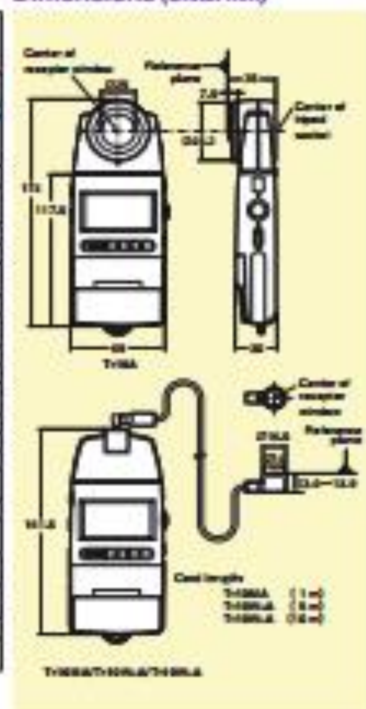


Main Specifications of T-10A

Model	Illuminance Meter T-10A (Standard receptor head)	Illuminance Meter T-10MA (Mini receptor head)	Illuminance Meter T-10WsA (Waterproof mini receptor head)	Illuminance Meter T-10WLA (Waterproof mini receptor head)
Type	Multi-function digital illuminance meter with detachable receptor head (Multi-point measurements of 2 to 30 points is possible)			
Illuminance meter class	Conforms to requirements for Class AA of JIS C 1609-1:2006 "Illuminance meters Part 1: General measuring instruments" Conforms to DIN 5032 Part 7 Class B		Conforms to requirements for special illuminance meters of JIS C 1609-1:2006 *1	
Receptor	Silicon photocell			
Relative spectral response	Within 6% (f1') of the CIE spectral luminous efficiency V(λ)			
Cosine response (f2)	Within 3%		Within 10%	
Measuring range	Auto range (5 manual ranges at the time of analog output)			
Measuring function	Illuminance (lx), illuminance difference (lx), illuminance ratio (%), integrated illuminance (lx·h), integration time (h), average illuminance (lx)			
Measuring range: Illuminance	0.01 to 299,900 lx; 0.001 to 29,990 fcd		1.00 to 299,900 lx; 0.1 to 29,990 fcd *2	
Measuring range: Integrated illuminance	0.01 to 999,900 × 10^3 lx·h 0.001 to 99,990 × 10^3 fcd·h / 0.001 to 9999 h			
User calibration function	CCF (Color Correction Factor) setting function; Measurement value × 0.500 to 2.000			
Linearity	±2% ±1 digit of displayed value			
Temperature/ humidity drift	Within ±3%			
Digital output	USB			
Analog output	1 mV/digit, 3 V at maximum reading; Output impedance: 10 kΩ; 90% response time: 28 ms			
Display	3 or 4 significant-digit LCD with backlight illumination (Automatic illumination)			
Power source	2 AA-size batteries / AC adapter AC-A308 (optional) for 1 to 10 receptors) or AC adapter AC-A311 (optional) for 1 to 30 receptors)			
Battery life	72 hours or longer (when alkaline batteries are used) in continuous measurement			
Operating temperature /humidity range	-10 to 40°C, relative humidity 85% or less (at 35°C) with no condensation		5 to 40°C, relative humidity of 85% or less (at 35°C) with no condensation	
Storage temperature / humidity range	-20 to 55°C, relative humidity 85% or less (at 35°C) with no condensation		0 to 55°C, relative humidity of 85% or less (at 35°C) with no condensation	
Dimensions	69 × 174 × 35 mm	Main body: 69 × 161.5 × 30 mm Receptor: Ø16.5 × 13.6 mm		
Cord length	–	1 m	5 m	10 m
Weight (without batteries)	200 g (7.0 oz.)	205 g	280 g (Receptor head only: 130 g)	340 g (Receptor head only: 200 g)

*1 Conforms to requirements for Class AA of JIS C 1609-1:2006 for all items except [illegible] response (f2).
*2 Although measurements below 1.00 lx are possible, they may not be stable due to the effects of electrical noise.
Notes regarding mini receptors and waterproof mini receptors
*Do not touch the cable during measurements. Doing so may result in unstable measurement values.
*Secure the cable during measurements. Failure to do so may result in unstable measurement values.

Dimensions (Units: mm)



SAFETY PRECAUTIONS

For correct use and for your safety, be sure to read the instruction manual before using the instrument.

- Always connect the instrument to the specified power supply voltage. Improper connection may cause a fire or electric shock.
- Be sure to use the specified batteries. Using improper batteries may cause a fire or electric shock.

KONICA MINOLTA SENSING, INC.
Konica Minolta Sensing Americas, Inc.
Konica Minolta Sensing Europe B.V.
Konica Minolta (CHINA) Investment Ltd.
Konica Minolta Sensing Singapore Pte Ltd.
KONICA MINOLTA SENSING, INC.

http://konicaminolta.com/instruments/about/network

9242-4871-12 BCBAPK

Appendix B- Unihedron Sky Quality Meter-L Manual

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.

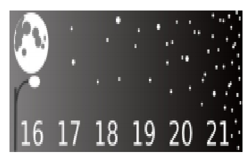
The SQM-L's reading is indicative of the sky brightness within its field of view. There must be no direct illumination or shading of the sensor by a terrestrial light source if the reading is to be meaningful.

* * *

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 C – Light Fixture Notice Form

Department of Natural and Environmental Resources

Light Fixture Recommendation

Property Information

Property Type	Choose an item.	**Date**	[Date]
Address			
Type of Notice	Choose an item.	**Change Needed For**	Choose an item.

Description of Light Fixture(s)

[Description of Problematic Light Fixture]

Plan for Improvement

[Plan for Improvement]

Benefits of Changing Light Fixture(s)

[Benefits of Changing Light Fixture(s)]

Questions? Contact the Department of Natural and Environmental Resources

Appendix D – Feedback Form

Light Fixture Feedback Form

Name (Optional):
Phone Number (Optional):
Email Address (Optional):

Is this light fixture in the vicinity of your : Choose an item.

Location of the light fixture: (Be descriptive as possible with street address, objects close to the light fixture, property located on, etc.)

Describe complaint against light fixture:

How bright would you consider the light fixture to be? Choose an item.

Is this light fixture close to the beach? Choose an item.

If so, does it allow light to travel onto the beach?Choose an item.

Please provide a daytime and nighttime photo of the light fixture:

Can you describe the property the light fixture is located on: Choose an item.

Can you describe the purpose the light fixture is used for: Choose an item.

Can you describe the level of shielding (examples are below):Choose an item.

- Fully Shielded: Shield fully encompasses the bulb preventing light from traveling above the horizontal

- Partially Shielded: Shield does not fully encompass the entire bulb and does not completely prevent light from traveling above the horizontal

- Improper Shielding: Shield fully encompasses the bulb but does not prevent light from traveling above the horizontal due to the angle

- No Shielding: No shield present

Can you describe the type of bulb (examples are below): Choose an item.

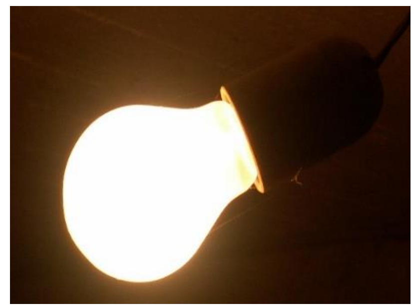

Low-Pressure


High-Pressure


Fluorescen


LED


Halogen


Incandescent

Is there any automatic shut off present (examples below)? Choose an item.

- Motion detector: Light is activated by the detection of motion, or turns out due to the absence of motion
- Timer: Light is activated and deactivated in accordance with a set schedule
- None: Lights are manually operated

Personal recommendation or comments on the light fixture:

Appendix E – Survey Report

Initial Report

Last Modified: 12/13/2014

1. Gender:

#	Answer		Response	%
1	Male		16	55%
2	Female		13	45%
	Total		29	100%

Statistic	Value
Min Value	1
Max Value	2
Mean	1.45
Variance	0.26
Standard Deviation	0.51
Total Responses	29

2. What age group do you belong to?

#	Answer		Response	%
1	Under 18		0	0%
2	18-30		2	7%
3	31-44		4	14%
4	45-59		12	41%
5	Over 60		11	38%
	Total		29	100%

Statistic	Value
Min Value	2
Max Value	5
Mean	4.10
Variance	0.81
Standard Deviation	0.90
Total Responses	29

3. How would you describe your role in the Isla Verde community? Select as many that apply.

#	Answer		Response	%
1	Business Owner		2	7%
2	Resident		23	80%
3	Employee		1	3%
4	Tourist/Visitor		2	7%
5	Other		1	3%

Statistic	Value
Min Value	1
Max Value	5
Total Responses	29

4. How would you describe the levels of outdoor artificial light in the community around your residence at night?

#	Question	1	2	3	4	5	Total Responses	Mean
1	Insufficient : Excessive	3	6	9	8	3	29	3.07

Statistic	Insufficient: Excessive
Min Value	1
Max Value	5
Mean	3.07
Variance	1.35
Standard Deviation	1.16
Total Responses	29

5. How much do you feel affected or bothered by light levels in your community?

#	Question	1	2	3	4	5	Total Responses	Mean
1	It doesn't bother me at all: It is irritating	13	6	5	5	0	29	2.07

Statistic	It doesn't bother me at all: Excessive
Min Value	1
Max Value	4
Mean	2.07
Variance	1.35
Standard Deviation	1.16
Total Responses	29

6. If you are bothered, are you able to reduce the light that enters your residence at night? Explain what you have done to reduce the light if anything.

Text Response
Curtains
Nothing
I don't know
None
More light for security
Removed metal halide bulbs and put in LEDs. Angled lights away from apartments and beach
Nothing
Curtains
Curtains, however bulbs don't work in most areas of Puerto Rico so there isn't much light to bother me
Nothing

Statistic	Value
Total Responses	10

7. What do you believe the ideal level of light to be outside of your residence at night?

#	Question	1	2	3	4	5	Total Responses	Mean
1	Totally dark (no visibility): The most light as possible (as if it were daytime)	1	4	17	6	1	29	3.07

Statistic	Totally dark (no visibility): The most light as possible (as if it were daytime)
Min Value	1
Max Value	5
Mean	3.07
Variance	0.64
Standard Deviation	0.80
Total Responses	29

8. Have you considered moving to another place because of the light level outside your residence?

#	Answer		Response	%
1	Yes		0	0%
2	No		29	100%
	Total		29	100%

Statistic	Value
Min Value	2
Max Value	2
Mean	2.00
Variance	0.00
Standard Deviation	0.00
Total Responses	29

9. How would you describe the lighting at night in the community around your residence?

#	Question	1	2	3	4	5	Total Responses	Mean
1	Totally dark (no visibility): Very bright (as if it were day)	0	4	19	4	1	28	3.07

Statistic	Totally dark (no visibility): Very bright (as if it were day)
Min Value	2
Max Value	5
Mean	3.07
Variance	0.44
Standard Deviation	0.66
Total Responses	28

10. Do you know what light pollution is?

#	Question	1	2	3	4	5	Total Responses	Mean
1	Not at all: Very familiar	6	1	2	9	11	29	3.62

Statistic	Not at all: Very familiar
Min Value	1
Max Value	5
Mean	3.62
Variance	2.39
Standard Deviation	1.54
Total Responses	29

11. What do you think you can do to help the light pollution problem in Puerto Rico? Explain

Text Response
Modify the light fixtures, change the direction so that it lights up the intended area
Educate
Increase the level of clarity
Change the light bulbs and the model of the streetlights and eliminate the billboards but not all
Less streetlights or billboards
It depends on areas
Light guards on the lights facing the ocean
Educate the residents
Nothing- not bothered
Educate about the problem and change or fix the light fixtures
Regulate the light levels
Install lights that use batteries or that use solar panels
I don’t know
Put fixtures that light downwards
Limit operating hours and voltage of luminaires
Eliminate billboards from avenues and in general
Designate areas by the type of activity and if it is near the sea, don’t let it affect the animals
I didn’t know that it exists
Surrounding areas with too much illumination and billboards should be controlled

Statistic	Value
Total Responses	19

12. Have you noticed any of the following in the area of Isla Verde? Select all that apply.

#	Answer		Response	%
1	Glare: any intense and blinding light that reduces visibility		10	48%
2	Sky glow: brightening of the night sky with an orange-yellow glow		12	57%
3	Light Trespass: light in an unwanted or needed area		14	67%
4	Light Clutter: an excessive grouping of lights		12	57%

Statistic	Value
Min Value	1
Max Value	4
Total Responses	21

13. Please explain your answer to the previous question. You can use examples, but please do not identify any business by name or location.

Text Response
In this area there are hotels that light excessive areas of the beach
Many advertisements
B.) you can't see the stars c.) hotels and the beaches d.)tourist areas
The billboards along the street
NA
There is a concept of wanting to mark properties with light
Light that exceeds the boundaries of the property, causing light in nesting areas of leatherbacks
Lights on the roofs of structures that would light a ball park
Billboard
Billboards LED that excessively illuminate, marginal Isla Verde,,,,
I don’t have a response
Outdoor screens, excessive signs, too much lights lighting areas without use, etc.

Statistic	Value
Total Responses	12

14. Do you think changing your outdoor lighting habits would negatively affect your business or style of life?

#	Answer		Response	%
1	Yes		4	15%
2	No		23	85%
	Total		27	100%

Statistic	Value
Min Value	1
Max Value	2
Mean	1.85
Variance	0.13
Standard Deviation	0.36
Total Responses	27

15. In relation to public lighting in your community, how do you feel walking alone on the beach in Isla Verde at night?

#	Question	1	2	3	4	5	Total Responses	Mean
1	I do not feel safe: I feel very safe	9	6	10	3	1	29	2.34

Statistic	I do not feel safe: I feel very safe
Min Value	1
Max Value	5
Mean	2.34
Variance	1.31
Standard Deviation	1.14
Total Responses	29

16. How does the lighting of businesses and residences surrounding the beach in Isla Verde at night compare to lighting at other beaches that you have visited in Puerto Rico or other countries?

#	Answer		Response	%
1	Worse		7	26%
2	The same		14	52%
3	Better		6	22%
	Total		27	100%

Statistic	Value
Min Value	1
Max Value	3
Mean	1.96
Variance	0.50
Standard Deviation	0.71
Total Responses	27

17. From the list, select all that you think are ecological effects of light pollution because of excessive or unnecessary outdoor lighting.

#	Answer		Response	%
1	Migration pattern of birds		12	44%
2	Disorientation of sea turtle migration to the sea		22	81%
3	Nighttime exposure of many organisms to predators and other dangers		13	48%
4	The loss of the use of the habitat		13	48%
5	None of the above, therefore light pollution does not cause harm		2	7%
6	Death of insects or other organisms because of luminaires that generate heat		9	33%
7	Change in the circadian cycles of the organisms (with nighttime activity when there shouldn't be)		12	44%

Statistic	Value
Min Value	1
Max Value	7
Total Responses	27

18. Do you know any example of these effects on organisms or animals that are inhabitants or visit the beach in Isla Verde?

#	Answer		Response	%
1	Yes		21	75%
2	No		7	25%
	Total		28	100%

Statistic	Value
Min Value	1
Max Value	2
Mean	1.25
Variance	0.19
Standard Deviation	0.44
Total Responses	28

19. Explain your previous answer.

Text Response
Impacts some ecological species: turtles, insects
Nesting turtles
turtle
The turtles
Sometimes the leatherbacks come to the beach to put their eggs
Turtle population has diminished
Turtles
Disorientation of sea turtles and the decrease of turtle nesting
The turtles
Affects the nesting of leatherbacks
Turtle hatchlings walk to the strong lights instead of the reflection of the moonlight
Decrease in turtles
The amount of leatherbacks nesting decrease
Disorientation of turtles
Turtles
Turtle disorientation and to insects, other effects also

Statistic	Value
Total Responses	16

20. In relation to the outdoor lighting in residential and commercial properties that surround Isla Verde beach, what are the outdoor light uses that you have seen?

#	Answer		Response	%
1	Lighting in gardens		17	61%
2	Lighting on gates and entrances		22	79%
3	Public post lighting		16	57%
4	Lighting for signs and outdoor public announcements		15	54%
5	Lighting for sidewalks, paths in businesses or residences		13	46%
6	Lighting for pools		13	46%
7	None of the above		0	0%
8	Lighting on the water or the sand		11	39%
9	Lighting using lasers or lights that move		4	14%

Statistic	Value
Min Value	1
Max Value	9
Total Responses	28

21. With respect to the use of outdoor lighting that reaches the san don the Isla Verde beach, what do you believe applies the most?

#	Answer		Response	%
1	It should light the entire coast so that the beach can be used at night at any hour.		4	14%
2	The control and management of outdoor lighting of some businesses or residential properties should be improved.		20	71%
3	As it is now is good, it is not necessary to change the outdoor lighting in this zone at all.		4	14%
	Total		28	100%

Statistic	Value
Min Value	1
Max Value	3
Mean	2.00
Variance	0.30
Standard Deviation	0.54
Total Responses	28

Appendix F- Data Sheets

Daytime Site Assessment Sheet

SITE NUMBER	DATE	TIME	LATITUDE	LONGITUDE	LOCATION
9	11/20	9:38 am	18° 26' 54.417" N	66° 2' 4.245" W	Phase 3

	OBSERVATIONS	PHOTOGRAPHS
NORTH	Ocean	
EAST	Ocean	
SOUTH	Low Level Vegetation/Trees/Wall/Apartments	
WEST	Low Level Vegetation/Trees/Wall/Apartments	
EXTRA	Close Proximity to Water	

Nighttime Site Assessment Sheet

SITE NUMBER	DATE	TIME	LATITUDE	LONGITUDE	LOCATION
9	11/24	9:38 pm	18° 26’ 54.417” N	66° 2’ 4.245” W	Phase 3

	OBSERVATIONS	PHOTOGRAPHS
NORTH	Ocean	
EAST	Ocean Distant Miscellaneous Lights	
SOUTH	Low Level Vegetation/Trees/Wall/Apartments 1 Fence Light 1 Lamp Post	
WEST	Low Level Vegetation/Trees/Wall/Apartments 2 Lamp Posts 2 Residential Flood Lights	
EXTRA	Close Proximity to Water	

Data Collection Sheet

SITE NUMBER	DATE	TIME	WEATHER	TEMP	LATITUDE	LONGITUDE	LOCATION
9	11/24	9:38 pm	Cloudy	81°	18° 26’ 54.417” N	66° 2’ 4.245” W	Phase 3

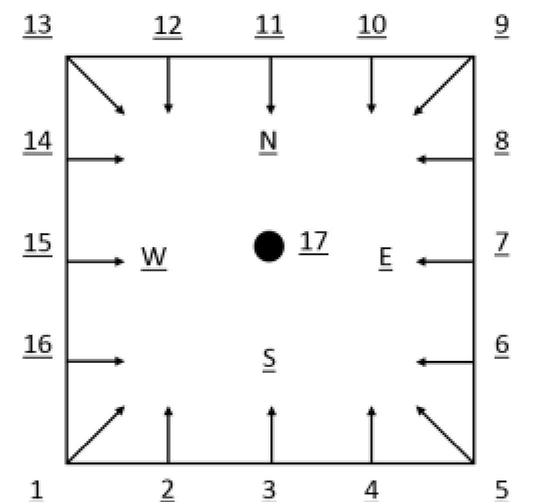
Extech/Konica Minolta Measurements

	Extech	Konica Minolta
1	2.48	4.100
2	0.57	1.103
3	0.48	0.103
4	0.24	0.123

	Extech	Konica Minolta
5	0.42	0.635
6	1.06	0.871
7	0.62	0.702
8	0.57	0.951

	Extech	Konica Minolta
9	0.72	1.034
10	0.78	0.869
11	0.74	0.958
12	0.65	0.786

	Extech	Konica Minolta
13	0.35	0.410
14	0.31	0.349
15	0.66	0.108
16	1.92	0.990



Sky Quality Meter Measurements

DATE	TIME	WEATHER	TEMP
11/20	7:48 pm	Clear	82°

17	17.48	17.44	17.82

Daytime Site Assessment Sheet

SITE NUMBER	DATE	TIME	LATITUDE	LONGITUDE	LOCATION
11	11/20	9:32 am	18° 26’ 49.049” N	66° 1’ 58.776” W	Phase 3

	OBSERVATIONS	PHOTOGRAPHS
NORTH	Ocean	
EAST	Ocean Beach	
SOUTH	Building/Trees/Low Level Vegetation/P	
WEST	Low Level Vegetation/Wall/Trees/Fence/Apartments	
EXTRA	Close Proximity to Water	

Nighttime Site Assessment Sheet

SITE NUMBER	DATE	TIME	LATITUDE	LONGITUDE	LOCATION
11	11/24	9:21 pm	18° 26' 49.049" N	66° 1' 58.776" W	Phase 3

	OBSERVATIONS	PHOTOGRAPHS
NORTH	Ocean	
EAST	Ocean Beach Distant Miscellaneous Lights	
SOUTH	Building/Trees/Low Level Vegetation Light Trespass (can't see source)	
WEST	Low Level Vegetation/Wall/Trees/Fence/Apartments 3 Lamps Posts 2 Residential Lights	
EXTRA	Close Proximity to Water	

Data Collection Sheet

SITE NUMBER	DATE	TIME	WEATHER	TEMP	LATITUDE	LONGITUDE	LOCATION
11	11/24	9:21 pm	Cloudy	81°	18° 26' 49.049" N	66° 1' 58.776" W	Phase 3

Extech/Konica Minolta Measurements

	Extech	Konica Minolta
1	0.00	0.016
2	0.00	0.010
3	0.00	0.011
4	0.00	0.022

	Extech	Konica Minolta
5	0.00	0.053
6	0.00	0.055
7	0.00	0.053
8	0.05	0.053

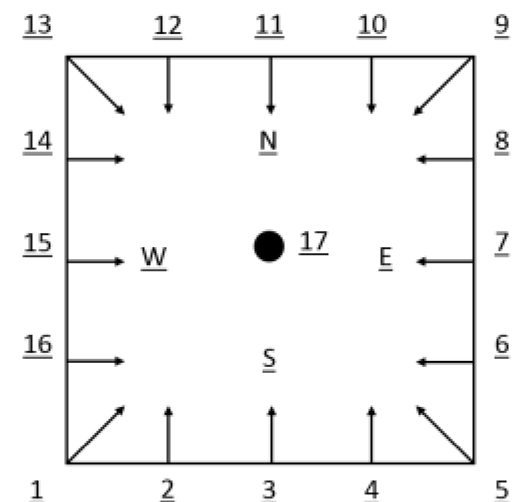
	Extech	Konica Minolta
9	0.00	0.067
10	0.08	0.185
11	0.13	0.223
12	0.20	0.237

	Extech	Konica Minolta
13	0.01	0.048
14	0.00	0.013
15	0.00	0.011
16	0.00	0.010

Sky Quality Meter Measurements

DATE	TIME	WEATHER	TEMP
11/20	7:39 pm	Clear	82°

17	18.14	18.14	18.14



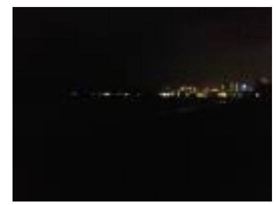
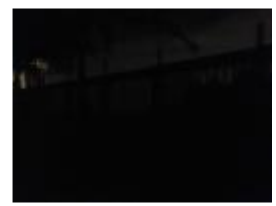
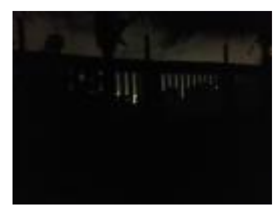
Daytime Site Assessment Sheet

SITE NUMBER	DATE	TIME	LATITUDE	LONGITUDE	LOCATION
12	11/20	9:30 am	18° 26’ 47.494” N	66° 1’ 55.308” W	Phase 3

	OBSERVATIONS	PHOTOGRAPHS
NORTH	Ocean	
EAST	Ocean/Beach	
SOUTH	Low Level Vegetation/Fence/Trees	
WEST	Low Level Vegetation/Fence/Trees	
EXTRA	Close Proximity to Water	

Nighttime Site Assessment Sheet

SITE NUMBER	DATE	TIME	LATITUDE	LONGITUDE	LOCATION
12	11/	9:30 am	18° 26’ 47.494” N	66° 1’ 55.308” W	Phase 3

	OBSERVATIONS	PHOTOGRAPHS
NORTH	Ocean	
EAST	Ocean/Beach Distant Miscellaneous Lights	
SOUTH	Low Level Vegetation/Fence/Trees	
WEST	Low Level Vegetation/Fence/Trees Distant Miscellaneous Lights	
EXTRA	Close Proximity to Water	

Data Collection Sheet

SITE NUMBER	DATE	TIME	WEATHER	TEMP	LATITUDE	LONGITUDE	LOCATION
12	11/24	9:03 pm	Cloudy	81°	18° 26’ 47.494” N	66° 1’ 55.308” W	Phase 3

Extech/Konica Minolta Measurements

	Extech	Konica Minolta
1	0.00	0.004
2	0.00	0.004
3	0.00	0.004
4	0.00	0.005

	Extech	Konica Minolta
5	0.00	0.005
6	0.00	0.006
7	0.00	0.006
8	0.00	0.007

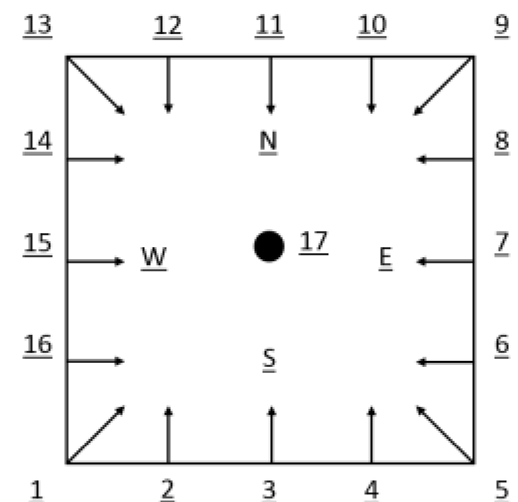
	Extech	Konica Minolta
9	0.00	0.004
10	0.00	0.006
11	0.00	0.005
12	0.00	0.005

	Extech	Konica Minolta
13	0.00	0.004
14	0.00	0.005
15	0.00	0.004
16	0.00	0.004

Sky Quality Meter Measurements

DATE	TIME	WEATHER	TEMP
11/20	7:34 pm	Clear	82°

17	18.26	18.29	18.28



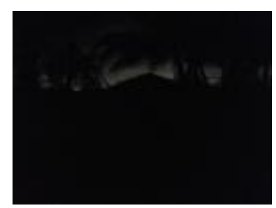
Daytime Site Assessment Sheet

SITE NUMBER	DATE	TIME	LATITUDE	LONGITUDE	LOCATION
13	11/20	9:26 am	18° 26’ 45.963” N	66° 1’ 52.488” W	Phase 3

	OBSERVATIONS	PHOTOGRAPHS
NORTH	Ocean	
EAST	Ocean/Beach	
SOUTH	Hill/Low Level Vegetation/Trees	
WEST	Hill/Low Level Vegetation/Trees	
EXTRA	Close Proximity to Water	

Nighttime Site Assessment Sheet

SITE NUMBER	DATE	TIME	LATITUDE	LONGITUDE	LOCATION
13	11/24	8:40 pm	18° 26’ 45.963” N	66° 1’ 52.488” W	Phase 3

	OBSERVATIONS	PHOTOGRAPHS
NORTH	Ocean	
EAST	Ocean/Beach Distant Miscellaneous Lights	
SOUTH	Hill/Low Level Vegetation/Trees Distant Miscellaneous Lights	
WEST	Hill/Low Level Vegetation/Trees	
EXTRA	Close Proximity to Water	

Data Collection Sheet

SITE NUMBER	DATE	TIME	WEATHER	TEMP	LATITUDE	LONGITUDE	LOCATION
13	11/24	8:40 pm	Cloudy	81°	18° 26’ 45.963” N	66° 1’ 52.488” W	Phase 3

Extech/Konica Minolta Measurements

	Extech	Konica Minolta
1	0.00	0.009
2	0.00	0.008
3	0.00	0.010
4	0.00	0.010

	Extech	Konica Minolta
5	0.00	0.010
6	0.00	0.014
7	0.00	0.016
8	0.00	0.018

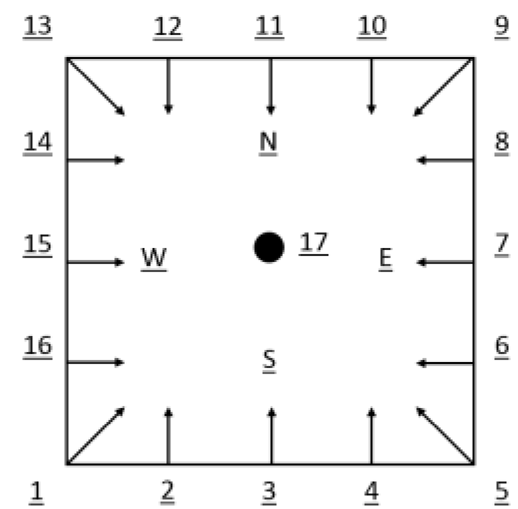
	Extech	Konica Minolta
9	0.00	0.020
10	0.00	0.006
11	0.00	0.009
12	0.00	0.007

	Extech	Konica Minolta
13	0.00	0.030
14	0.00	0.030
15	0.00	0.019
16	0.00	0.043

Sky Quality Meter Measurements

DATE	TIME	WEATHER	TEMP
11/20	7:30 pm	Clear	82°

17	18.30	18.31	18.28



Daytime Site Assessment Sheet

SITE NUMBER	DATE	TIME	LATITUDE	LONGITUDE	LOCATION
14	11/20	9:24 am	18° 26' 44.689" N	66° 1' 49.302" W	Phase 3

	OBSERVATIONS	PHOTOGRAPHS
NORTH	Ocean	
EAST	Ocean/Beach	
SOUTH	Low Level Vegetation/Hill/Trees/Fence/Apartments	
WEST	Low Level Vegetation/Hill/Trees/Fence/Apartments	
EXTRA		

Nighttime Site Assessment Sheet

SITE NUMBER	DATE	TIME	LATITUDE	LONGITUDE	LOCATION
14	11/24	8:23 pm	18° 26' 44.689" N	66° 1' 49.302" W	Phase 3

	OBSERVATIONS	PHOTOGRAPHS
NORTH	Ocean	
EAST	Ocean/Beach Distant Miscellaneous Lights	
SOUTH	Low Level Vegetation/Hill/Trees/Fence/Apartments 3 Lamp Posts	
WEST	Low Level Vegetation/Hill/Trees/Fence/Apartments Light Trespass (cannot see source)	
EXTRA		

Data Collection Sheet

SITE NUMBER	DATE	TIME	WEATHER	TEMP	LATITUDE	LONGITUDE	LOCATION
14	11/24	8:23 pm	Cloudy	81°	18° 26’ 44.689” N	66° 1’ 49.302” W	Phase 3

Extech/Konica Minolta Measurements

	Extech	Konica Minolta
1	0.00	0.003
2	0.00	0.003
3	0.00	0.003
4	0.00	0.003

	Extech	Konica Minolta
5	0.00	0.005
6	0.00	0.007
7	0.00	0.009
8	0.00	0.013

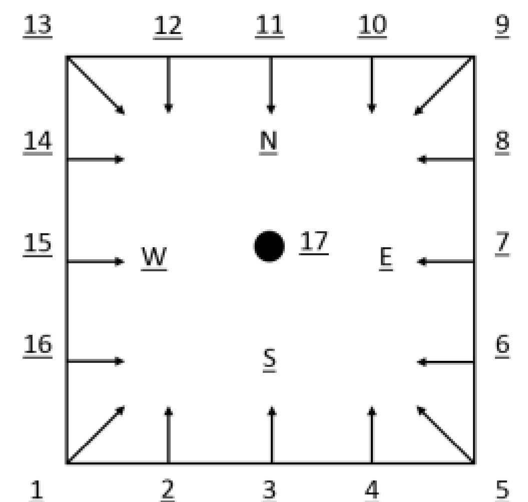
	Extech	Konica Minolta
9	0.00	0.005
10	0.00	0.044
11	0.04	0.072
12	0.02	0.045

	Extech	Konica Minolta
13	0.05	0.062
14	0.00	0.036
15	0.00	0.029
16	0.00	0.030

Sky Quality Meter Measurements

DATE	TIME	WEATHER	TEMP
11/20	7:26 pm	Clear	82°

17	18.29	18.25	18.23



Daytime Site Assessment Sheet

SITE NUMBER	DATE	TIME	LATITUDE	LONGITUDE	LOCATION
15	11/20	9:20 am	18° 26'43.391" N	66° 1' 46.214" W	Phase 3

	OBSERVATIONS	PHOTOGRAPHS
NORTH	Ocean	
EAST	Ocean/Beach	
SOUTH	Low Level Vegetation/Hill/Trees/Fence/Apartments	
WEST	Low Level Vegetation/Hill/Trees/Fence/Apartments	
EXTRA		

Nighttime Site Assessment Sheet

SITE NUMBER	DATE	TIME	LATITUDE	LONGITUDE	LOCATION
15	11/24	8:01 pm	18° 26’43.391” N	66° 1’ 46.214” W	Phase 3

	OBSERVATIONS	PHOTOGRAPHS
NORTH	Ocean	
EAST	Ocean/Beach Distant Miscellaneous Lights	
SOUTH	Low Level Vegetation/Hill/Trees/Fence/Apartments 3 Residential Lights	
WEST	Low Level Vegetation/Hill/Trees/Fence/Apartments 1 Flood Light 1 Residential Light 1 Lamp Post	
EXTRA		

Data Collection Sheet

SITE NUMBER	DATE	TIME	WEATHER	TEMP	LATITUDE	LONGITUDE	LOCATION
15	11/24	8:01 pm	Cloudy	81°	18° 26’43.391” N	66° 1’ 46.214” W	Phase 3

Extech/Konica Minolta Measurements

	Extech	Konica Minolta
1	0.00	0.006
2	0.00	0.006
3	0.00	0.006
4	0.00	0.005

	Extech	Konica Minolta
5	0.00	0.011
6	0.02	0.053
7	0.01	0.044
8	0.02	0.031

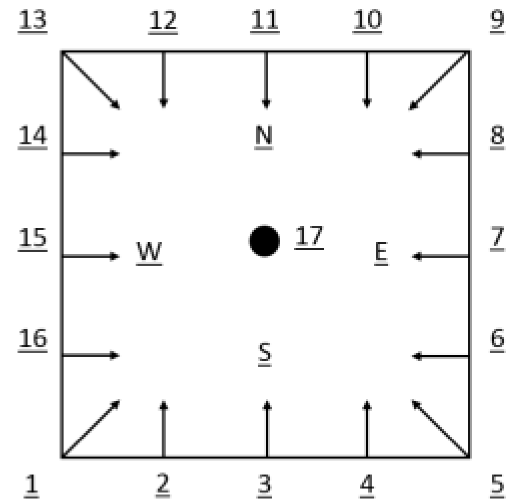
	Extech	Konica Minolta
9	0.06	0.143
10	0.05	0.123
11	0.07	0.120
12	0.01	0.048

	Extech	Konica Minolta
13	0.05	0.064
14	0.00	0.020
15	0.00	0.020
16	0.00	0.012

Sky Quality Meter Measurements

DATE	TIME	WEATHER	TEMP
11/20	7:21 pm	Clear	82°

17	18.26	18.26	18.21



Daytime Site Assessment Sheet

SITE NUMBER	DATE	TIME	LATITUDE	LONGITUDE	LOCATION
16	11/20	9:17 am	18° 26'42.310" N	66° 1' 43.054" W	Phase 3

	OBSERVATIONS	PHOTOGRAPHS
NORTH	Ocean	
EAST	Beach	
SOUTH	Low Level Vegetation/Trees/Fence/Apartments	
WEST	Low Level Vegetation/Trees/Fence/Apartments	
EXTRA		

Nighttime Site Assessment Sheet

SITE NUMBER	DATE	TIME	LATITUDE	LONGITUDE	LOCATION
16	11/20	8:32 pm	18° 26’42.310” N	66° 1’ 43.054” W	Phase 3

	OBSERVATIONS	PHOTOGRAPHS
NORTH	Ocean	
EAST	Beach Distant Miscellaneous Lights	
SOUTH	Low Level Vegetation/Trees/Fence/Apartments 1 Lamp Post 7 Fence Lights 1 Doorway Light	
WEST	Low Level Vegetation/Trees/Fence/Apartments 1 Lamp Post 5 Fence Lights	
EXTRA		

Data Collection Sheet

SITE NUMBER	DATE	TIME	WEATHER	TEMP	LATITUDE	LONGITUDE	LOCATION
16	11/20	8:32 pm	Clear	82°	18° 26’42.310” N	66° 1’ 43.054” W	Phase 3

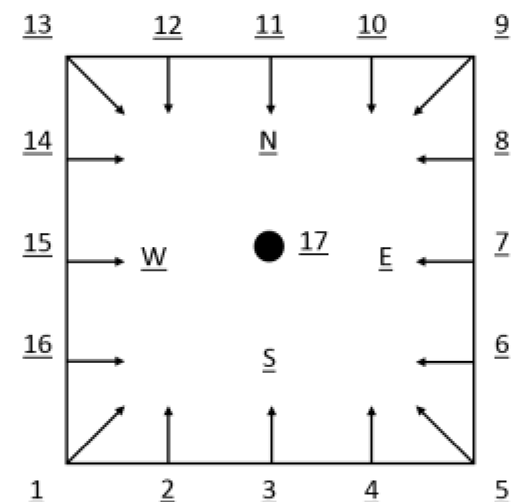
Extech/Konica Minolta Measurements

	Extech	Konica Minolta
1	0.00	0.004
2	0.00	0.004
3	0.00	0.005
4	0.00	0.004

	Extech	Konica Minolta
5	0.00	0.010
6	0.00	0.015
7	0.00	0.014
8	0.00	0.019

	Extech	Konica Minolta
9	0.00	0.033
10	0.00	0.033
11	0.00	0.038
12	0.00	0.034

	Extech	Konica Minolta
13	0.00	0.025
14	0.00	0.022
15	0.00	0.017
16	0.00	0.019



Sky Quality Meter Measurements

DATE	TIME	WEATHER	TEMP
11/20	7:17 pm	Clear	82°

17	18.26	18.26	18.28

Daytime Site Assessment Sheet

SITE NUMBER	DATE	TIME	LATITUDE	LONGITUDE	LOCATION
17	11/20	8:56 am	18° 26' 41.364" N	66° 1' 39.799" W	Phase 3

	OBSERVATIONS	PHOTOGRAPHS
NORTH	Ocean	
EAST	Ocean/Beach	
SOUTH	Low Level Vegetation/Trees/Fence Apartments	
WEST	Low Level Vegetation/Trees/Fence Apartments	
EXTRA		

Nighttime Site Assessment Sheet

SITE NUMBER	DATE	TIME	LATITUDE	LONGITUDE	LOCATION
17	11/20	8:16 pm	18° 26’ 41.364” N	66° 1’ 39.799” W	Phase 3

	OBSERVATIONS	PHOTOGRAPHS
NORTH	Ocean	
EAST	Ocean/Beach Distant Miscellaneous Lights	
SOUTH	Low Level Vegetation/Trees/Fence Apartments 2 Lamp Posts 10 Fence Lights	
WEST	Low Level Vegetation/Trees/Fence Apartments 5 Lamp Posts 4 Fence Lights	
EXTRA		

Data Collection Sheet

SITE NUMBER	DATE	TIME	WEATHER	TEMP	LATITUDE	LONGITUDE	LOCATION
17	11/20	8:16 pm	Clear	82°	18° 26' 41.364" N	66° 1' 39.799" W	Phase 3

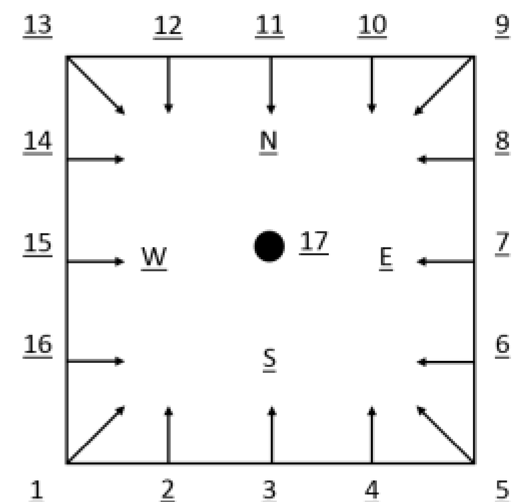
Extech/Konica Minolta Measurements

	Extech	Konica Minolta
1	0.00	0.003
2	0.00	0.003
3	0.00	0.003
4	0.00	0.003

	Extech	Konica Minolta
5	0.00	0.005
6	0.00	0.011
7	0.00	0.018
8	0.00	0.015

	Extech	Konica Minolta
9	0.00	0.032
10	0.00	0.028
11	0.00	0.021
12	0.00	0.034

	Extech	Konica Minolta
13	0.00	0.021
14	0.00	0.016
15	0.00	0.019
16	0.00	0.014



Sky Quality Meter Measurements

DATE	TIME	WEATHER	TEMP
11/19	8:26 pm	Clear	81°

17	18.45	18.47	18.41

Daytime Site Assessment Sheet

SITE NUMBER	DATE	TIME	LATITUDE	LONGITUDE	LOCATION
18	11/20	8:52 am	18° 26’ 40.719” N	66° 1’ 36.459” W	Phase 3

	OBSERVATIONS	PHOTOGRAPHS
NORTH	Ocean	
EAST	Beach	
SOUTH	Hill/Low Level Vegetation/Trees/Apartments	
WEST	Trees/Fence/Low Level Vegetation/Apartments	
EXTRA		

Nighttime Site Assessment Sheet

SITE NUMBER	DATE	TIME	LATITUDE	LONGITUDE	LOCATION
18	11/20	7:57 pm	18° 26' 40.719" N	66° 1' 36.459" W	Phase 3

	OBSERVATIONS	PHOTOGRAPHS
NORTH	Ocean	
EAST	Beach Distant Miscellaneous Lights	
SOUTH	Hill/Low Level Vegetation/Trees/Apartments Bar Lights 1 Lamp Post	
WEST	Trees/Fence/Low Level Vegetation/Apartments 2 Lamp Posts 9 Fence Lights	
EXTRA		

Data Collection Sheet

SITE NUMBER	DATE	TIME	WEATHER	TEMP	LATITUDE	LONGITUDE	LOCATION
18	11/20	7:57 pm	Clear	82°	18° 26’ 40.719” N	66° 1’ 36.459” W	Phase 3

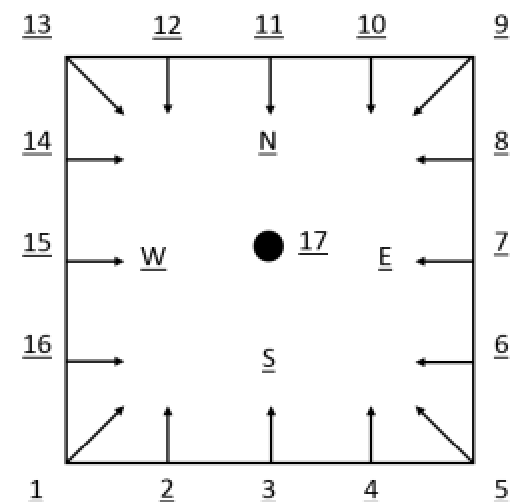
Extech/Konica Minolta Measurements

	Extech	Konica Minolta
1	0.00	0.003
2	0.00	0.004
3	0.00	0.003
4	0.00	0.003

	Extech	Konica Minolta
5	0.00	0.006
6	0.00	0.011
7	0.00	0.014
8	0.00	0.018

	Extech	Konica Minolta
9	0.00	0.026
10	0.00	0.029
11	0.00	0.029
12	0.00	0.033

	Extech	Konica Minolta
13	0.00	0.021
14	0.00	0.015
15	0.00	0.013
16	0.00	0.010



Sky Quality Meter Measurements

DATE	TIME	WEATHER	TEMP
11/19	8:41 pm	Clear	81°

17	18.38	18.45	18.45

Daytime Site Assessment Sheet

SITE NUMBER	DATE	TIME	LATITUDE	LONGITUDE	LOCATION
19	11/20	8:46 am	18° 26’ 40.022” N	66° 1’33.130” W	Phase 3

	OBSERVATIONS	PHOTOGRAPHS
NORTH	Ocean	
EAST	Beach	
SOUTH	Trash Barrels/Trees/Fence/Apartments	
WEST	Trees/Hotel/Restaurant/Fence	
EXTRA		

Nighttime Site Assessment Sheet

SITE NUMBER	DATE	TIME	LATITUDE	LONGITUDE	LOCATION
19	11/20	7:41 pm	18° 26’ 40.022” N	66° 1’33.130” W	Phase 3

	OBSERVATIONS	PHOTOGRAPHS
NORTH	Ocean	
EAST	Beach Distant Miscellaneous Lights	
SOUTH	Trash Barrels/Trees/Fence/Apartments 1 Residential Light	
WEST	Trees/Hotel/Restaurant/Fence Red Lighting	
EXTRA		

Data Collection Sheet

SITE NUMBER	DATE	TIME	WEATHER	TEMP	LATITUDE	LONGITUDE	LOCATION
19	11/20	7:41 pm	Clear	82°	18° 26’ 40.022” N	66° 1’33.130” W	Phase 3

Extech/Konica Minolta Measurements

	Extech	Konica Minolta
1	0.00	0.004
2	0.00	0.003
3	0.00	0.003
4	0.00	0.003

	Extech	Konica Minolta
5	0.00	0.005
6	0.00	0.009
7	0.00	0.014
8	0.00	0.010

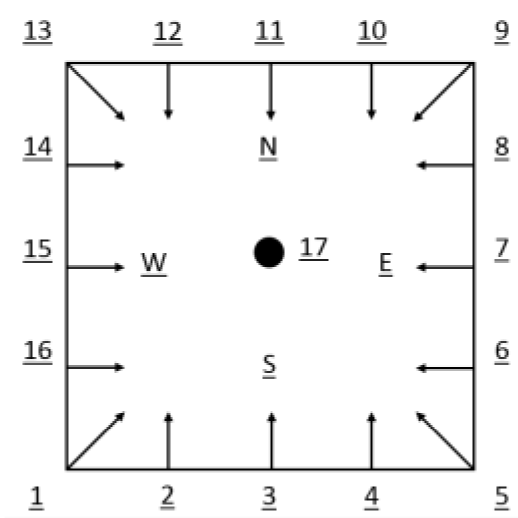
	Extech	Konica Minolta
9	0.00	0.036
10	0.00	0.032
11	0.00	0.033
12	0.00	0.051

	Extech	Konica Minolta
13	0.00	0.035
14	0.00	0.017
15	0.00	0.017
16	0.00	0.017

Sky Quality Meter Measurements

DATE	TIME	WEATHER	TEMP
11/19	8:21 pm	Clear	81°

17	18.31	18.40	18.36



Daytime Site Assessment Sheet

SITE NUMBER	DATE	TIME	LATITUDE	LONGITUDE	LOCATION
20	11/20	8:46 am	18° 26’ 39.360” N	66° 1’ 29.795” W	Phase 3

	OBSERVATIONS	PHOTOGRAPHS
NORTH	Ocean	
EAST	Beach	
SOUTH	Safety Sign/Trees/fence/Hotel	
WEST	Trees/Fence/Hotel	
EXTRA		

Nighttime Site Assessment Sheet

SITE NUMBER	DATE	TIME	LATITUDE	LONGITUDE	LOCATION
20	11/20	7:21 pm	18° 26’ 39.360” N	66° 1’ 29.795” W	Phase 3

	OBSERVATIONS	PHOTOGRAPHS
NORTH	Ocean	
EAST	Beach Distant Miscellaneous Lights	
SOUTH	Safety Sign/Trees/fence/Hotel 5 Lamp Posts	
WEST	Trees/Fence/Hotel 9 Lamp Posts	
EXTRA		

Data Collection Sheet

SITE NUMBER	DATE	TIME	WEATHER	TEMP	LATITUDE	LONGITUDE	LOCATION
20	11/20	7:21 pm	Clear	82°	18° 26' 39.360" N	66° 1' 29.795" W	Phase 3

Extech/Konica Minolta Measurements

	Extech	Konica Minolta
1	0.00	0.005
2	0.00	0.005
3	0.00	0.004
4	0.00	0.004

	Extech	Konica Minolta
5	0.00	0.009
6	0.00	0.012
7	0.00	0.014
8	0.00	0.014

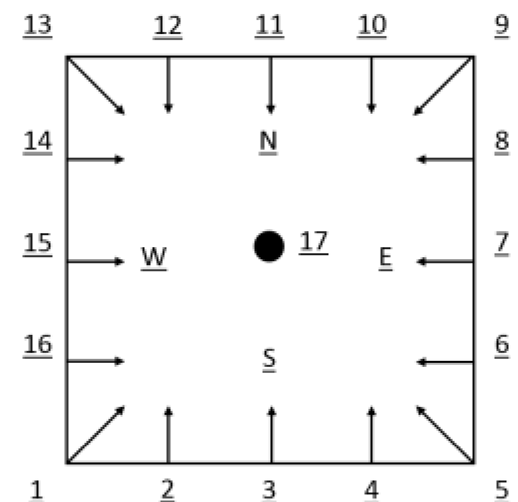
	Extech	Konica Minolta
9	0.00	0.030
10	0.00	0.035
11	0.00	0.039
12	0.00	0.040

	Extech	Konica Minolta
13	0.00	0.027
14	0.00	0.020
15	0.00	0.020
16	0.00	0.016

Sky Quality Meter Measurements

DATE	TIME	WEATHER	TEMP
11/19	8:26 pm	Clear	81°

17	18.33	18.35	18.30



Daytime Site Assessment Sheet

SITE NUMBER	DATE	TIME	LATITUDE	LONGITUDE	LOCATION
21	11/20	8:43 am	18° 26' 38.840" N	66° 1' 26.431" W	Phase 3

	OBSERVATIONS	PHOTOGRAPHS
NORTH	Ocean	
EAST	Beach/Trees/Hotels	
SOUTH	Trees/Fence/Low Level Vegetation/Hotel	
WEST	Trees/Fence Hotel	
EXTRA		

Nighttime Site Assessment Sheet

SITE NUMBER	DATE	TIME	LATITUDE	LONGITUDE	LOCATION
21	11/20	7:05 pm	18° 26’ 38.840” N	66° 1’ 26.431” W	Phase 3

	OBSERVATIONS	PHOTOGRAPHS
NORTH	Ocean	
EAST	Beach/Trees/Hotels Distant Miscellaneous Hotel/Residential Lights	
SOUTH	Trees/Fence/Low Level Vegetation/Hotel 8 Light Posts 1 Residential Light	
WEST	Trees/Fence Hotel 4 Light Posts	
EXTRA		

Data Collection Sheet

SITE NUMBER	DATE	TIME	WEATHER	TEMP	LATITUDE	LONGITUDE	LOCATION
21	11/20	7:05 pm	Clear	82°	18° 26' 38.840" N	66° 1' 26.431" W	Phase 3

Extech/Konica Minolta Measurements

	Extech	Konica Minolta
1	0.00	0.006
2	0.00	0.006
3	0.00	0.006
4	0.00	0.006

	Extech	Konica Minolta
5	0.00	0.007
6	0.00	0.010
7	0.00	0.009
8	0.00	0.011

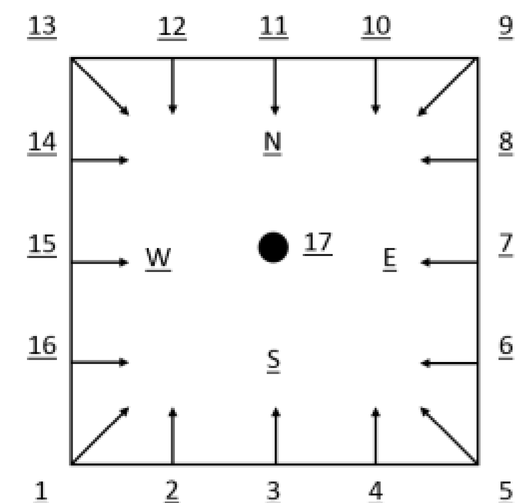
	Extech	Konica Minolta
9	0.00	0.033
10	0.00	0.048
11	0.00	0.059
12	0.01	0.061

	Extech	Konica Minolta
13	0.00	0.055
14	0.00	0.029
15	0.00	0.021
16	0.00	0.018

Sky Quality Meter Measurements

DATE	TIME	WEATHER	TEMP
11/19	8:28 pm	Clear	81°

17	18.46	18.39	18.43



Daytime Site Assessment Sheet

SITE NUMBER	DATE	TIME	LATITUDE	LONGITUDE	LOCATION
22	11/20	8:40 am	18° 26’ 38.372” N	66° 1’ 23.059” W	Phase 3

	OBSERVATIONS	PHOTOGRAPHS
NORTH	Ocean	
EAST	Beach/Trees/Hotels	
SOUTH	Street/Fence/Trees/Hotel	
WEST	Low Level Vegetation/Trees/Trash Barrels/Fence Hotel	
EXTRA		

Nighttime Site Assessment Sheet

SITE NUMBER	DATE	TIME	LATITUDE	LONGITUDE	LOCATION
22	11/19	8:40 am	18° 26’ 38.372” N	66° 1’ 23.059” W	Phase 3

	OBSERVATIONS	PHOTOGRAPHS
NORTH	Ocean	
EAST	Beach/Trees/Hotels Miscellaneous Hotel Lights 3 Street Lights	
SOUTH	Street/Fence/Trees/Hotel 8 Street Lights 1 Residential Lights	
WEST	Low Level Vegetation/Trees/Trash Barrels/Fence Hotel 7 Street Lights 1 Residential Lights	
EXTRA		

Data Collection Sheet

SITE NUMBER	DATE	TIME	WEATHER	TEMP	LATITUDE	LONGITUDE	LOCATION
22	11/19	9:00 pm	Clear	81°	18° 26' 38.372" N	66° 1' 23.059" W	Phase 3

Extech/Konica Minolta Measurements

	Extech	Konica Minolta
1	0.00	0.007
2	0.00	0.006
3	0.00	0.006
4	0.00	0.015

	Extech	Konica Minolta
5	0.01	0.035
6	0.01	0.036
7	0.00	0.039
8	0.08	0.131

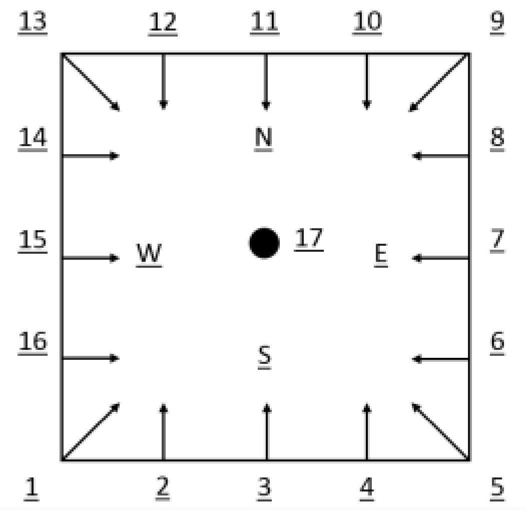
	Extech	Konica Minolta
9	0.07	0.130
10	0.08	0.148
11	0.08	0.144
12	0.07	0.094

	Extech	Konica Minolta
13	0.08	0.081
14	0.08	0081
15	0.04	0.045
16	0.07	0.095

Sky Quality Meter Measurements

DATE	TIME	WEATHER	TEMP
11/19	8:31 pm	Clear	81°

17	18.34	18.34	18.34



Daytime Site Assessment Sheet

SITE NUMBER	DATE	TIME	LATITUDE	LONGITUDE	LOCATION
23	11/20	8:37	18° 26' 38.289" N	66° 1' 19.668" W	Phase 3

	OBSERVATIONS	PHOTOGRAPHS
NORTH	Ocean	
EAST	Beach/Trees/Apartments	
SOUTH	Trash Barrels/Residences/Street	
WEST	Trees/Residences/Street	
EXTRA		

Nighttime Site Assessment Sheet

SITE NUMBER	DATE	TIME	LATITUDE	LONGITUDE	LOCATION
23	11/19	8:42 pm	18° 26' 38.289" N	66° 1' 19.668" W	Phase 3

	OBSERVATIONS	PHOTOGRAPHS
NORTH	Ocean	
EAST	Beach/Trees/Apartments Miscellaneous Hotel Lights 4 Street Lights	
SOUTH	Trash Barrels/Residences/Street 13 Street Lights	
WEST	Trees/Residences/Street 14 Street Lights	
EXTRA		

Data Collection Sheet

SITE NUMBER	DATE	TIME	WEATHER	TEMP	LATITUDE	LONGITUDE	LOCATION
23	11/19	8:42 pm	Clear	81°	18° 26’ 38.289” N	66° 1’ 19.668” W	Phase 3

Extech/Konica Minolta Measurements

	Extech	Konica Minolta
1	0.00	0.007
2	0.00	0.006
3	0.00	0.006
4	0.00	0.005

	Extech	Konica Minolta
5	0.00	0.007
6	0.00	0.018
7	0.00	0.024
8	0.00	0.019

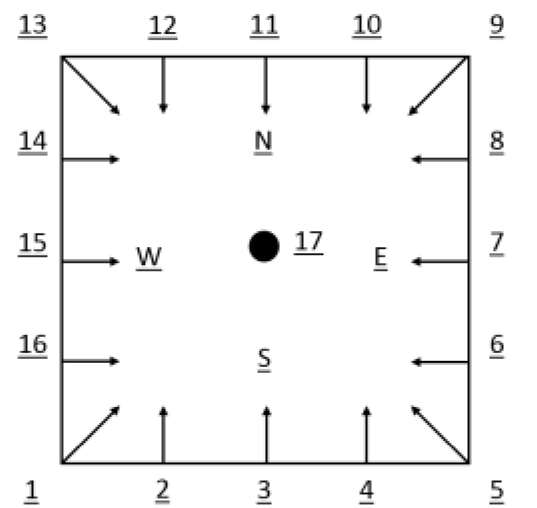
	Extech	Konica Minolta
9	0.00	0.035
10	0.01	0.062
11	0.01	0.068
12	0.00	0.064

	Extech	Konica Minolta
13	0.00	0.053
14	0.00	0.048
15	0.00	0.051
16	0.00	0.033

Sky Quality Meter Measurements

DATE	TIME	WEATHER	TEMP
11/19	8:42 pm	Clear	81°

17	18.34	18.34	18.32



Daytime Site Assessment Sheet

SITE NUMBER	DATE	TIME	LATITUDE	LONGITUDE	LOCATION
24	11/20	8:33 am	18° 26’ 38.581” N	66° 1’ 16.274” W	Phase 3

	OBSERVATIONS	PHOTOGRAPHS
NORTH	Ocean	
EAST	Trash Barrels/Trees/Fence	
SOUTH	Apartments/Fence/Street	
WEST	Trees/Apartments/Lamp Post/Bar	
EXTRA		

Nighttime Site Assessment Sheet

SITE NUMBER	DATE	TIME	LATITUDE	LONGITUDE	LOCATION
24	11/19	8:20 pm	18° 26’ 38.581” N	66° 1’ 16.274” W	Phase 3

	OBSERVATIONS	PHOTOGRAPHS
NORTH	Ocean	
EAST	Trash Barrels/Trees/Fence 1 Street Light	
SOUTH	Apartments/Fence/Street 13 Street Lights Bar Lights	
WEST	Trees/Apartments/Lamp Post/Bar Miscellaneous Hotel/Bar Lights 1 Street Light	
EXTRA		

Data Collection Sheet

SITE NUMBER	DATE	TIME	WEATHER	TEMP	LATITUDE	LONGITUDE	LOCATION
24	11/19	8:20 pm	Clear	81°	18° 26’ 38.581” N	66° 1’ 16.274” W	Phase 3

Extech/Konica Minolta Measurements

	Extech	Konica Minolta
1	0.00	0.014
2	0.00	0.007
3	0.00	0.006
4	0.00	0.005

	Extech	Konica Minolta
5	0.00	0.035
6	0.00	0.054
7	0.00	0.041
8	0.00	0.051

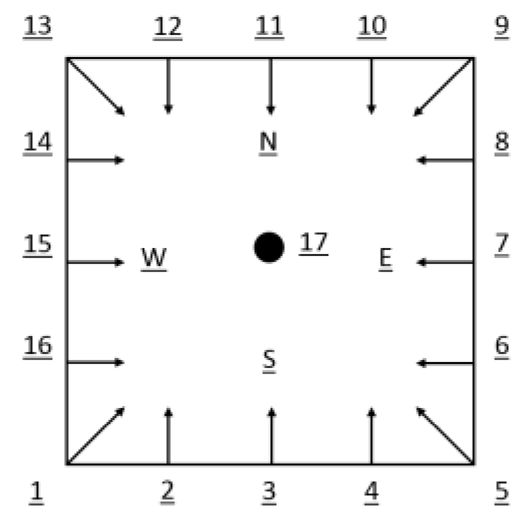
	Extech	Konica Minolta
9	0.00	0.065
10	0.01	0.068
11	0.04	0.089
12	0.04	0.101

	Extech	Konica Minolta
13	0.06	0.042
14	0.00	0.020
15	0.01	0.077
16	0.01	0.063

Sky Quality Meter Measurements

DATE	TIME	WEATHER	TEMP
11/19	8:20 pm	Clear	81°

17	18.38	18.35	18.36



Daytime Site Assessment Sheet

SITE NUMBER	DATE	TIME	LATITUDE	LONGITUDE	LOCATION
25	11/20	8:30 am	18° 26’ 39.177” N	66° 1’ 12.927” W	Phase 3

	OBSERVATIONS	PHOTOGRAPHS
NORTH	Ocean	
EAST	Beach/Low Level Vegetation/Trees	
SOUTH	Low Level Vegetation/Trees/Vegetation	
WEST	Beach/Trees/Fence	
EXTRA		

Nighttime Site Assessment Sheet

SITE NUMBER	DATE	TIME	LATITUDE	LONGITUDE	LOCATION
25	11/19	7:50 pm	18° 26’ 39.177” N	66° 1’ 12.927” W	Phase 3

	OBSERVATIONS	PHOTOGRAPHS
NORTH	Ocean	
EAST	Beach/Low Level Vegetation/Trees 1 Tree Light	
SOUTH	Low Level Vegetation/Trees/Vegetation 2 Walkway Lights Gazebo Light	
WEST	Beach/Trees/Fence Miscellaneous Hotel Lights Street Lights	
EXTRA		

Data Collection Sheet

SITE NUMBER	DATE	TIME	WEATHER	TEMP	LATITUDE	LONGITUDE	LOCATION
25	11/19	7:50 pm	Clear	81°	18° 26’ 39.177” N	66° 1’ 12.927” W	Phase 3

Extech/Konica Minolta Measurements

	Extech	Konica Minolta
1	0.01	0.019
2	0.00	0.008
3	0.00	0.012
4	0.00	0.010

	Extech	Konica Minolta
5	0.00	0.009
6	0.00	0.010
7	0.00	0.019
8	0.00	0.012

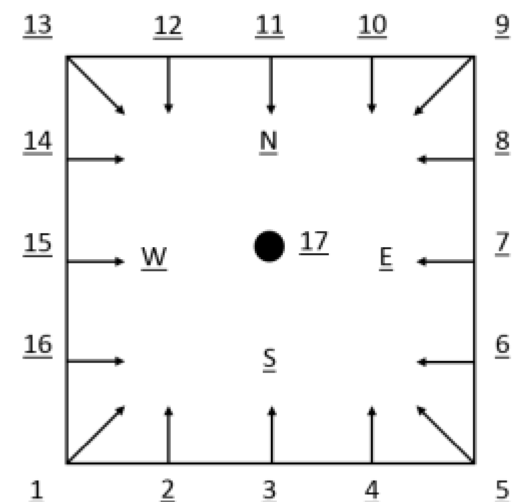
	Extech	Konica Minolta
9	0.00	0.036
10	0.00	0.051
11	0.00	0.052
12	0.00	0.060

	Extech	Konica Minolta
13	0.02	0.083
14	0.02	0.057
15	0.02	0.085
16	0.06	0.086

Sky Quality Meter Measurements

DATE	TIME	WEATHER	TEMP
11/19	7:50 pm	Clear	81°

17	18.45	18.42	18.45



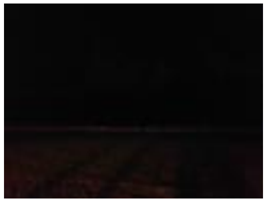
Daytime Site Assessment Sheet

SITE NUMBER	DATE	TIME	LATITUDE	LONGITUDE	LOCATION
26	11/20	8:27 am	18° 26’ 39.940” N	66° 1’ 9.617” W	Phase 3

	OBSERVATIONS	PHOTOGRAPHS
NORTH	Ocean	
EAST	Low Level Vegetation/Trees/Hotel	
SOUTH	Gym/Fence	
WEST	Bar/Trees	
EXTRA		

Nighttime Site Assessment Sheet

SITE NUMBER	DATE	TIME	LATITUDE	LONGITUDE	LOCATION
26	11/19	7:25 pm	18° 26’ 39.940” N	66° 1’ 9.617” W	Phase 3

	OBSERVATIONS	PHOTOGRAPHS
NORTH	Ocean	
EAST	Low Level Vegetation/Trees/Hotel Miscellaneous Hotel Lights	
SOUTH	Gym/Fence 5 Structure Lights	
WEST	Bar/Trees 4 Structure Lights Miscellaneous Bar Lights	
EXTRA		

Data Collection Sheet

SITE NUMBER	DATE	TIME	WEATHER	TEMP	LATITUDE	LONGITUDE	LOCATION
26	11/19	7:25 pm	Clear	81°	18° 26’ 39.940” N	66° 1’ 9.617” W	Phase 3

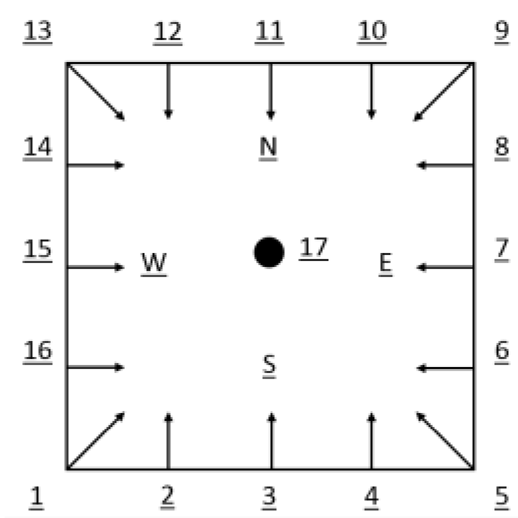
Extech/Konica Minolta Measurements

	Extech	Konica Minolta
1	0.00	0.014
2	0.00	0.022
3	0.00	0.010
4	0.00	0.008

	Extech	Konica Minolta
5	0.00	0.017
6	0.10	0.112
7	0.09	0.164
8	0.11	0.186

	Extech	Konica Minolta
9	0.14	0.256
10	0.18	0.294
11	0.22	0.328
12	0.20	0.326

	Extech	Konica Minolta
13	0.16	0.158
14	0.03	0.084
15	0.05	0.061
16	0.05	0.078



Sky Quality Meter Measurements

DATE	TIME	WEATHER	TEMP
11/19	7:25 pm	Clear	81°

17	18.33	18.42	18.26

Daytime Site Assessment Sheet

SITE NUMBER	DATE	TIME	LATITUDE	LONGITUDE	LOCATION
27	11/20	8:25 am	18° 26' 41.225" N	66° 1' 6.435" W	Phase 3

	OBSERVATIONS	PHOTOGRAPHS
NORTH	Ocean	
EAST	Hotel/Restaurant/ Trees	
SOUTH	Hotel Pool/Low Level Vegetation/Trees	
WEST	Vegetation/Beach/Trees	
EXTRA		

Nighttime Site Assessment Sheet

SITE NUMBER	DATE	TIME	LATITUDE	LONGITUDE	LOCATION
27	11/19	7:05 pm	18° 26’ 41.225” N	66° 1’ 6.435” W	Phase 3

	OBSERVATIONS	PHOTOGRAPHS
NORTH	Ocean	
EAST	Hotel/Restaurant/ Trees Miscellaneous Hotel/Bar Lights 1 Tree Light	
SOUTH	Hotel Pool/Low Level Vegetation/Trees Miscellaneous Hotel Lights 1 Tree Light	
WEST	Vegetation/Beach/Trees Miscellaneous Hotel Lights	
EXTRA		

Data Collection Sheet

SITE NUMBER	DATE	TIME	WEATHER	TEMP	LATITUDE	LONGITUDE	LOCATION
27	11/19	7:05 pm	Clear	81°	18° 26’ 41.225” N	66° 1’ 6.435” W	Phase 3

Extech/Konica Minolta Measurements

	Extech	Konica Minolta
1	0.00	0.006
2	0.00	0.003
3	0.00	0.002
4	0.00	0.003

	Extech	Konica Minolta
5	0.00	0.004
6	0.00	0.007
7	0.00	0.009
8	0.00	0.010

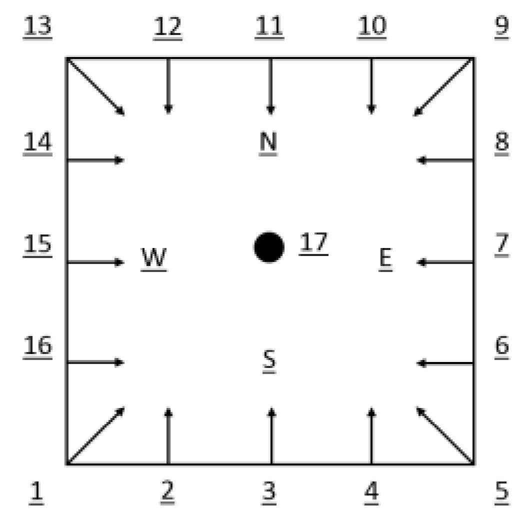
	Extech	Konica Minolta
9	0.00	0.021
10	0.00	0.019
11	0.00	0.018
12	0.00	0.015

	Extech	Konica Minolta
13	0.00	0.015
14	0.00	0.011
15	0.00	0.010
16	0.00	0.014

Sky Quality Meter Measurements

DATE	TIME	WEATHER	TEMP
11/19	7:05 pm	Clear	81°

17	18.45	18.48	18.51



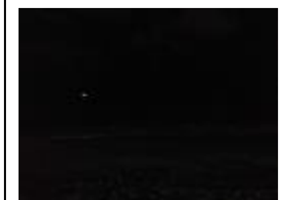
Daytime Site Assessment

SITE NUMBER	DATE	TIME	LATITUDE	LONGITUDE	LOCATION
28	11/10	10:53 am	18° 26’ 42.628” N	66° 1’ 3.446” W	Phase 1

	OBSERVATIONS	PHOTOGRAPHS
NORTH	Ocean	
EAST	Hotels/Residences	
SOUTH	Hotels/Residences/Vegetation	
WEST	Hotels/Residences/Vegetation	
EXTRA		

Nighttime Site Assessment

SITE NUMBER	DATE	TIME	LATITUDE	LONGITUDE	LOCATION
28	11/18	8:33 pm	18° 26’ 42.628” N	66° 1’ 3.446” W	Phase 1

	OBSERVATIONS	PHOTOGRAPHS
NORTH	Ocean Cruise Ship	
EAST	Hotels/Residences Miscellaneous Hotel Lights 3 Lamp Posts	
SOUTH	Hotels/Residences/Vegetation 2 Lamp Posts	
WEST	Hotels/Residences/Vegetation Distant Miscellaneous Hotel Lights	
EXTRA		

Data Collection Sheet

SITE NUMBER	DATE	TIME	WEATHER	TEMP	LATITUDE	LONGITUDE	LOCATION
28	11/18	8:33 pm	Partly Cloudy	82°	18° 26' 42.628" N	66° 1' 3.446" W	Phase 1

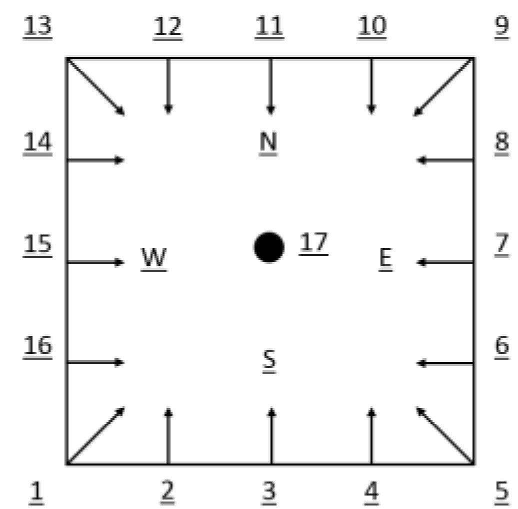
Extech/Konica Minolta Measurements

	Extech	Konica Minolta
1	0.04	0.852
2	0.00	0.012
3	0.00	0.011
4	0.00	0.011

	Extech	Konica Minolta
5	0.00	0.015
6	0.00	0.028
7	0.00	0.017
8	0.00	0.012

	Extech	Konica Minolta
9	0.00	0.012
10	0.02	0.750
11	0.00	0.013
12	0.10	0.150

	Extech	Konica Minolta
13	0.09	0.157
14	0.11	0.185
15	0.10	0.016
16	0.09	0.156



Sky Quality Meter Measurements

DATE	TIME	WEATHER	TEMP

17			

Daytime Site Assessment

SITE NUMBER	DATE	TIME	LATITUDE	LONGITUDE	LOCATION
33	11/10	10:28 am	18° 26’ 42.650” N	66° 0’ 53.443” W	Phase 1

	OBSERVATIONS	PHOTOGRAPHS
NORTH	Ocean	
EAST	Beach/Hotels	
SOUTH	Cement Wall/Vegetation	
WEST	Cement Wall/Vegetation	
EXTRA		

Nighttime Site Assessment

SITE NUMBER	DATE	TIME	LATITUDE	LONGITUDE	LOCATION
33	11/17	7:02 pm	18° 26’ 42.650” N	66° 0’ 53.443” W	Phase 1

	OBSERVATIONS	PHOTOGRAPHS
NORTH	Ocean	
EAST	Beach/Hotels Miscellaneous Hotel Lights	
SOUTH	Cement Wall/Vegetation Miscellaneous Building Lights 1 Street Light	
WEST	Cement Wall/Vegetation 1 Street Light	

Data Collection Sheet

SITE NUMBER	DATE	TIME	WEATHER	TEMP	LATITUDE	LONGITUDE	LOCATION
33	11/17	7:02 pm	Partly Cloudy	82°	18° 26’ 42.650” N	66° 0’ 53.443” W	Phase 1

Extech/Konica Minolta Measurements

	Extech	Konica Minolta
1	0.00	0.005
2	0.00	0.007
3	0.00	0.020
4	0.00	0.042

	Extech	Konica Minolta
5	0.00	0.047
6	0.07	0.094
7	0.02	0.093
8	0.01	0.067

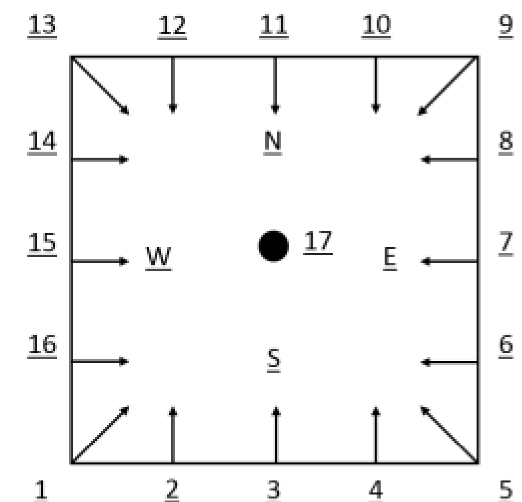
	Extech	Konica Minolta
9	0.00	0.016
10	0.07	0.021
11	0.25	0.079
12	0.00	0.021

	Extech	Konica Minolta
13	0.00	0.021
14	0.00	0.012
15	0.00	0.009
16	0.00	0.008

Sky Quality Meter Measurements

DATE	TIME	WEATHER	TEMP
11/17	7:02 pm	Partly Cloudy	82°

17	17.21	17.16	17.59



Daytime Site Assessment

SITE NUMBER	DATE	TIME	LATITUDE	LONGITUDE	LOCATION
34	11/10	10:20 am	18° 26’ 41.280” N	66° 0’ 50.571” W	Phase 1

	OBSERVATIONS	PHOTOGRAPHS
NORTH	Ocean	
EAST	Beach/Hotels	
SOUTH	Hotels/Residences	
WEST	Bildings/Restaurant	
EXTRA		

Nighttime Site Assessment

SITE NUMBER	DATE	TIME	LATITUDE	LONGITUDE	LOCATION
34	11/17	10:20 am	18° 26’ 41.280” N	66° 0’ 50.571” W	Phase 1

	OBSERVATIONS	PHOTOGRAPHS
NORTH	Ocean	
EAST	Beach/Hotels Hotel lights on trees	
SOUTH	Hotels/Residences 2 Tree Lights Miscellaneous Hotel Lights	
WEST	Buildings/Restaurant 1 Street Light 1 Tree Light	
EXTRA		

Data Collection Sheet

SITE NUMBER	DATE	TIME	WEATHER	TEMP	LATITUDE	LONGITUDE	LOCATION
34	11/17	7:33 pm	Partly Cloudy	82°	18° 26’ 41.280” N	66° 0’ 50.57” W	Phase 1

Extech/Konica Minolta Measurements

	Extech	Konica Minolta
1	0.00	0.011
2	0.00	0.008
3	0.00	0.010
4	0.00	0.016

	Extech	Konica Minolta
5	0.00	0.034
6	0.00	0.235
7	0.03	0.015
8	0.00	0.039

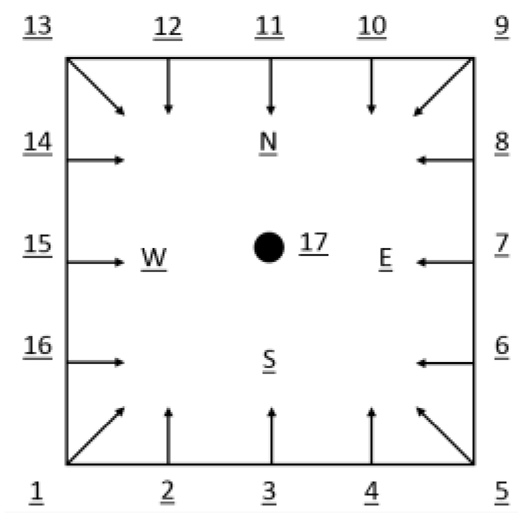
	Extech	Konica Minolta
9	0.00	0.066
10	0.00	0.033
11	0.00	0.047
12	0.00	0.023

	Extech	Konica Minolta
13	0.00	0.020
14	0.00	0.018
15	0.00	0.017
16	0.00	0.034

Sky Quality Meter Measurements

DATE	TIME	WEATHER	TEMP
11/17	7:33	Partly Cloudy	82°

17	18.23	18.24	18.31



Daytime Site Assessment

SITE NUMBER	DATE	TIME	LATITUDE	LONGITUDE	LOCATION
35	11/10	10:15 am	18° 26' 40.272" N	66° 0' 47.282" W	Phase 1

	OBSERVATIONS	PHOTOGRAPHS
NORTH	Ocean	
EAST	Beach/Hotels	
SOUTH	Hotels	
WEST	Club	
EXTRA		

Nighttime Site Assessment

SITE NUMBER	DATE	TIME	LATITUDE	LONGITUDE	LOCATION
35	11/17	7:50 pm	18° 26’ 40.272” N	66° 0’ 47.282” W	Phase 1

	OBSERVATIONS	PHOTOGRAPHS
NORTH	Ocean 1 Boat Light	
EAST	Beach/Hotels 1 Tree Light	
SOUTH	Hotels 4 Tree Light Miscellaneous Hotel Lights	
WEST	Club 4 Tree Lights Miscellaneous Hotel Lights	
EXTRA		

Data Collection Sheet

SITE NUMBER	DATE	TIME	WEATHER	TEMP	LATITUDE	LONGITUDE	LOCATION
35	11/17	7:50 pm	Partly Cloudy	82°	18° 26' 40.272" N	66° 0' 47.282" W	Phase 1

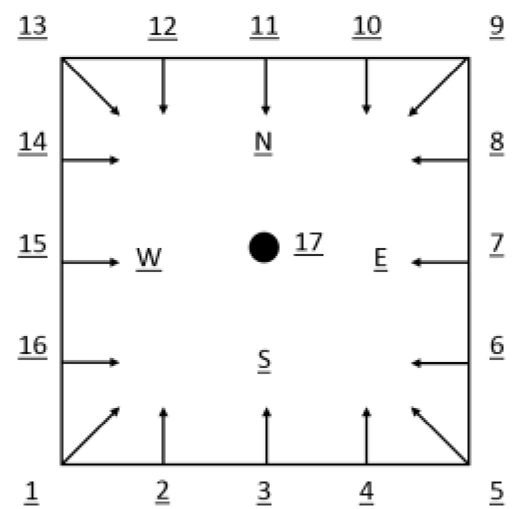
Extech/Konica Minolta Measurements

	Extech	Konica Minolta
1	0.00	0.057
2	0.00	0.040
3	0.00	0.030
4	0.00	0.039

	Extech	Konica Minolta
5	0.00	0.122
6	0.00	0.070
7	0.00	0.040
8	0.00	0.053

	Extech	Konica Minolta
9	0.01	0.072
10	0.00	0.056
11	0.00	0.057
12	0.01	0.082

	Extech	Konica Minolta
13	0.04	0.017
14	0.09	0.088
15	0.02	0.181
16	0.00	0.064



Sky Quality Meter Measurements

DATE	TIME	WEATHER	TEMP
11/17	7:50 pm	Partly Cloudy	82°

17	18.31	18.35	18.33

Daytime Site Assessment

SITE NUMBER	DATE	TIME	LATITUDE	LONGITUDE	LOCATION
36	11/10	9:54 am	18° 26' 38.500" N	66° 0' 44.036" W	Phase 1

	OBSERVATIONS	PHOTOGRAPHS
NORTH	Ocean	
EAST	Beach/Hotels	
SOUTH	Apartments/Residences	
WEST	Hotels	
EXTRA		

Nighttime Site Assessment

SITE NUMBER	DATE	TIME	LATITUDE	LONGITUDE	LOCATION
36	11/17	8:14 pm	18° 26' 38.500" N	66° 0' 44.036" W	Phase 1

	OBSERVATIONS	PHOTOGRAPHS
NORTH	Ocean	
EAST	Beach/Hotels 11 Fence Lights	
SOUTH	Apartments/Residences 2 Lamp Posts 1 Residential Light	
WEST	Hotels 1 Lamp Posts 1 Residential Light	
EXTRA		

Data Collection Sheet

SITE NUMBER	DATE	TIME	WEATHER	TEMP	LATITUDE	LONGITUDE	LOCATION
36	11/17	8:14 pm	Partly Cloudy	82°	18° 26' 38.500" N	66° 0' 44.036" W	Phase 1

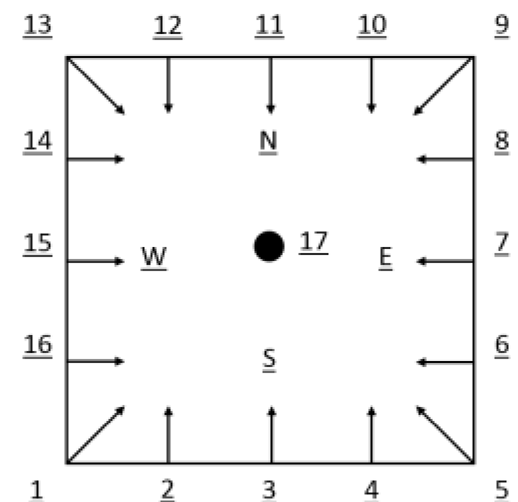
Extech/Konica Minolta Measurements

	Extech	Konica Minolta
1	0.00	0.005
2	0.00	0.006
3	0.00	0.006
4	0.00	0.006

	Extech	Konica Minolta
5	0.00	0.008
6	0.00	0.014
7	0.00	0.013
8	0.00	0.014

	Extech	Konica Minolta
9	0.00	0.035
10	0.00	0.051
11	0.00	0.037
12	0.00	0.042

	Extech	Konica Minolta
13	0.00	0.039
14	0.00	0.035
15	0.00	0.020
16	0.00	0.028



Sky Quality Meter Measurements

DATE	TIME	WEATHER	TEMP

17			

Daytime Site Assessment

SITE NUMBER	DATE	TIME	LATITUDE	LONGITUDE	LOCATION
37	11/10	9:08 am	18° 26’ ” N	66° 0’ 40.674” W	Phase 1

	OBSERVATIONS	PHOTOGRAPHS
NORTH	Ocean	
EAST	Beach	
SOUTH	Buildings	
WEST	Beach	
EXTRA		

Nighttime Site Assessment

SITE NUMBER	DATE	TIME	LATITUDE	LONGITUDE	LOCATION
37	11/17	8:40 pm	18° 26’ 37.967” N	66° 0’ 40.674” W	Phase 1

	OBSERVATIONS	PHOTOGRAPHS
NORTH	Ocean	
EAST	Beach Miscellaneous Hotel Lights 2 Lamp Posts	
SOUTH	Buildings 3 Lamp Posts	
WEST	Beach 8 Lamp Posts	
EXTRA		

Data Collection Sheet

SITE NUMBER	DATE	TIME	WEATHER	TEMP	LATITUDE	LONGITUDE	LOCATION
37	11/17	8:40 pm	Partly Cloudy	82°	18° 26’ 37.967” N	66° 0’ 40.674” W	Phase 1

Extech/Konica Minolta Measurements

	Extech	Konica Minolta
1	0.00	0.011
2	0.00	0.010
3	0.00	0.021
4	0.00	0.041

	Extech	Konica Minolta
5	0.00	0.059
6	0.04	0.069
7	0.04	0.078
8	0.08	0.150

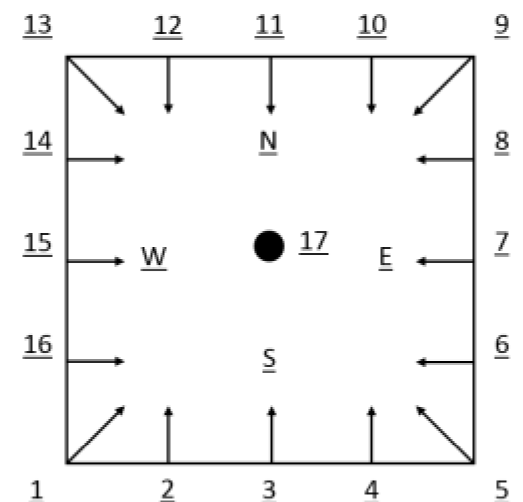
	Extech	Konica Minolta
9	0.13	0.245
10	0.14	0.183
11	0.11	0.189
12	0.13	0.110

	Extech	Konica Minolta
13	0.04	0.071
14	0.00	0.028
15	0.02	0.035
16	0.02	0.092

Sky Quality Meter Measurements

DATE	TIME	WEATHER	TEMP

17			



Daytime Site Assessment

SITE NUMBER	DATE	TIME	LATITUDE	LONGITUDE	LOCATION
38	11/10	11:30 am	18° 26’ 37.822” N	66° 0’ 37.304” W	Phase 1

	OBSERVATIONS	PHOTOGRAPHS
NORTH	Ocean	
EAST	Beach/Trees/Hotel	
SOUTH	Trees/Residences	
WEST	Trees/Residences	
EXTRA		

Nighttime Site Assessment

SITE NUMBER	DATE	TIME	LATITUDE	LONGITUDE	LOCATION
38	11/17	9:05 pm	18° 26’ 37.822” N	66° 0’ 37.304” W	Phase 1

	OBSERVATIONS	PHOTOGRAPHS
NORTH	Ocean	
EAST	Beach/Trees/Hotel 2 Lamp Posts 3 Hotel Lights	
SOUTH	Trees/Residences	
WEST	Trees/Residences Miscellaneous Hotel Lights	
EXTRA		

Data Collection Sheet

SITE NUMBER	DATE	TIME	WEATHER	TEMP	LATITUDE	LONGITUDE	LOCATION
38	11/17	9:05 pm	Partly Cloudy	82°	18° 26' 37.822" N	66° 0' 37.302" W	Phase 1

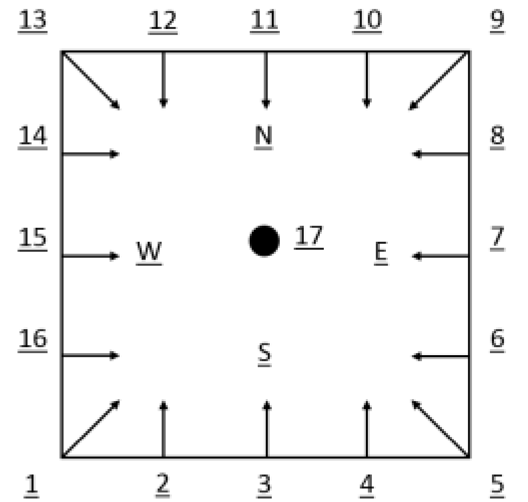
Extech/Konica Minolta Measurements

	Extech	Konica Minolta
1	0.00	0.005
2	0.00	0.005
3	0.00	0.014
4	0.00	0.005

	Extech	Konica Minolta
5	0.00	0.016
6	0.00	0.043
7	0.00	0.016
8	0.01	0.036

	Extech	Konica Minolta
9	0.03	0.082
10	0.00	0.051
11	0.00	0.045
12	0.00	0.024

	Extech	Konica Minolta
13	0.00	0.026
14	0.00	0.010
15	0.00	0.016
16	0.00	0.012



Sky Quality Meter Measurements

DATE	TIME	WEATHER	TEMP

17			

Daytime Site Assessment

SITE NUMBER	DATE	TIME	LATITUDE	LONGITUDE	LOCATION
39	11/10	11:33 am	18° 26’ 38.227” N	66° 0’ 33.922” W	Phase 1

	OBSERVATIONS	PHOTOGRAPHS
NORTH	Ocean	
EAST	Trees/Hotel	
SOUTH	Hotel	
WEST	Hotel/Residences/Trees	
EXTRA		

Nighttime Site Assessment

SITE NUMBER	DATE	TIME	LATITUDE	LONGITUDE	LOCATION
39	11/18	7:05 pm	18° 26’ 38.227” N	66° 0’ 33.922” W	Phase 1

	OBSERVATIONS	PHOTOGRAPHS
NORTH	Ocean 1 Boat Light	
EAST	Trees/Hotel 2 Tree Lights Miscellaneous Hotel Lights	
SOUTH	Hotel Miscellaneous Hotel Lights	
WEST	Hotel/Residences/Trees 3 Lamp Posts	
EXTRA		

Data Collection Sheet

SITE NUMBER	DATE	TIME	WEATHER	TEMP	LATITUDE	LONGITUDE	LOCATION
39	11/18	7:05 pm	Partly Cloudy	82°	18° 26’ 38.227” N	66° 0’ 33.922” W	Phase 1

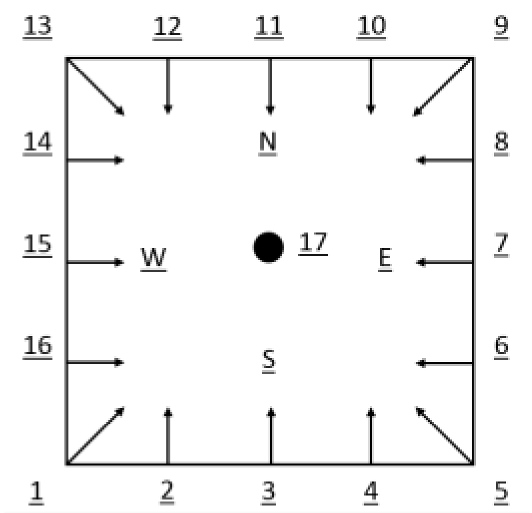
Extech/Konica Minolta Measurements

	Extech	Konica Minolta
1	0.09	0.130
2	0.02	0.084
3	0.02	0.088
4	0.02	0.093

	Extech	Konica Minolta
5	0.04	0.101
6	0.12	0.101
7	0.17	0.115
8	0.20	0.286

	Extech	Konica Minolta
9	1.01	1.268
10	0.32	0.389
11	1.04	1.312
12	0.74	0.225

	Extech	Konica Minolta
13	0.28	0.401
14	0.89	0.944
15	0.57	0.596
16	0.56	0.766



Sky Quality Meter Measurements

DATE	TIME	WEATHER	TEMP

17			

Daytime Site Assessment

SITE NUMBER	DATE	TIME	LATITUDE	LONGITUDE	LOCATION
40	11/10	11:38 am	18° 26’ 38.652” N	66° 0’ 30.545” W	Phase 1

	OBSERVATIONS	PHOTOGRAPHS
NORTH	Ocean	
EAST	Vegetation	
SOUTH	Hotel	
WEST	Beach/Hotel	
EXTRA		

Nighttime Site Assessment

SITE NUMBER	DATE	TIME	LATITUDE	LONGITUDE	LOCATION
40	11/18	7:24 pm	18° 26’ 38.652” N	66° 0’ 30.545” W	Phase 1

	OBSERVATIONS	PHOTOGRAPHS
NORTH	Ocean	
EAST	Vegetation Lights from Peninsula	
SOUTH	Hotel 1 Street Light Hotel Sign	
WEST	Beach/Hotel Miscellaneous Hotel Lights (Stairs, Rooms) 5 Tree Lights Hotel Sign	
EXTRA		

Data Collection Sheet

SITE NUMBER	DATE	TIME	WEATHER	TEMP	LATITUDE	LONGITUDE	LOCATION
40	11/18	7:24 pm	Partly Cloudy	82°	18° 26’ 38.652” N	66° 0’ 30.545” W	Phase 1

Extech/Konica Minolta Measurements

	Extech	Konica Minolta
1	0.00	0.007
2	0.00	0.007
3	0.00	0.006
4	0.00	0.005

	Extech	Konica Minolta
5	0.00	0.010
6	0.00	0.058
7	0.08	0.141
8	0.07	0.088

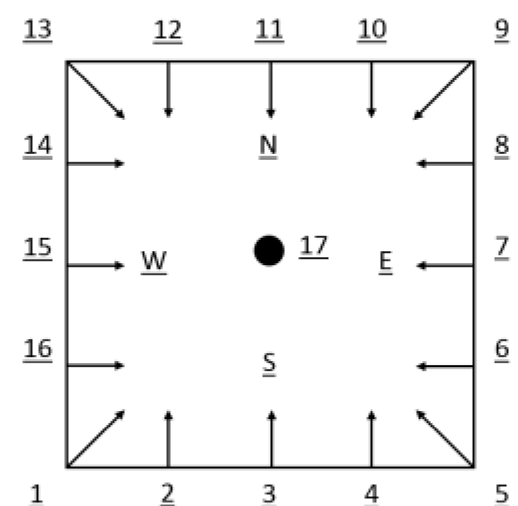
	Extech	Konica Minolta
9	0.01	0.066
10	0.00	0.045
11	0.00	0.075
12	0.00	0.036

	Extech	Konica Minolta
13	0.00	0.022
14	0.00	0.014
15	0.00	0.011
16	0.00	0.009

Sky Quality Meter Measurements

DATE	TIME	WEATHER	TEMP

17			



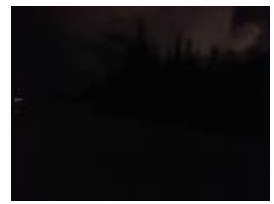
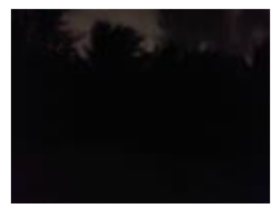
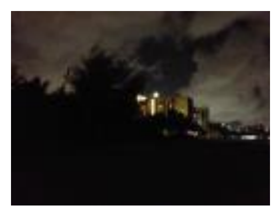
Daytime Site Assessment

SITE NUMBER	DATE	TIME	LATITUDE	LONGITUDE	LOCATION
41	11/10	11:45	18° 26’ 40.109” N	66° 0’ 27.210” W	Phase 1

	OBSERVATIONS	PHOTOGRAPHS
NORTH	Ocean	
EAST	Beach/Vegetation	
SOUTH	Vegetation	
WEST	Vegetation	
EXTRA	Vegetation/Beach/Hotel	

Nighttime Site Assessment

SITE NUMBER	DATE	TIME	LATITUDE	LONGITUDE	LOCATION
41	11/18	7:42 pm	18° 26’ 40.109” N	66° 0’ 27.210” W	Phase 1

	OBSERVATIONS	PHOTOGRAPHS
NORTH	Ocean	
EAST	Beach/Vegetation	
SOUTH	Vegetation	
WEST	Vegetation/Beach/Hotel Distant Miscellaneous Hotel Lights	
EXTRA		

Data Collection Sheet

SITE NUMBER	DATE	TIME	WEATHER	TEMP	LATITUDE	LONGITUDE	LOCATION
41	11/18	7:42 pm	Partly Cloudy	82°	18° 26’ 40.109” N	66° 0’ 27.270” W	Phase 1

Extech/Konica Minolta Measurements

	Extech	Konica Minolta
1	0.00	0.006
2	0.00	0.006
3	0.00	0.006
4	0.00	0.005

	Extech	Konica Minolta
5	0.00	0.011
6	0.00	0.016
7	0.00	0.015
8	0.00	0.014

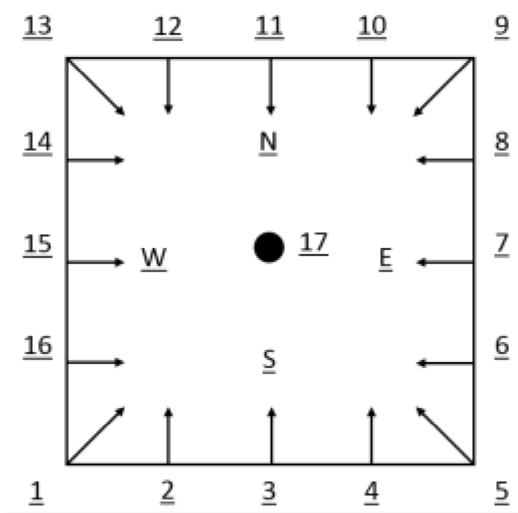
	Extech	Konica Minolta
9	0.00	0.014
10	0.00	0.010
11	0.00	0.010
12	0.00	0.008

	Extech	Konica Minolta
13	0.00	0.005
14	0.00	0.004
15	0.00	0.005
16	0.00	0.005

Sky Quality Meter Measurements

DATE	TIME	WEATHER	TEMP

17			



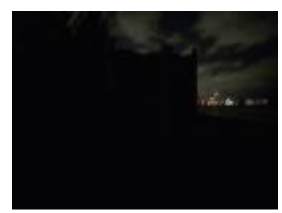
Daytime Site Assessment

SITE NUMBER	DATE	TIME	LATITUDE	LONGITUDE	LOCATION
42	11/10	11:52 am	18° 26' " N	66° 0' 23.887" W	Phase 1

	OBSERVATIONS	PHOTOGRAPHS
NORTH	Ocean	
EAST	Public Beach/Vegetation	
SOUTH	Vegetation	
WEST	Beach/Vegetation	
EXTRA		

Nighttime Site Assessment

SITE NUMBER	DATE	TIME	LATITUDE	LONGITUDE	LOCATION
42	11/13	7:05 pm	18° 26’ 40.860” N	66° 0’ 23.887” W	Phase 1

	OBSERVATIONS	PHOTOGRAPHS
NORTH	Ocean	
EAST	Public Beach/Vegetation Lights from the Peninsula	
SOUTH	Vegetation	
WEST	Beach/Vegetation Lights from the Mid-Point	
EXTRA		

Data Collection Sheet

SITE NUMBER	DATE	TIME	WEATHER	TEMP	LATITUDE	LONGITUDE	LOCATION
42	11/13	7:05 pm	Partly Cloudy	82°	18° 26' 40.860" N	66° 0' 23.887" W	Phase 1

Extech/Konica Minolta Measurements

	Extech	Konica Minolta
1	0.00	0.002
2	0.00	0.002
3	0.00	0.002
4	0.00	0.003

	Extech	Konica Minolta
5	0.00	0.003
6	0.00	0.004
7	0.00	0.005
8	0.00	0.006

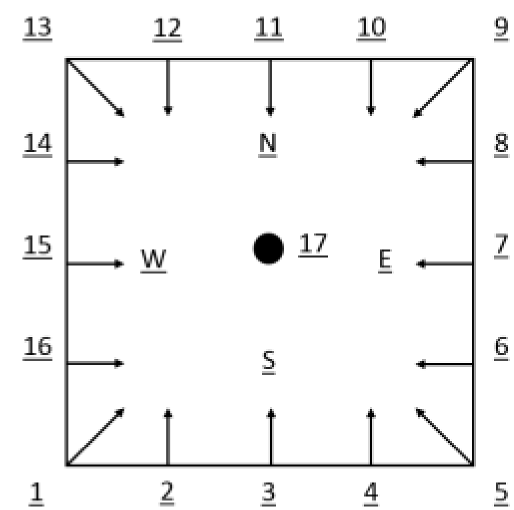
	Extech	Konica Minolta
9	0.00	0.007
10	0.00	0.004
11	0.00	0.004
12	0.00	0.003

	Extech	Konica Minolta
13	0.00	0.002
14	0.00	0.002
15	0.00	0.002
16	0.00	0.002

Sky Quality Meter Measurements

DATE	TIME	WEATHER	TEMP

17			



Appendix G- Inventory Identification Photographs

Photo Identification Number

#1

#2

#3

#4

#5

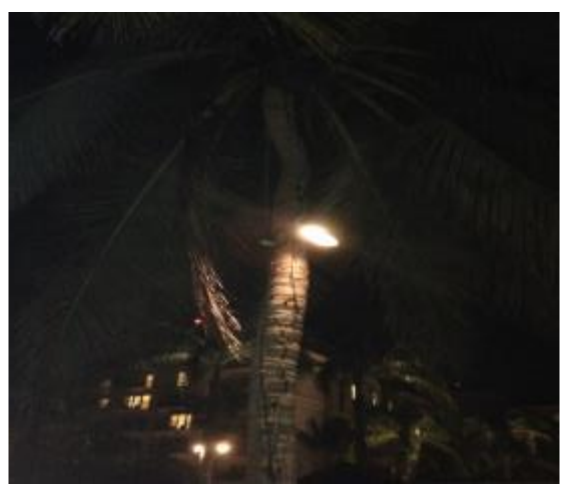
#6

#7

#8

#9

#10

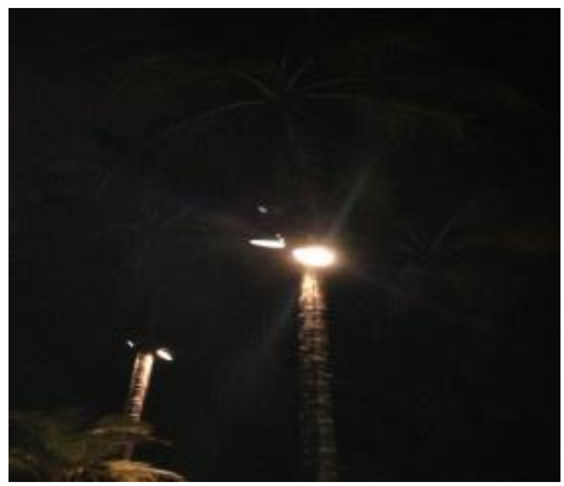


#11

#14

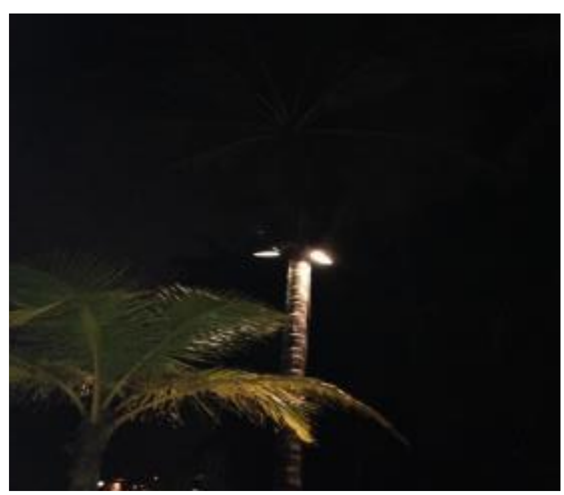
#12

#15

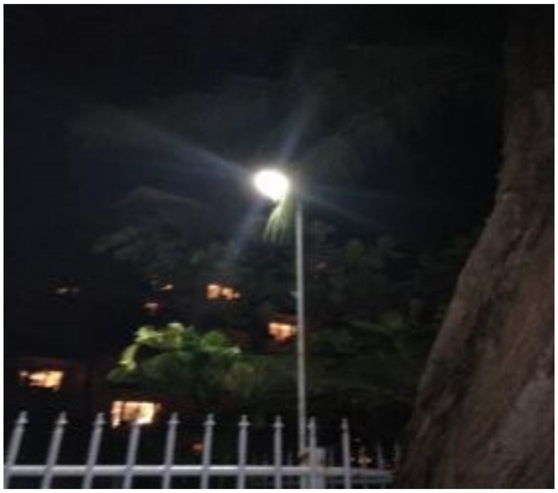


#13

#16



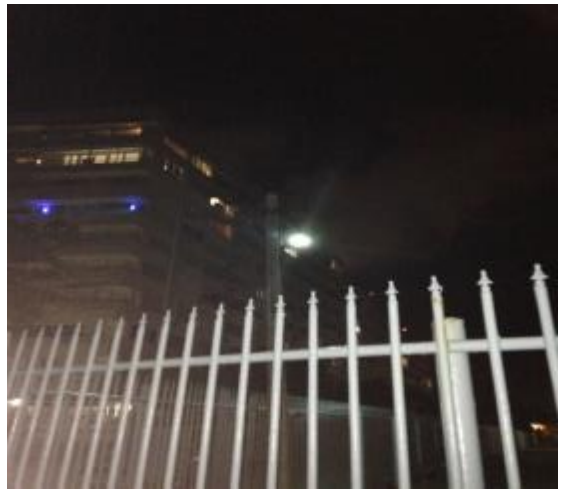
#17



#18

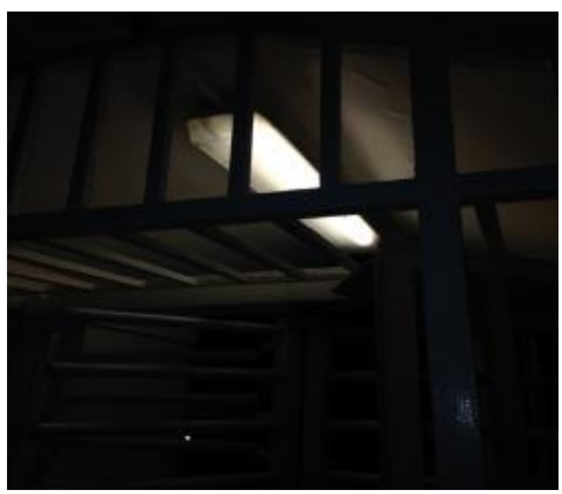
#19

#20



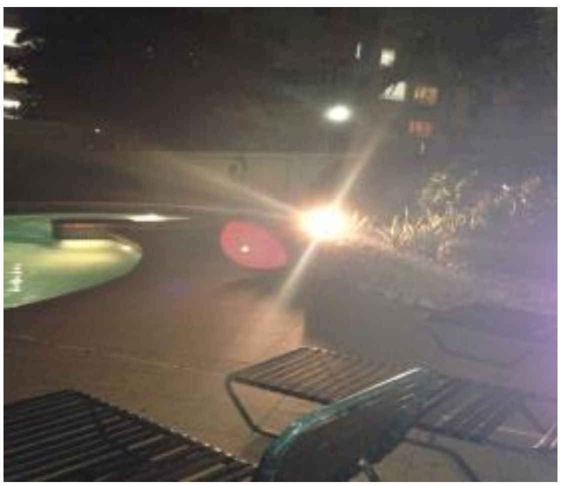
#21

#22



#23

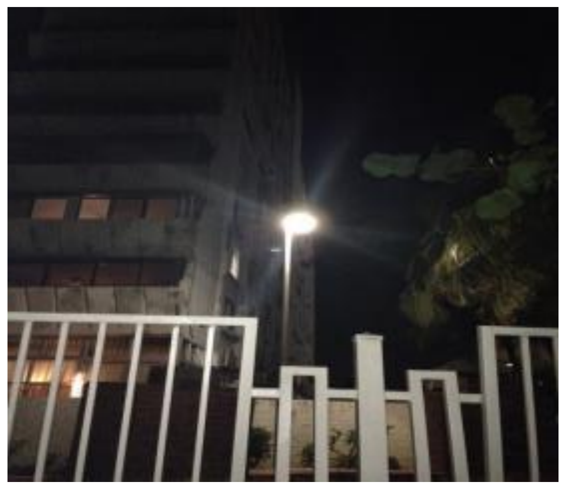
#24



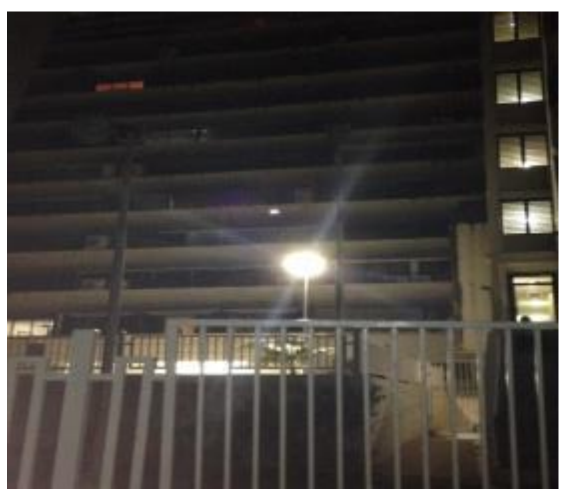
#25

#26

#27



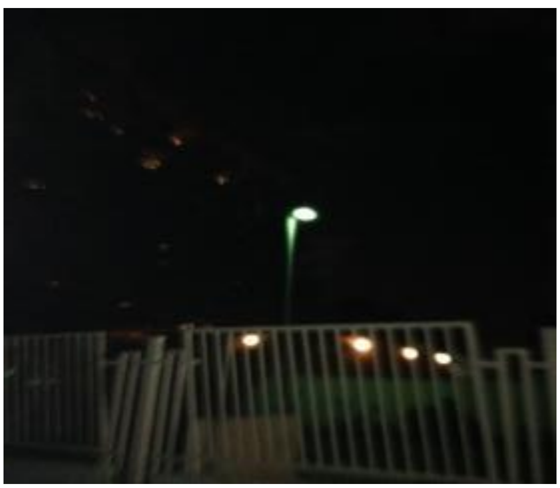
#28



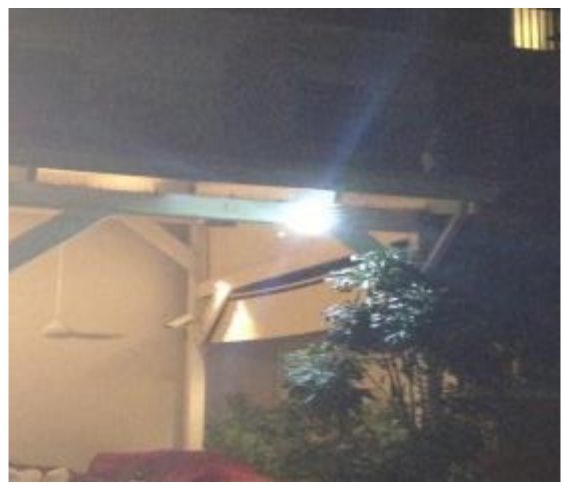
#29

#32

#30

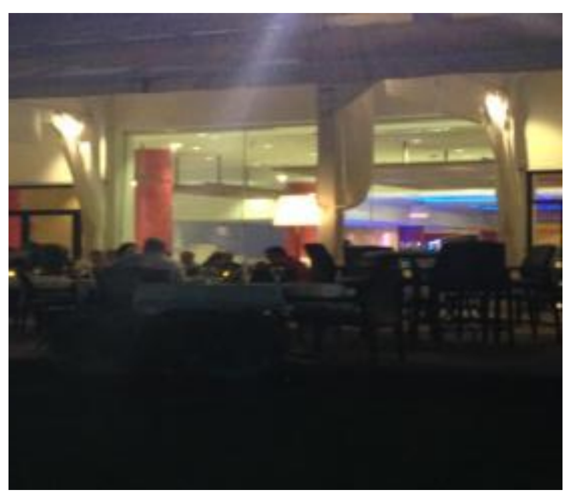


#33



#31

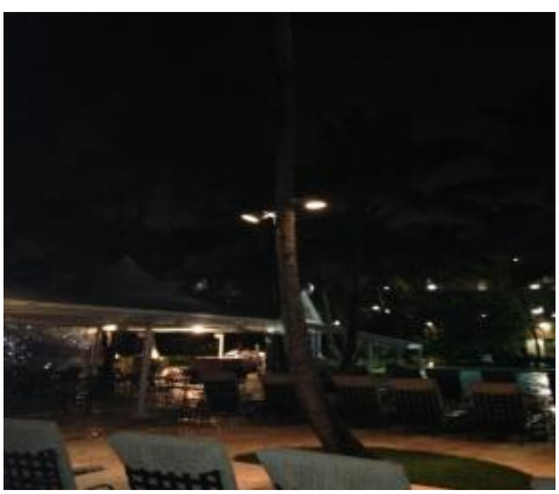
#34



#35

#36

#37



#38

#39

#40

#41

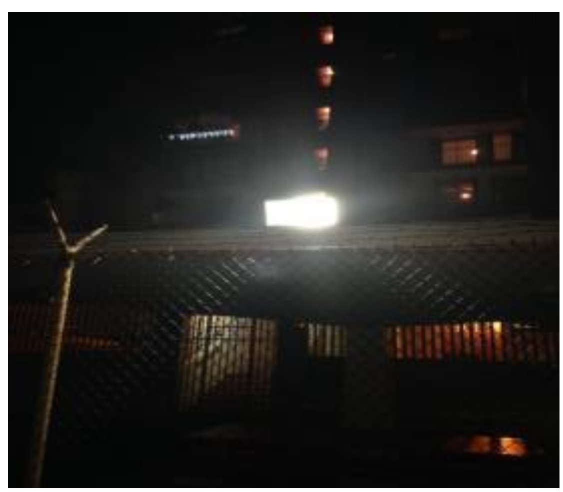
#44

#42

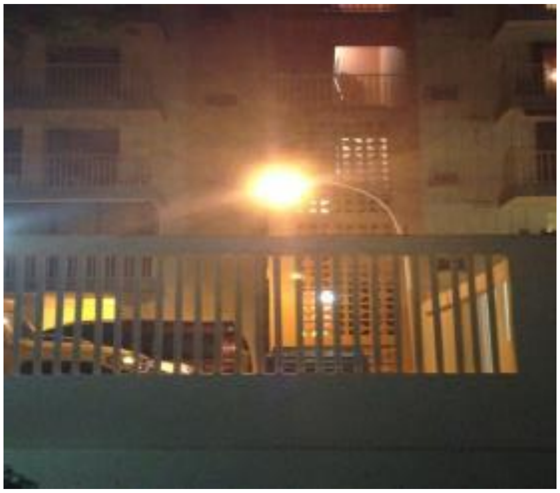
#45

#43

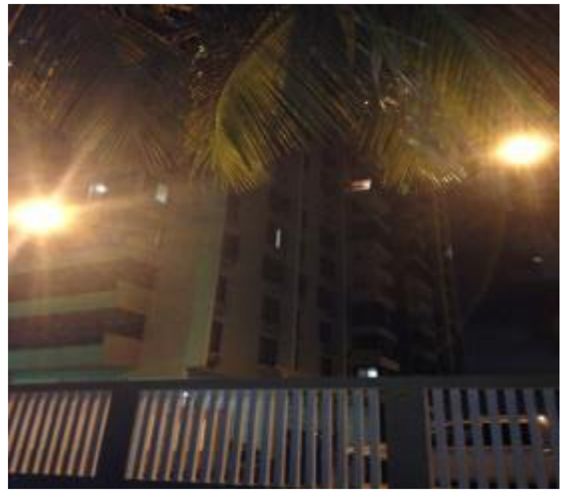
#46



#47



#50

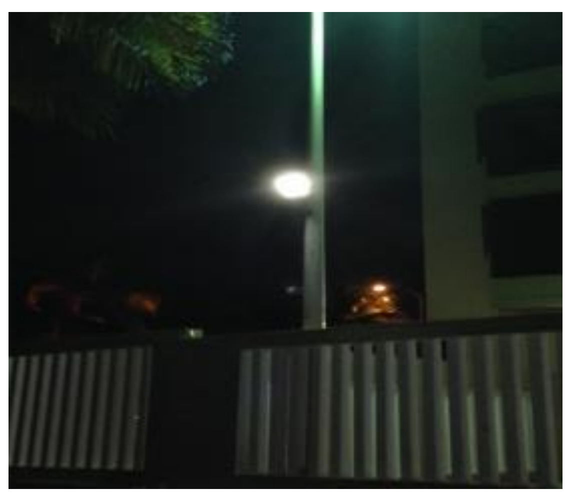


#48

#51

#49

#52



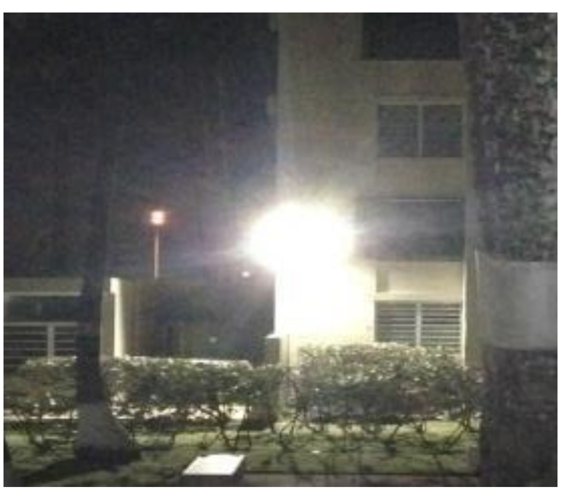
#53

#56

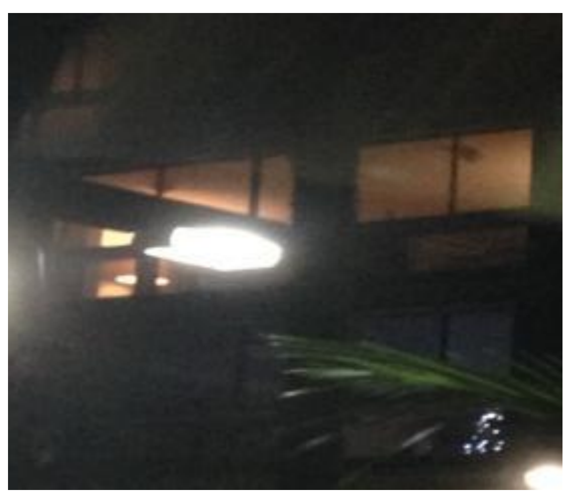
#54

#57

#55

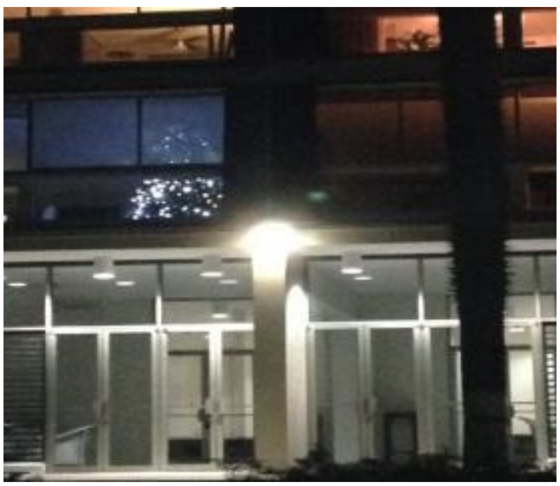


#58

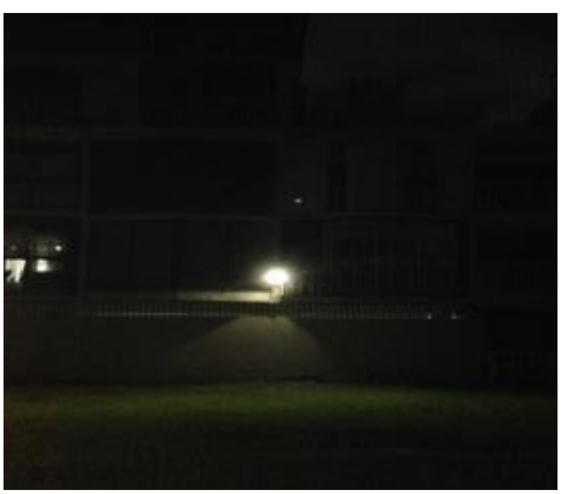


#59

#60



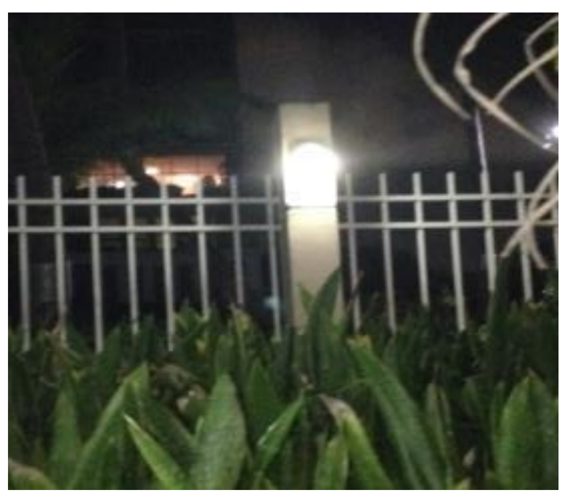
#61



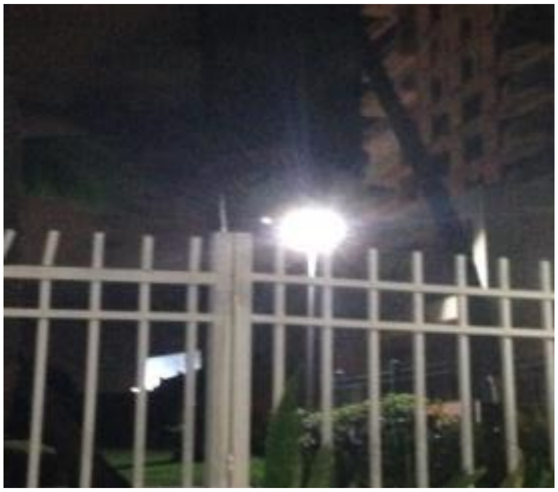
#62

#63

#64



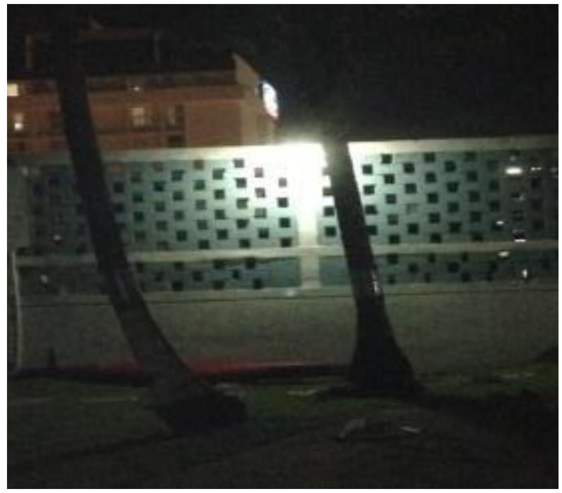
#65



#66

#67

#68



#69

#70

#71

#72

#73

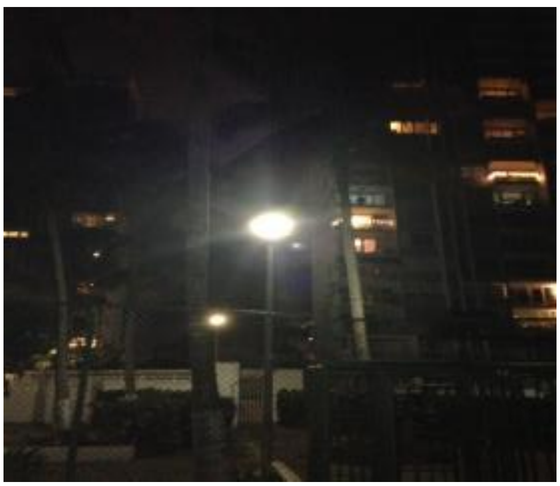
#74

#75

#76

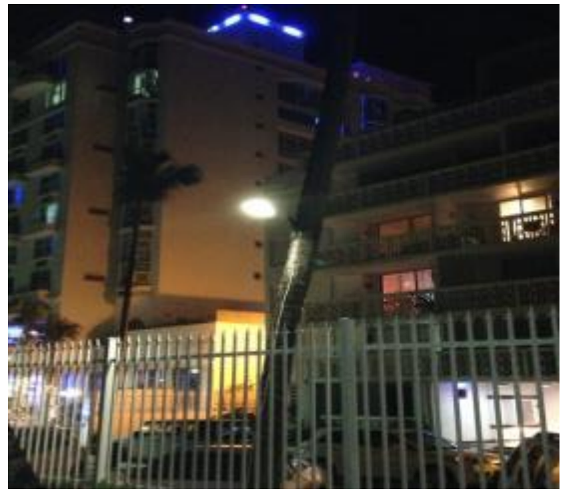
#77

#78



#79

#80



#81

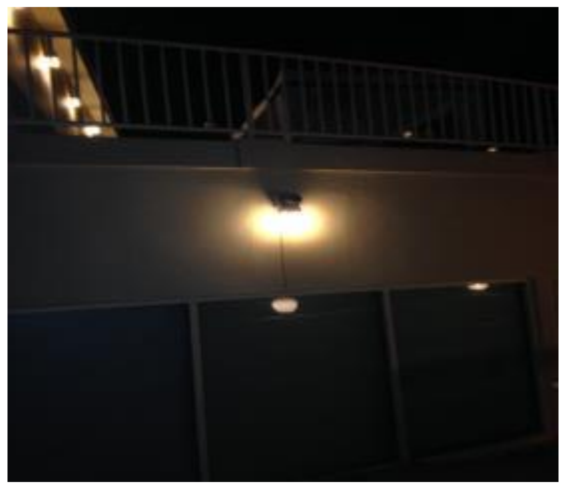
#82

#84

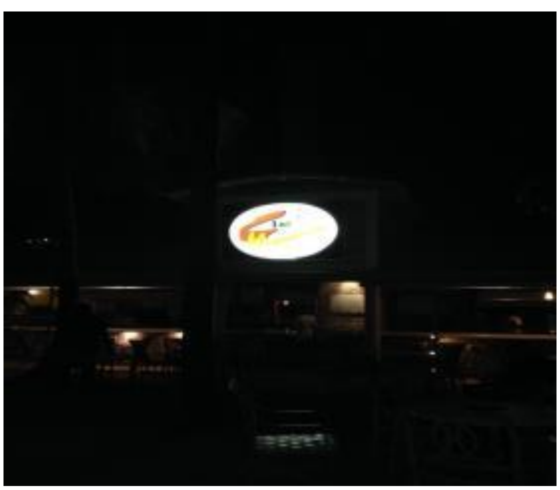
#87

#85

#88



#86



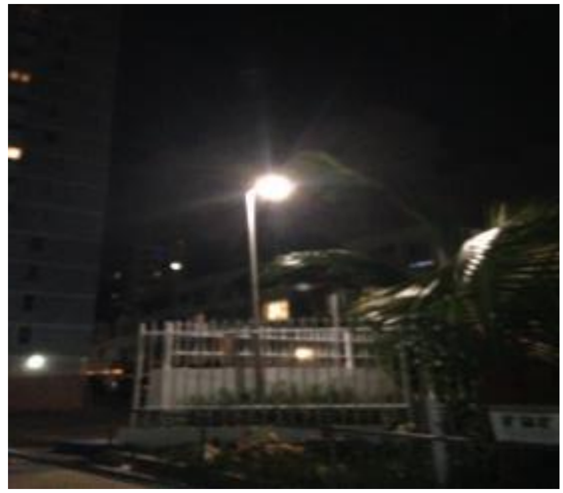
#89

#90

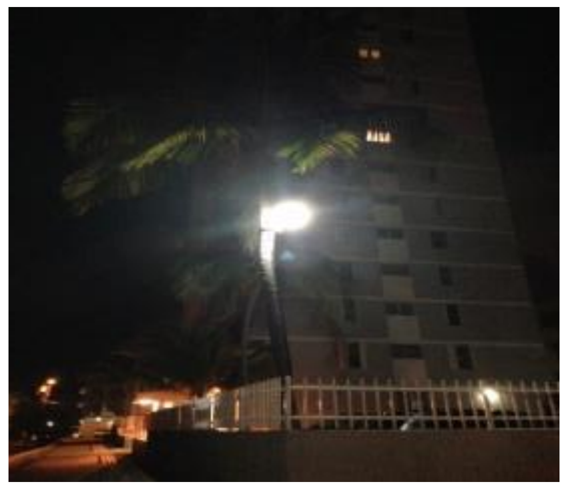
#91

#92

#93



#94



***83 Missing Picture**