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Light Pollution Levels on Beaches: How Window Tinting Effects Disorientation of Sea Turtles on Hilton Head Island

Kathryn (Kate) Hettiger
Augustana College, Rock Island Illinois

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Kate Hettiger

Senior Inquiry

Dr. Nicole Lindor

Augustana College

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Abstract

Loggerhead sea turtles, an endangered species, are decreasing at alarming rates worldwide. Artificial light from beachfront hotels on Hilton Head Island are causing disorientation in Loggerhead sea turtle hatchlings affecting their ability to successfully find the ocean. To mitigate this, exterior windows facing the ocean will be tinted using either tinting spray, which will be implemented at the Marriott Grande Ocean, or using tinting film, which will be implemented at the Marriott Westin. During the typical nesting and hatching season (May-October), sea turtle hatchling tracks will be recorded using drones to compare the effects of various levels of light pollution on degrees of disorientation. Following the tinting, it is expected that levels of light pollution on the beaches will decrease, allowing for more hatchlings to find the ocean successfully. These mitigation efforts are important to implement to increase the population of Loggerhead sea turtles on Hilton Head Island and eventually other endangered sea turtles and marine species.

Introduction

Almost 98% of sea turtle nests and surrounding areas were exposed to light pollution from coastal development (Fuentes, 2016). Consequences of light pollution, the presence of unnatural or artificial lighting, include negative effects on eating habits, physiology, reproductive ability, and rates of predation for sea turtles (Pothukuchi 2021, Harder 2002). Light pollution is becoming an increasing problem for animals as more human settlements are now along beaches, referred to as coastal squeeze. Coastal squeeze occurs when less beach area and animal habitat are available due to human urbanization on beaches (Biddiscombe 2020, Taylor and Cozens 2010). As beaches become popular vacation spots, more homes and hotels are being built along the coastline. It has been predicted that urbanization in the U.S. Southeast will increase by 139% by 2060. South Carolina coasts are projected to have the largest increase of urban area with an increase of 261% by 2060 (Terando et al. 2014). This increase is alarming for wildlife, in particular sea turtles, as habitats will be destroyed following the rapid urbanization of the area. It has been argued that sea turtles can and will adapt to changes caused by coastal squeeze in order to sustain their population but not without strain to their future generations (Biddiscombe, 2020).

Hotels and other developments are adding artificial light to beachfronts that disorient sea turtle hatchlings as they try to reach the ocean. While outdoor restaurants and seating areas seem to be playing a role in these rising rates of artificial light from hotels (Knowles et al. 2009, Lake and Eckert 2009), this experiment will not be looking at outdoor lighting but instead looking at lights coming from hotel rooms to see how important the impact these beachfront hotels have on sea turtles is. There are multiple other factors that can lead to disorientation of sea turtle hatchlings that are out of the scope of this experiment including lighting from cars or airports, stores, homes, as well as human activity, prevalence of predators and vegetation or erosion on

beaches (Arianoustou, 1998, Bourgeois et al. 2009, Silva et al. 2017). All of these factors are important in creating conservation efforts for sea turtles; however, light pollution is the biggest problem affecting them globally (Brei et al. 2016, Silva et al. 2017).

Sea Turtle Nesting and Hatching Processes

This study is interested in how disorientation and light pollution are related to nesting and hatching of sea turtles. Nesting usually takes place during the summer (April-September) at night (after 10pm until dawn) when the water is warmest, and the environment is the darkest and quietest to find a spot to lay eggs. Sea turtles are unable to avoid light polluted areas, as they are known to return to the beach they hatched on to lay their eggs. The turtle will then dig a hole to put the eggs in before covering them back up and disguising the nest from nearby predators. Females will lay three to five nests a season with around 100 eggs in each. Once all the eggs are laid and covered again, the mother heads back to the sea not to return until the next nesting season (NSU Florida, 2021). The mother uses the light reflecting off the ocean to orient herself once again toward the sea.

Once the eggs have fully developed, they will begin to hatch in the middle to end of summer until around October. This is the usual hatching period because in April, water temperatures begin to rise, signaling to the mother to begin her nesting process. After this is done, depending on the species of sea turtle, there are different incubation periods that must happen, with beach temperatures determining the sex of the hatchlings (NSU Florida, 2021). Around 80% of the sea turtle hatchlings eggs laid will hatch when the time comes (NSU Florida, 2021). These hatchlings tend to emerge from the nest all at once to increase their chances of survival against predators. Visual cues, such as the moonlight at night coming off the ocean, are imperative for them to find the ocean just as female adult sea turtles use moonlight after nesting.

They are searching for the brightest and lowest horizon, but oftentimes artificial light interferes with that, decreasing their chances of survival (Zheleva, 2012). When this happens, the hatchlings are disoriented and have a hard time finding their way to the ocean and instead follow the brightest source of light, which is typically inland.

Background on Loggerhead Sea Turtles

Of the different species of sea turtles, the endangered Loggerhead, *Caretta caretta*, has been observed to be easily disoriented. Loggerhead sea turtles are the second largest species of sea turtle just behind the Leatherback and can weigh upwards of 250 to 1,000 pounds. They are easily identifiable by their large heads and are known for their large jaws used to eat conch, bivalves, crabs, jellyfish, shrimp, sponges, fish, seaweed, and seagrass (National Geographic 2021, Figure 1). They are often found in the Atlantic, Pacific, and Indian Oceans along with the Mediterranean Sea. Focusing specifically on the United States, Loggerhead sea turtles are the most common species of sea turtles found in the country. They can be seen along the coastlines of North and South Carolina, Georgia, Alabama, and Florida (Plotkin and Spotila 2010). All of these areas are projected to see large increases in urbanization in the next 40 years (Terando et al. 2014) which will directly affect the Loggerhead sea turtle population as coastal squeeze will continue to destroy their habitats.

Ecological Impact of Loggerhead Sea Turtles

Loggerhead sea turtles are classified as vulnerable species, just one step down from endangered (World Wildlife Fund, 2021). Larger rates of failed sea turtle nesting and death of sea turtle hatchlings are being found worldwide due to light pollution. With the population of Loggerhead sea turtles already dropping from millions to the current estimated number being around 50,00, it is hard to ignore factors like light pollution that are contributing to lowering

these numbers. Lack of mitigation efforts against light pollution will negatively affect many different aspects of the marine ecosystem. Loggerhead sea turtles help maintain the health of coral reefs by eating sponges which allow for coral reefs to grow with less competition and maintain seagrass beds by extensively grazing reworking the marine sediment balance on the seafloor (Lovich et al. 2018, World Wildlife Fund 2021). With the integrity of coral reefs diminishing, it is imperative that Loggerhead sea turtles are in abundance to help maintain its health. Loggerhead sea turtles also help maintain the ocean floor sediment balance by creating foraging disturbances that actively rework the sediments (Lovich et al. 2018, World Wildlife Fund 2021). Alongside their status as a keystone species their ecosystem relies on them for survival by using their shells to create a habitat (National Geographic, 2021). They are also known to contribute energy within and between ecosystems in four pathways during nesting and hatching: to predators through ingestion, to land through detritivores, decomposers, and plants, to the environment through heat or gas exchange and to the ocean through hatchlings (Bouchard and Bjorndal 2000). The many attributes sea turtles bring to the marine ecosystem supports the need for mitigation efforts to help maintain the population of sea turtles.

Study Focus

This experiment will focus specifically on sea turtle hatchlings and how the light pollution affects their ability to successfully find the sea after hatching. This study will specifically be filling a gap in previous research because, to date, there are no known studies regarding Loggerhead sea turtle disorientation in North America. It is also furthering research regarding light shielding by studying the effects of window tinting at hotels as an effective method of mitigation of light pollution on beaches. Lastly, it will be using a new method to collect sea turtle hatchling tracks and patterns of disorientation using drones rather than by hand

like other studies. The study hypothesizes that artificial light from hotels on Hilton Head Island's beachfront will affect the success of Loggerhead sea turtle hatchlings reaching the ocean. However, tinting exterior windows at beachfront hotels using both film and spray can help mitigate the effects of light pollution on these turtles.

Materials and Methods

Study Area

This experiment will be on Hilton Head Island in South Carolina. Hilton Head Island was chosen because of the gap in research about artificial light in this region and what mitigation efforts can be put into place to help sea turtles most effectively during nesting and hatching season. The Marriott Grande Ocean Hotel on Alder Lane beach and Marriott Westin Hilton Head Resort and Spa on Islanders beach will be the two hotels of focus for this study (Figure 2). The study area will span the length of five nests from each hotel. These locations were chosen because Loggerhead sea turtles are known to nest on these beaches in Hilton Head Island and both hotels are some of the larger, more busy hotels on the island as well as are on the more populated beaches compared to some of the others on the island. The Westin was chosen because the hotel has already implemented exterior film on its new outdoor event center to reduce artificial light coming from their property (Hilton Head Insider, 2018). As a control, five nests on Burkes beach will also be studied. Burkes beach is uninhabited along the beachfront thus will have low levels of artificial light that can directly affect sea turtles (Figure 2).

It is important to note that in the town of Hilton Head, there are already mitigation efforts in place to help protect the sea turtles that come to their shores. The most important one to make note of is the light ordinance put in place. They require that all outdoor lights are turned off or covered by 10 pm each night until 6 am during nesting and hatching season from May through

October. It is also recommended that all blinds in houses are closed from 10 pm to 6 am during nesting and hatching season as well. There are fines from the town associated with noncompliance (Hilton Head Insider, 2018). While this shows the care the town already has for sea turtles, it could skew the results of the study. With this ordinance, the study is being conducted in an area with some level of protection already put in place for sea turtles against artificial light which may not be the case in other places where the study may be replicated. This does, however, allow for a conservative estimate of disorientation in the area, but will suggest if more efforts still need to be put in place to effectively lower the levels of light pollution and disorientation of sea turtles long-term. It is the hope that this light ordinance coupled with the window tinting method implemented in this study will positively affect the success rates of sea turtle hatchlings reaching the ocean and increase the Loggerhead population on Hilton Head Island and eventually nesting sites worldwide.

Recording Sea Turtle Tracks

Throughout hatching season, Loggerhead sea turtle tracks will be recorded. In previous studies, sea turtle tracks were collected by mapping the tracks by hand at dawn every morning during hatching season (Bourgeois et al. 2009). This method was found to be time consuming and have high levels of variability, but a drone can efficiently and accurately collect this same data (Dimitriadis et al. 2017). With that, this study will be done using a drone that will be deployed every morning at dawn from July to October. Drones have previously been used to take photos of the sea rays in the ocean to help track their migration and movement patterns. Images taken from an altitude of up to 55 m were processed using a system called ImageJ that can take different measurements of the sea rays directly from the photos provided. The drones used previously were DJI Mavic Pro quadcopter drones that were flown using the DJI GO app on a

smartphone (Oleksyn et al. 2020). Drones have also been used to track sea turtles. DJI Phantom 3 quadcopter drones were flown using the DJI GO app on a computer to track the mating patterns and sex distribution of sea turtles. From altitudes of 10 to 100m the drones were able to successfully track and differentiate not only the sex of the sea turtle but also the difference between adult and juvenile sea turtles (Schofield et al. 2017, Figure 4).

This study will use a combination of methods from multiple. A DJI quadcopter drone will fly over Alder Lane beach, Islanders beach, and Burkes beach at altitudes of 25 and 50m to ensure the clearest photos are taken. This will be done at dawn each morning during the nesting and hatching period, assuming weather does not hinder the ability to successfully execute this. Weather conditions are an important limitation to this study to address as it can affect the ability of drones to be used to record sea turtle hatchling tracks. In the case of high winds, rain, or other inclement weather. To address this, researchers will still plan to collect this data on days of inclement weather but understand that some results may not be as clear as those one days with better weather conditions.

The images will then be analyzed using ImageJ to differentiate patterns and signs of disorientation from those unaffected within the sea turtle tracks (Figure 3). Disorientation can be seen when the tracks of the sea turtle hatchlings go in the wrong direction from the sea (inland) or when tracks go in circles (Dimitriadis et al. 2017). This will be compared to unaffected sea turtle hatchling tracks, meaning that they take the shortest path to the ocean from their nest. The data collected from ImageJ will later be used to graph the number of stray tracks and number of disoriented sea turtles in correlation to the amount of artificial light from the three different beaches being studied (Figure 5). This new method using drones was chosen due to the high

variability associated with counting tracks by hand and the relatively low costs and availability that come with using the types of drones mentioned in previous studies.

Light Pollution Measurements

This experiment will be measuring artificial light on the three beaches and determining the amount of light pollution present in each. This will be done using a portable light meter and GPS. The coastal light coming from the hotels and skyglow visible from the beaches will be noted using the GPS, while the measurements of light intensity, in units of lux, will be taken using the portable light meter (Dimitriadis et al. 2017). The levels of artificial light will be measured and recorded at each of the three beaches (Alder Lane beach, Islanders beach, and Burkes beach) the second week of the month from May through October. Measurements will be recorded from 10pm until dawn as done as this is when most turtles would be active.

Mitigation Efforts Using Window Tinting

To test the effects of light pollution reduction on these beachfronts, windows will be tinted in all windows facing the beach at both hotels. At the Marriott Grande Ocean, tinting spray will be used on the exterior of all windows that face the ocean. The spray that will be used is the cheapest option for window tinting, is permanent, and is easy and quick to apply (Marsell, 2017). At the Marriott Westin, tinting film will be used on the exterior of all windows that face the ocean. The film being used will be solar window film that provides privacy, reduces energy usage, reduces heat let in, protected against UV rays and infrared light all while still allowing in natural light. This film usually lasts seven to twelve years (RC Window Films, 2021). When putting the tinting material on the exterior of windows, rather than interior, it can help to protect the windows from weather damage for many years that, in the long term, will be cost effective for hotels (RC Window Films, 2021). A limitation associated with this process may include

variability within the installation process of window tinting. To account for the lowest levels of variability, the company being used to install these window tintings will be asked to use the same people each day and each will be assigned a section of windows to oversee the application of tinting so variability can be controlled by the section of the hotel.

By implementing spray and film, it examines if both types of exterior window tinting are effective in dampening the effects of light pollution. This can fill a current gap in research because no current studies have examined the effects of these two types of exterior tinting at hotels to determine how it affects sea turtle disorientation. Determining the effectiveness of these two types of window tinting can establish how it should be used on hotels and housing all along the beachfronts in Hilton Head Island-not just at these two hotels. This method, if successful, could also be used at hotels globally that are on beachfronts as well as any other establishments built on beaches. The hotels would not be responsible for the expenses as part of taking part in the experiment. All the rooms and windows would be properly prepared prior to May 1 to ensure the experiment can start when nesting season begins.

After installation of the window tinting at the two hotels and beginning the second week of May, light pollution levels will be taken in the same way as they were taken previously, during the second week of the month from May through October from 10pm until dawn. The data will be measured and recorded and then compared to the sea turtle hatchling track patterns and disorientation levels to determine the effect of reduced artificial light on turtle disorientation (Figure 5).

Statistical Analysis

To summarize, the information collected from the amounts of light pollution along with the sea turtle tracks and levels of disorientation will be compared (Figure 5). As seen in a

previous study, the relationship between light pollution and stray tracks of sea turtle hatchlings will be assessed (Dimitriadis et al. 2017). Photographs taken from the drones shown with the analyzed data from ImageJ will also be provided to aid the experiment (Figures 3 and 4). All the data will be compared to the control on Burkes beach in a table to determine if both methods are effective or could be used more globally moving forward. The results of the study will help further mitigation efforts of light pollution on sea turtles on Hilton Head Island in the future.

Expected Outcomes

It is expected that by tinting windows in hotel rooms facing beaches, less artificial light will be reflected onto the beach, thus less sea turtle hatchlings will become disoriented while trying to find the sea. The hatchling will be able to find the ocean using visual cues from the moon which can in turn increase the population of Loggerhead sea turtles. It is also expected that the public will support the proposed changes and will be willing to help pay for these mitigation efforts if their beach experiences are not tainted (Sayan et al. 2011).

Previous Studies

This experiment is the first of its kind in using window tinting spray and window tinting film on exterior windows on beachfront hotels to dampen the effects of light pollution. Past studies have shown a multitude of different methods used to mitigate the effects of light pollution. Some previous studies looked at the effects of sodium lighting and different colored lights including yellow, orange, and red. Low pressure sodium lamps emitting yellow wavelengths have been found to not disorient sea turtles like regular lights do (Harder, 2002). The turtles were not distracted by light at this wavelength thus it could be useful in spots where light is easily seen on beaches. But this would only be useful for sea turtles as it was determined that other animals were still distracted and disoriented by this light. On the other hand, it has

been found that yellow and orange lights disoriented nesting female Loggerhead sea turtles and disrupted their ability to find the sea. It was also found that red light neither hurt nor helped the nesting sea turtles (Silva et al. 2017). It would then be worth testing this hypothesis about yellow lights in another study area to determine definitive results regarding its effectiveness. It can be expected that this is not the most effective method in trying to mitigate the effects of artificial light on sea turtles, while instead, window tinting at major hotels along beaches is expected to be more effective.

Another mitigation effort tried the use of informational pamphlets in hotels to educate guests about the effects of light pollution on sea turtles. This method was found to be ineffective as many guests found the approach to be nonpersonal. Due to this fact, they did not pay attention to the pamphlet or its content no matter how important it was. Those who did look at the pamphlet felt no personal connection to the material and believed there was no difference they could make in the short time they were visiting (Mascovich et al. 2018). Overall, it was determined that informational pamphlets about light pollution and sea turtles are relatively ineffective, whereas adding exterior window tinting at hotels prevents the guests from having to act themselves each night to prevent light from potentially disorienting sea turtle hatchlings.

The information and results from previous studies further justify why window tinting can be an effective method for mitigating the effects of light pollution on sea turtle hatchlings. While studies did result in minor changes, it can be expected that the tinting will make the largest and longest lasting impact on these animals with the least amount of human interaction. This can be expected because the tinting will be able to block a major source of artificial light on beaches while also being cost effective. Exterior film tinting would be expected to last for 7-12 years

while exterior spray tinting is permanent, making these solutions long term (Marsell 2017, El Kacemi).

Conclusions

Results would show disorientation of loggerhead sea turtle hatchlings is expected to decrease following the addition of tinting material to the windows at hotel beachfronts. This would then create better opportunities for the hatchlings to successfully find the sea after hatching. By decreasing the amount of artificial light on beachfronts, the success of sea turtle hatchlings finding the sea will increase so the population of sea turtles is expected to increase. This could, in turn, help move Loggerhead sea turtles, and eventually other species of sea turtles, off the endangered species list. As the number of Loggerhead sea turtles increases, their ability to maintain the health of coral reefs and seagrass beds, rework and maintain ocean floor sediment balance, create habitats for other plants and animals, and exchange energy within and between ecosystems increases (Lovich et al. 2018, Bouchard and Bjorndal 2000).

Future Research and Possible Solutions

How can the results of this study and work of other studies bring ideas for future research within this area? Assuming the success of this study, future studies could apply the same principle of light shielding at hotels. This could even go as far as homes and other establishments along beaches. A future study could look at the effects of the same window tinting on sea turtle nesting rather than hatching. It has been shown that artificial light and light pollution affect female sea turtles while coming to shore for nesting (Silva et al. 2017). It can be assumed that the same light shielding at hotels used to mitigate effects on hatchlings can be successful in this way. As mentioned previously, another future study could include mitigating the effects of light pollution from outdoor restaurants and event areas along beaches, particularly from hotels on

these beachfronts (Knowles et al. 2009, Lake & Eckert 2009). This could be done using the same window tinting method from this study, or other avenues could be assessed to find the right solution for that area.

There is some research regarding migration patterns of adult Loggerhead sea turtles in South Carolina moving both north and south along shorelines (Plotkin and Spotila 2010). But it was unknown why some migrated north, rather than south like most of their counterparts. That brings about questions of how these turtles are genetically different and what role that plays in these migration patterns. With this, researchers propose that conservation efforts and plans of protection for the creatures should span to these more northern areas, as these migration patterns are not often recognized (Plotkin and Spotila 2010). The success rate of sea turtle hatchlings following their successful journey to the sea could also be assessed with more reliable methods of tracking. This could mean tracking the turtle after hatching in its first couple years of life using something other than a tag on its shell as that was proven to have multiple drawbacks and unaccounted complications (Abalo-Morla et al. 2018). This could provide quantitative results of how many hatchlings survive and what types of migration patterns they take following their hatching. There is very little known about sea turtle hatchling migration patterns, however, as the first study to be done using trackers on shells of hatchlings was conducted in 2018. Other factors are known to affect sea turtle hatchling success in making it to the sea. These include the amount of debris found on beaches ranging from cigarette butts to straws to plastic fragments and the natural environment and landscape of nesting beaches meaning the presence or absence of dunes, other beach vegetation, or other obstacles (Ivar et al. 2011).

The effects of lighting on beaches with different wavelengths and how that contributes to disorientation of sea turtle hatchlings could also be investigated further (Simoes et al. 2017).

Further research could be done pertaining to the use of drones to gather tracking information, but instead of for sea turtles, other endangered species. The method is very low cost and requires very little work to be done by humans compared to manually counting like in other studies. This method has a potential for very promising use on a large scale, thus it could be used for many other types of marine species and endangered species from many different areas. All these proposed future studies could be tested in conjunction with the proposed light shielding or window tinting to compare rates of success. Looking at mitigating these factors, and in particular artificial light, can help determine what further steps can or need to be taken to increase the sea turtle population survival.

It has been shown that once tourists and beach goers are aware of the ongoing problems facing sea turtles and how mitigation efforts could be put in place to combat them, they were more willing to pay for conservation efforts. Through the use of questionnaires in Turkey, researchers have been able to assess the knowledge tourists have about the connection between tourism and sea turtles. The same group of tourists in Turkey were sent a follow up survey regarding their willingness to pay for conservation efforts on beaches (Sayan et al. 2011). This is just one example of humans being willing to take the steps to affect change for sea turtles. Further studies could assess this same willingness in different countries and on different beachfronts to help justify immediate and long-term mitigation efforts. But these studies showed that there is a very strong correlation between tourism and conservation efforts, so the willingness of humans to pay for mitigation efforts is a step in the right direction toward change.

A connection between ecotourism and conservation efforts regarding sea turtles has also been identified. Ecotourism in this context is tourism but the tourists have a special interest in learning about the species, area, and efforts to help conserve their habitats. In Tortuguero, Costa

Rica, ecotourists were concerned with conserving the beaches to ensure sea turtle nesting and hatching success. They were also willing to pay for things like admission to the park, packets, and more when the money goes toward sea turtle conservation on the beach they are visiting (Meletis et al. 2010). As in Turkey, this shows the important relationship between sea turtle conservation efforts and tourism.

While it is important that humans are willing to contribute and pay for conservation efforts, the effects of light pollution on sea turtles can be extremely costly. It has been estimated that around 1,800 sea turtles in the Caribbean alone have been lost due to light pollution in the past two decades, with numbers rising in recent years (Brei et al. 2016). Based on money spent on raising sea turtles in captivity, it is estimated that $288 million would be spent on conservation efforts to combat this loss of sea turtles from light pollution. This number was found based on the spending amount for each sea turtle if the egg were brought into captivity and the sea turtle was released into the wild later in their life cycle (Brei et al. 2016). By raising the sea turtle in captivity, it eliminates the effects of light pollution and thus increases survival rates, which is particularly useful for sea turtles as most species are already endangered (Brei et al. 2016). Although studies have shown humans are willing to contribute money for conservation, with estimates of how much money needs to be spent in the Caribbean alone, it can be assumed that conservation efforts against light pollution will cost humans large amounts of money if behaviors are not changed. All of these are possible solutions that can be implemented to lower the effects of light pollution on sea turtles and in turn increase their population over time, moving them off the endangered species list.

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Appendix

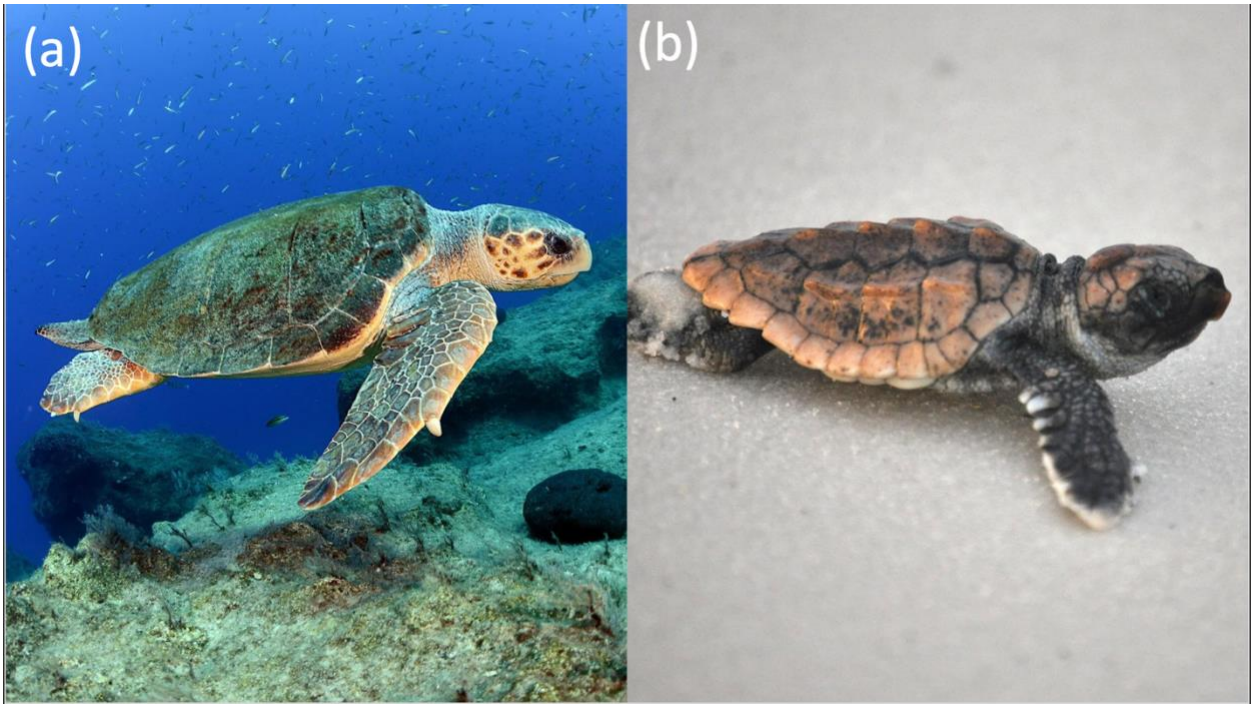

Figure 1. Images showing *Caretta caretta* or better known as a Loggerhead sea turtle. (a) Image of an adult Loggerhead (DHA, 2021). (b) Image of a hatchling or juvenile Loggerhead (Echols, 2013).

Figure 2. Images showing the beaches, along with the hotels, being studied on Hilton Head Island. (a) Image of Marriott Westin Hilton Head Resort and Spa on Islanders beach (Hilton Head Island Hotel…, 2021). (b) Image of the Marriott Grande Ocean Hotel on Alder Lane beach (Marriott's Grande Ocean…, 2021). (c) Image of Burkes beach, the control beach with no hotels (Burkes Beach Hilton Head, 2021).

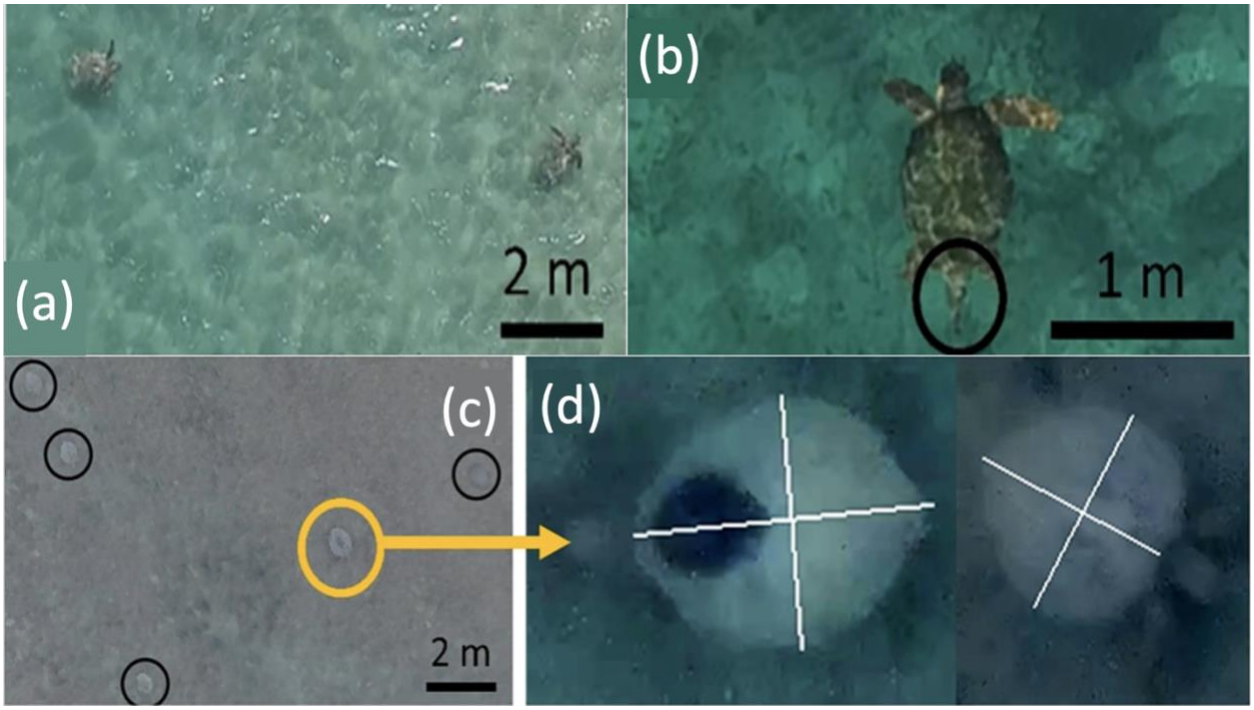

Figure 3. Images showing the use of drones to record sea turtles and use of ImageJ to analyze those photos. (a) Image of sea turtles in the ocean taken from a drone at 60m. (b) Zoomed image distinguishing a male sea turtle taken from a drone. (c) Image showing circled sea turtles helping to estimate population size. (d) Analysis of shape and measurements of sea turtles from image (c) using ImageJ. (Schofield et al., 2019)

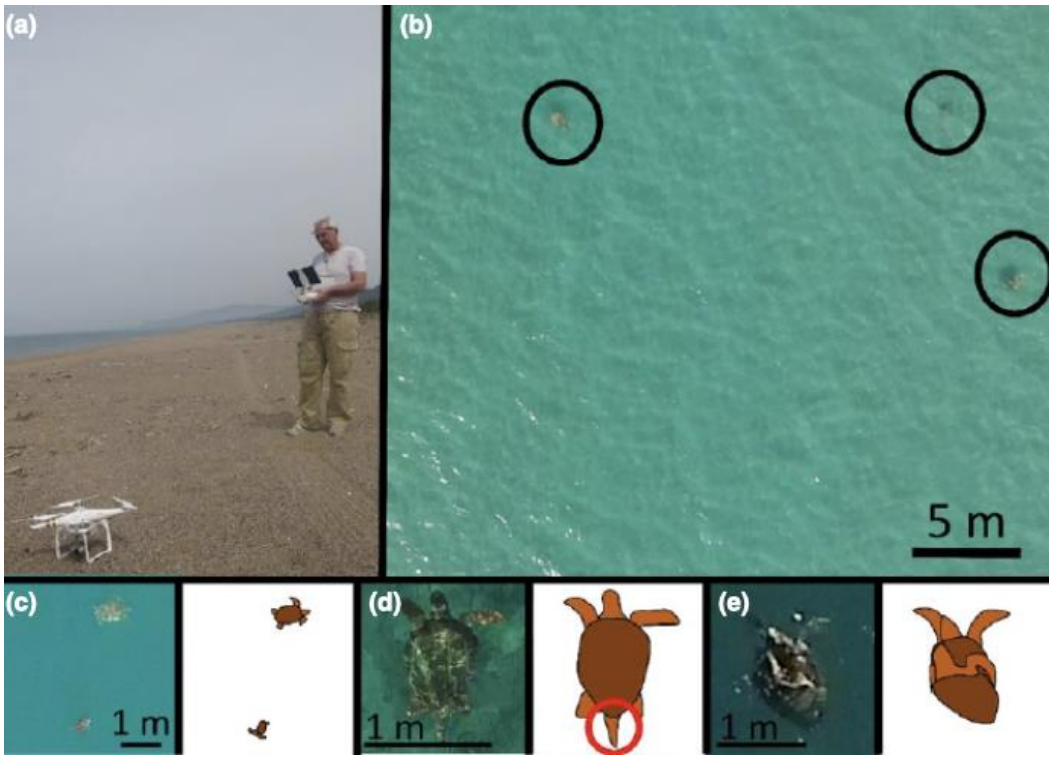

Figure 4. Images showing how drones can be used to identify sea turtles in the ocean. (a) Image showing the drone being used to track sea turtles in the ocean. (b) Image of sea turtles taken from the drone at 30m. (c) The zoomed image on the left is showing sea turtles taken from the drone and the image on the right is showing a computer recreation of the drone image showing the difference between an adult sea turtle (top) and hatchling (bottom). (d and e) The zoomed images on the left of both (d) and (e) are showing sea turtles taken from the drone and the images on the right are showing a computer recreation of the drone image showing the difference between male (d) and female (e) sea turtles. (Schofield et al., 2017)

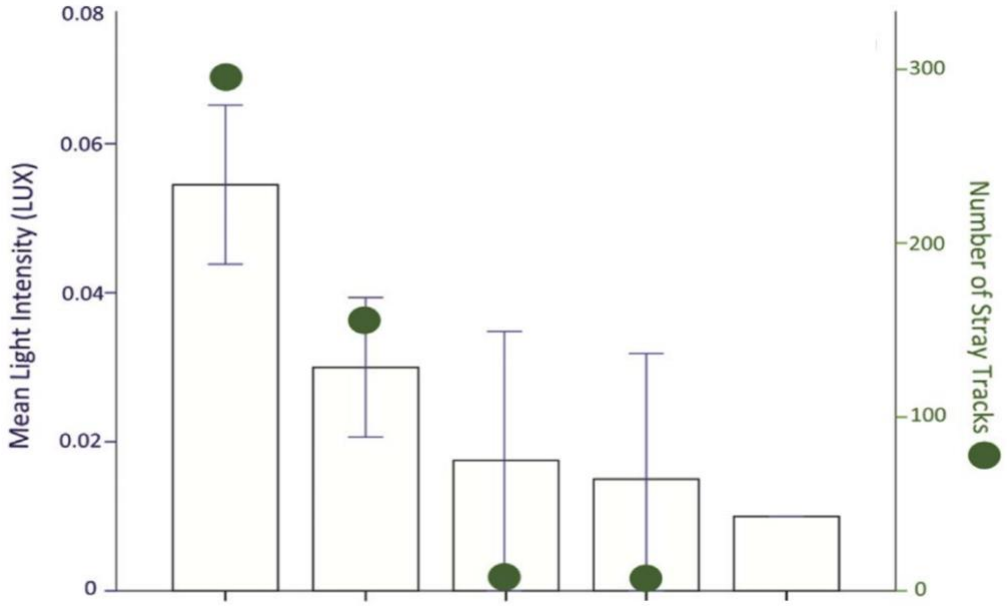

Figure 5. Bar graph demonstrating correlation between the number of stray tracks (indicating disorientation) from sea turtle hatchlings and amount of light pollution. The highest number of stray tracks were observed in areas with the largest amount of artificial light. (Dimitriadis et al., 2017)