Effects of Light Pollution on Loggerhead Sea Turtle (*Caretta caretta*) Nesting Behavior in Georgia and South Carolina

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Abstract:

Loggerhead sea turtles (*Caretta caretta*) are a species of endangered sea turtle, whose nesting and hatching success can be hindered by light pollution. We hypothesize that beaches with lower light pollution levels will have higher nesting success, i.e. higher number of nests, higher ratio of nests to false crawls, higher nest success, higher beach success, and lower nest relocation percentage. Using data from SeaTurtle.org and the 2015 VIIRS light data, we analyzed the effects of light pollution on loggerhead sea turtle nesting behavior. We performed a series on linear regressions to examine the relationship between light pollution and six sea turtle nesting success variables. We found a significant positive relationship between light pollution and the ratio of nests to false crawls, and a significant positive relationship between light pollution and the nest relocation percentage. The other four linear regressions were not statistically significant. However, low R^2 values indicate that light pollution does not explain much of the variation in these nesting success variables, and further studies should be conducted to investigate sea turtle nesting behavior.

Introduction:

Loggerhead sea turtles (*Caretta caretta*) are a species of endangered sea turtle in oceans throughout the globe (Berry et al., 2013). When reproductively mature at 35 years old, females will come ashore to lay their eggs (Lasala et al., 2013). One major impedance to both egg laying and hatching success is beachfront light pollution. Light pollution is chronic or periodic artificial increased illumination of the sky (Longcore and Rich, 2004). Light pollution is also a good proxy for urbanization (Zhang and Seto, 2011). It has also been documented that cloud cover can increase the intensity of light pollution (Kyba et al., 2011). The light pollution at the coasts have been increasing in intensity since the early 1990s (Kamrowski et al., 2014). To deal with this issue, many coastal communities are adopting lighting ordinances to reduce the ecological consequences of light pollution (Lake and Eckert, 2009).

Loggerhead sea turtle hatchlings are attracted to light between the wavelengths of 350 nm (UV) – 600 nm (red), and will approach the light (Fritsches, 2012). Hatchlings use the moonlight on the waves to find the ocean, but the urban light pollution can confuse the hatchlings, causing them to crawl inland rather than to the ocean (Lorne and Salmon, 2007; Pendoley and Kamrowski, 2016). Furthermore, this artificial light pollution can lead to change in nesting behavior, including increased chances of false crawls and laying nests lower than the high tide line, leaving the nest vulnerable to be submerged at high tide (Witherington, 1992).

Our question of interest is how does light pollution affect the nesting behavior of female sea turtles? We hypothesize that beaches with lower light pollution levels will have higher nesting success, i.e. higher number of nests, higher ratio of nests to false crawls, higher nest success, higher beach success, and lower nest relocation percentage.

Methods:

1. Nesting Data

The nesting data came from data collected for and reported by SeaTurtle.org (SeaTurtle.org, 2015). We chose to use the nesting statistics for all sites in Georgia and South Carolina, which amounts to 56 total sites analyzed. Georgia sites are reported by Georgia Department of Natural Resources and South Carolina sites are reported by South Carolina Department of Natural Resources.

Certified personnel who are trained by the respective Department of Natural Resources collect the data for SeaTurtle.org. Every morning, each site is monitored for turtle tracks from nesting females and emerging hatchlings. Nesting female tracks are followed to determine if a nest was laid or if it was a false crawl. If a nest cavity is identified, then a stick is used to probe for eggs to verify the presence of a nest. If a nest is identified, then it is up to the area director to decide if the nest needs to be relocated; nests are relocated if there is too much ambient light or if the nest is below the high tide line. Five days after the initial emergence of the hatchlings from a nest, the nest is excavated to determine how many eggs were laid and how many hatched and if the un-hatched eggs were fertilized or not.

2. Light Pollution Data

The light pollution data is from a Bing light pollution map using VIIRS satellite data (Bing, 2015). We categorized the level of light pollution at each site by assigning the site to a light pollution bracket using the maximum light levels indicated on the map. The brackets are as follows: low (0.0-1.0 nW cm^{-2} sr^{-1}), medium (1.0-6.0 nW cm^{-2} sr^{-1}), high (6.0-40.0 nW cm^{-2} sr^{-1}), and very high (>40.0 nW cm^{-2} sr^{-1}). Due to the fact that the map is colorimetric, we assigned the following light values for the various brackets: 0.5 nW cm^{-2} sr^{-1} for low, 3.0 nW cm^{-2} sr^{-1} for medium, 20.0 nW cm^{-2} sr^{-1} for high, and 40.0 nW cm^{-2} sr^{-1} for very high.

3. Statistical Analysis

Because all of our data are numerical, and our goal is to see how light pollution influences various factors related to sea turtle nesting behavior and success, we performed linear regression analysis on each nesting behavior variable with light pollution levels. Before any analysis was performed, we checked the residual plots for each nesting behavior variable, and found that all residuals were centered around zero, and there was no obvious trend in the residuals. After checking these residuals plots, we tested whether these was a significant relationship between light pollution and the nesting behavior variables, and used a 0.05 level of significance for the linear regression analysis.

Results:

From our linear regression analysis, we found that there is a slight negative but not significant correlation between light pollution and the number of nests on a beach ($T = -1.533$, $p = 0.131$, $R^2 = 0.04168$, Figure 1A). We also found that there is a negative relationship between the light pollution and the number of false crawls on a beach, but the p-value was also not significant ($T = -1.231$, $p = 0.2238$, $R^2 = 0.02728$, Figure 1B). Our analysis also revealed that there is a significant positive relationship between light pollution and the ratio of the number of nests to the number of false crawls for a beach ($T = 3.010$, $p = 0.00397$, $R^2 = 0.1436$, Figure 1C). We also found a slight positive correlation between light pollution and nest success, but this p-value was not significant ($T = 1.816$, $P = 0.0749$, $R^2 = 0.05755$, Figure 1D). Our analysis showed a small positive correlation between light pollution and beach success, although this p-value was also not significant (T = 1.731, p = 0.0891, R^2 = 0.05259, Figure 1E). We found that there is a significant positive relationship between light pollution and nest relocation percentage (T = 2.496, p = 0.0156, R^2 = 0.1034, Figure 1F).

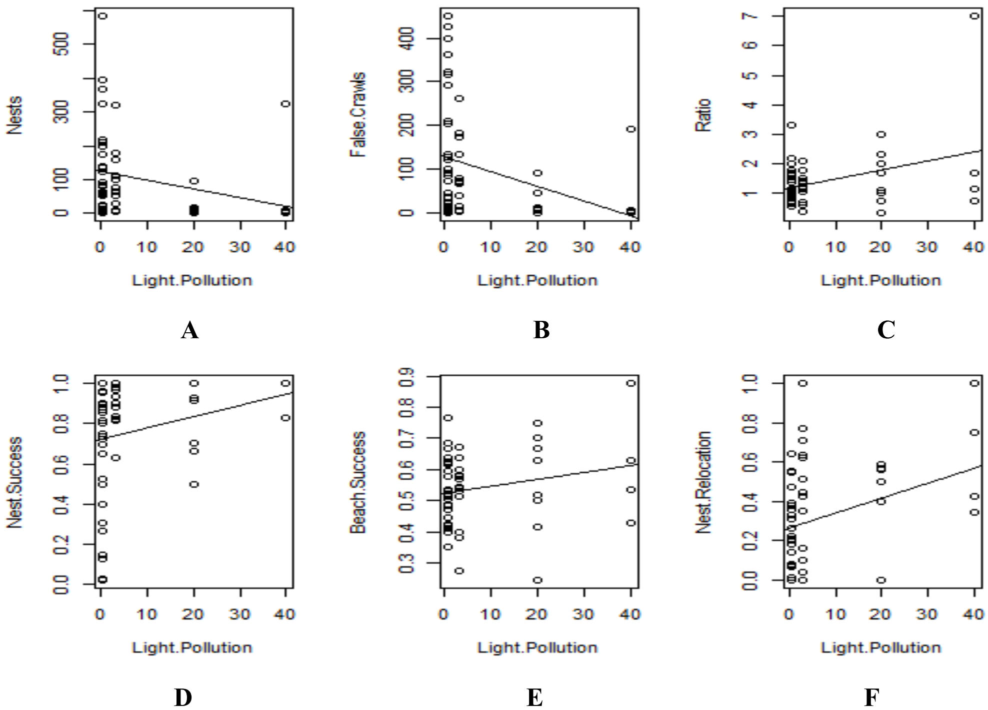

Figure 1: Each nesting behavior variable is plotted against Light Pollution data. A) shows the number of nests, B) the number of false crawls, C) the ratio of nests to false crawls, D) the nest success percentage, E) the beach success percentage, and F) the nest relocation percentage.

Discussion:

From our analysis, we got many results that did not agree with our hypothesis that increasing light pollution would have a negative impact on sea turtle nesting behavior. We found that as light pollution increased, the number of nests found on the beach increased, the number of false crawls decreased, the ratio of nests to false crawls increased, nest success increased, beach success increased, and nest relocation increased. However our only statistically significant results were the relationships between light pollution and the ratio of nests to false crawls and the percentage of nest relocations. We expected the ratio of nests to false crawls to decrease as light pollution increased, but we saw the opposite relationship. This might be related to the fact that beaches with more light pollution were typically larger, so there could have been areas of the beaches that did not have as much light pollution as quantified in our study. The positive relationship between light pollution and nest relocation percentage was expected. This is because it is more likely for sea turtles to lay nests in less suitable environments in beaches with higher light pollution, so more nests would need to be relocated.

For all of the linear regressions, the R^2 values are very low, ranging from 0.02 to 0.14. This indicates that only a small amount of the variation seen in the nesting behavior variables can be explained by light pollution as it was quantified for our project. This means that nesting behavior is much more complicated than we had originally anticipated. Two studies showed that climate factors influence the distribution of nests globally (Bovery and Wyneken, 2015; Pike, 2013). Sea temperature may also affect Loggerhead sea turtle nesting behavior as shown in a study conducted in 2014 (Lamont and Fujisaki, 2014). These studies agree with the idea that sea turtle behavior depends on many factors (Abecassis et al., 2013). For future studies, we might consider examining nest density on each beach to see if this has an impact on nesting success. We might also quantify light pollution data at each nest rather than using an overall value for an entire beach. This is because an overall value for light pollution may not accurately depict the light pollution environment that sea turtles are choosing to lay their nests. Another factor we could examine is sea temperature throughout nesting seasons.

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