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Beach composition preferences for nesting populations of leatherback sea turtles (Dermochelys coriacea), Armila Beach, Guna Yala Comarca

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SIT Study Abroad

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Abstract

Sea turtles play a critical role in marine ecosystems all over the world, including the Caribbean Sea. However, many sea turtle species are under threat due to anthropogenic impacts, such as habitat destruction and fisheries bycatch. This has caused significant declines in sea turtle populations around the world, which in turn has impacted marine ecosystems where sea turtles play critical roles in proper ecosystem functioning. A crucial part of the sea turtle life cycle that has been threatened by anthropogenic factors is nesting. Sea turtles rely on unspoiled beaches with particular physical characteristics for laying their eggs. One of the most important nesting sites for leatherback sea turtles (*Dermochelys coriacea)* in the Caribbean is Armila Beach, a five-kilometer long beach in the Guna Yala Comarca in Panama close to the border with Colombia.. Since the physical characteristics of beaches are of key importance to sea turtles, the goal of the study was to determine if there was a possible association between specific beach characteristics and the number of *D. coriacea* nests found at different sections of the beach. Using the Nesting Beach Indicator tool, 100-meter sections, the length of Armila's 5km beach was divided into fifty (50) one hundred meter (100m) sections and each section was assessed for its physical characteristics such as elevation, slope, sand type and width. It was found that *D. coriacea* strongly preferred to nest on sections of the beach where sediment composition was primarily sand as opposed to gravel or rocks. Apart from sediment type, only beach width was found to have a significant effect on the number of nests present.

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Acknowledgments

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Introduction

Ecological Importance of Sea Turtles

All around the world, sea turtles play critical ecological roles in marine ecosystems. Different species of sea turtles fulfill different niches, so the various sea turtle species all have an important role in the world's oceans. Green sea turtles (*Chelonia mydas*), are critical to sea grass ecosystems as they feed on seagrass and inhabit areas where sea grasses are present. This is important as not many species are consumers of seagrass (Mansfield et al. 2014). Hawksbill sea turtles (*Eretmochelys imbricata*) are important predators of sea sponges and thus are critical to coral reef ecosystems within the marine tropics (Lukowiak et al. 2018). Leatherback sea turtles (*Dermochelys coriacea*), although primarily pelagic, play a vital role in controlling populations of sea jellies throughout the world's oceans, which is their main source of food (Mrosovsky et al. 2019). It is also important to note that sea turtles as a group have existed far longer than humans. Turtles have existed for over 200 million years and sea turtles have existed for one hundred and ten million years (Conant 2015). Hence, turtles and sea turtles have played important ecological roles throughout the natural history of our world. Without sea turtles, most marine ecosystems would be significantly impacted (Jackson et al. 2001). This is especially true since many sea turtle species have a very wide range of distribution throughout tropical waters, including the Caribbean Sea (Campbell 2007).

Human Activity

Human activity has impacted marine ecosystems all over the world, and the Caribbean Sea is no exception to this. Many areas on the Caribbean coast have experienced increased human development over the last century which, when combined with an increasing human population, has had a negative impact on biodiversity (Cramer 2013). The Guna Yala comarca is one such example, as increased population has led locals to mine coral reefs and overfish lobster (Guzman et al. 2003). The tourism sector has also grown, which is part of the reason that there has been increased human development. This development has also damaged ecosystems like coral, and increased waste in the area damages the environment (Groschl 2018). As a result, there has been a significant decrease in nesting sites for sea turtles in the Caribbean (Mclenachan 2006).

Site Armila

There are several important nesting sites for leatherback sea turtles in the Caribbean. One such site is Armila Beach in Panama; a globally significant nesting site for *Dermochelys coriacea* close to the Panamanian-Colombian border in the Guna Yala comarca (Martinez et al. 2008). This beach is approximately five kilometers long on the side that is west of the Armila River. The coordinates of Armila lie between 8.3904000N, 77.2603500W–8.4000600N,77.2705900W (Martinez et al. 2008). Given the large numbers of nests deposited by nesting females, the preservation of this nesting site is of critical importance for the conservation of this species at the regional scale. In recent years, locals have come to embrace the leatherback turtles and, since 2010, have hosted a sea turtle festival every May (Nichols et al. 2014). The Guna people in Armila have also established laws that prohibit poaching of leatherback sea turtles for personal or commercial purposes and laws that forbid the destruction of nesting habitat (Martinez et al. 2008). It is clear that the leatherback sea turtles play an important role in the culture and life of the Guna people that inhabit Armila.

Artificial Light

Anthropogenic impacts have created a myriad of problems for sea turtles. One of the largest problems facing sea turtles as a result of an increase in anthropogenic impacts is the effect of artificial light on nesting sea turtles. It has been found that beaches with an increased amount of artificial light have a lower presence of nesting sea turtles, suggesting that the presence of this light is a deterrent for mother sea turtles (Price et al. 2018). Disorientation is another challenge created by artificial light both in the open ocean and for nesting. Many sea turtles use the natural light of the moon and stars to navigate the seas, something with which artificial light interferes, potentially disorienting and confusing sea turtle species (Davies et al. 2014). As a result, sea turtles might not come to shore even if they are housing eggs. Sea turtle hatchlings are also negatively affected by artificial light. The light disorients hatchlings, causing them to scurry towards land rather than the sea. Thus, light pollution is one factor increasing the already high mortality rate of hatchlings. The reason why artificial light is particularly problematic is because most sea turtle young hatch in early evening or at night, when artificial light prevails in the darkness (Davenport 1997). Light pollution is something that can be controlled to a certain extent. For example, many areas have implemented laws requiring coastal communities to turn off their lights at night during periods in which sea turtles are nesting. There are a variety of different methods that can be employed to reduce the amount of light pollution (Valera-Acevado et al. 2009).

Anthropogenic Impacts on Sea Turtles

Many sea turtles around the world are subject to poaching and hunting, further diminishing sea turtle numbers. (Cheng et al. 2018). Other factors negatively impacting turtle nesting include development of beaches, pollution of marine areas, climate change, and domestic animal presence, as some domesticated animals prey on hatchlings (Couchman et al. 2010). These disturbances have the potential to harm the populations of newborn sea turtle hatchlings. Plastic that washes up onto beaches is a serious problem as sea turtles often confuse plastic with sea jellies. This is particularly devastating for *Dermochelys coriacea,* a species whose primary food source is sea jellies. Oftentimes this plastic can be fatal to the sea turtles if ingested. In addition, plastic also negatively affects other species in the marine ecosystem (Mrosovsky et al. 2009). The issue is also complicated by the fact that many areas do not have easy access to recycling, such as the majority of Panama (Linowes and Hupert 2006). Rampant climate change threatens to raise the sea level of many sea turtle nesting beaches, affecting the ecosystems upon which sea turtles depend. The rise of sea levels in the future could severely diminish the quantity of suitable beach nesting sites for sea turtles worldwide (Mazaris et al. 2008).

Sensitivity of Sea Turtle Nests

Sea turtle nesting is very sensitive to the surrounding habitat, so even small changes can have large consequences. The foreseen increase in temperature throughout the world over the next century will undoubtedly have a negative impact on sea turtles. Along with some other reptiles, the sex of sea turtles is influenced by the temperature at which their eggs are incubated, or Temperature-dependent Sex Determination (TSD). Since the sex of turtles is influenced by the temperature of eggs, increased temperature has already and will continue to skew the sex ratio among turtles (Laloe and Hays 2014). Higher temperatures mean that hatchlings are more likely to be female. Thus, the ratio between sexes of sea turtles will likely become more unbalanced as time progresses.

<u>Beach Erosion</u>

Beach erosion is another issue that has harmed sea turtle nesting sites. This can lead to the destruction of coastal sites which could in turn lead to the disappearance of the favorable conditions that are needed for sea turtle nesting (Chaverri and Eckert 2007). Beach erosion can also expose sea turtle nests leading to the premature death of the eggs due to exposure and predation as predators can easily detect exposed eggs. Beach erosion is not inherently a human-caused process, but rising sea levels could contribute to the erosion of beaches (Feagin et al. 2005).

<u>Evaluation of Sea Turtle Nests</u>

Because the environment that surrounds nests can have important ramifications for hatchlings, sea turtles choose very particular types of beaches for nesting. Thus, understanding which types of beaches and features they prefer is important to the conservation of sea turtles. Sea turtles generally lay anywhere from 50-200 eggs at any one nest though this varies based on species and location (Davenport 1997). Sea turtles may have multiple nests at any one beach to ensure maximum survival. This is also likely why sea turtles lay so many eggs. Only a small portion of sea turtle hatchlings survive to adulthood. Beach preference differs among different species of sea turtles, so there is no one beach suitable for all sea turtles. *Dermochelys coriacea* tend to nest on beaches that are long, wide, have little mud and are usually characterized by a steep slope (Eckert et al. 1999). Overall, these conditions describe Armila Beach quite accurately, which is likely the reason it is a significant nesting site for the *Dermochelys coriacea* on the Caribbean coast (Martinez et al. 2008).

<u>Efforts in Protecting Sea Turtle Nests</u>

Poaching of sea turtles and nests is a serious issue, and so the protection of beaches where turtles nest has proven to be an effective conservation strategy (Hutton et al. 2011). Ecotourism is popular in many areas where there are sea turtles and has raised awareness about the plight of sea turtles leading to increased protection. However, ecotourism can be a double-edged sword. Oftentimes, increased tourism coincides with increased human development in order to accommodate these tourists (Varela-Acevedo et al. 2009). Further research of turtle nesting sites is needed to have a better understanding of how to protect sea turtles and how to evaluate what makes for effective nesting sites (Garcon et al. 2010). Many studies discuss the methods in which beaches are transected and nesting sites are evaluated. Precautions include using red light lamps at night as to not disturb nesting turtles (Couchman et al. 2009).

Research Question

Do the physical characteristics (slope, beach length, sediment type, and degree of anthropogenic disturbance) along different sections of the beach affect nesting site selection (in terms of number of nests deposited) of *Dermochelys coriacea* at Armila Beach, Guna Yala Comarca?

Methods

Background Work

All research was conducted along the five-kilometer stretch of Armila Beach, located west of the Armila River. In order to carry out the study, it was decided to divide Armila Beach into fifty (50) sections each measuring 100 meters in length. Additionally, the starting point was also chosen at this time. The first section began next to an enclosure for sea turtles in front of the town of Armila. Overall, there were 50 sections total, amounting to 5 kilometers mapped.

Quantifying the Beach

each site was measured into 100-meter-long, straight line transects (Couchmen et al. 2010). Anywhere from 3-6 sections were conducted each day, with a visual indicator being left nearby for where to continue the transect for another day. Each transect ran down the middle of the beach and any nest between the vegetation at the high end of the beach and the water was considered to be within the transect. Rebars were placed at opposite ends of each transect as a visual indicator to mark where each section began and ended. Beach width was also considered in terms of the strip of dry sand where nesting occurs between the high tide mark and the vegetation. The width of the beach varied considerably throughout Armila, due to natural physical variations in the shape of the coastline. For example, beach sections that were steeper and/or more eroded tended to be narrower, whereas parts where sand had built up could present a wider strip of dry sand apt for nesting. In order to address this in terms of nesting placement of individual nests, each 100 m stretch of beach was divided into 3 parts: *lower, middle, and upper*. The lower portions of the beach that were closest to the water were often covered in algae and seemed to be subject to more frequent washouts and/or erosion. The middle portion of the beach, where the algae ended and dry sand began, did not seem to experience the effects of the high tide as often, perhaps only in full or new moons. The upper portions of the beach that were closest to the vegetation appeared to stay dry even during full moon tides. In terms of position of individual nests, beach sections were divided into three equal distance categories: *lower, middle, and upper*.

Physical Characteristics of Beach Sites

Physical characteristics of the beach were assessed with the use of the Nesting Beach Indicator tool as a guide (Cousins et.al 2017). The Nesting Beach Indicator tool makes note of which types of beaches different sea turtle species prefer. Basic physical characteristics of each beach site were recorded. This included beach slope, amount of vegetation, and if there were any disturbances such as feral dogs or human structures. Data was analyzed using the Nesting Beach Indicator which provided a rapid assessment of the suitability of the beach as turtle nesting habitat (Cousins et al. 2017). Factors evaluated included beach sediment, beach elevation, beach slope, and human impact.

Beach elevation above high tide mark was categorized into three values: less than 0.5 meters, between 0.5 meters and 2 meters, and greater than 2 meters. Beach width above high tide was also measured, and categorized as less than 5 meters, between 5 and 15 meters and above 15 metersThe evaluation of beach slope was a rapid assessment, either low or "moderate to steep" based on observation alone.

Human impact assessment was also tested, specifically for the amount of litter on the beach and the amount of other debris or obstructions on the beach. The other human impact assessments could not be measured as artificial light cannot be measured during the day and development only occurred around the mouth of the river. Hence, it was determined that the impact was negligible for almost all of Armila since the town has little light at night and does not impact the beach except for the first section. The little light present at night from the Armila village was only factored in for the first section of the beach as light pollution since it was the only section where it was applicable. Scores were calculated in percentages with higher percentages having more potential for turtle nesting. Percentages between different sites were compared along with the composition of each beach section.

<u>Data Analysis</u>

The percentage scores in the Nesting Beach Indicator for each characteristic were computed. Human impact assessment was on a 1 to 5 scale for each category, so the sum of all categories was counted as the human impact score. The average human impact was calculated and then above and below average sites were compared with the use of Chi-Square tests to determine if there were any significant differences in number of nests. This also holds true for number of nesting sites for various categories including the amount of trash and debris, type of sediment, width of the beach and location of nests along the beach.

Ethics

This study did not involve any human participants nor was anyone within the Armila community interviewed. Thus, those parts of the IRB process that deal with the involvement of human participants or people interviewed was not applicable to this research study. Precautions were taken to minimize any impact to the sea turtles themselves. For instance, data collection occurred during the daytime. The reason for this is that sea turtles generally come ashore to lay their eggs during the night. It is rare for turtles to come ashore when there is still daylight. The presence of humans could potentially frighten sea turtles causing them to return to the sea before nesting. Thus, any potential harm to the sea turtles laying their eggs was avoided by only collecting data during daylight hours. Additionally, the use of insect repellant with DEET was avoided, as the effects of DEET are harmful to sea turtles. When walking on the beach, extra care was taken to not step on any possible nesting sites so as not jeopardize the survival of eggs within the nesting site. In the event that sea turtle hatchlings were observed, no human interference took place, even if there were natural predators present in the area. This applied to any eggs that were exposed to the surface. Turtle eggs were never reburied or touched. Overall, every effort was made to minimize any possible impact this research study might have on sea turtles.

Results

Within the five kilometers study site at Armila Beach, there was a total of 354 sea turtle nests counted, which translates to an average of 70.8 nests per kilometer. Of the 354 nests, 348 nests were found between 0 kilometers and 3.6 kilometers, where, the sediment was composed almost entirely of sand, and 6 nests were found between 3.6 and 5 kilometers where sediment was composed primarily of gravel and pebbles. Thus, all nests were found with in the first 72% of Armila. Chi-square test (p-value < 0.001) indicates a very significant difference between substrate types. All of the averages examined in the first 37 sections (3.6km) of the beach that were composed primarily of sand as opposed to the furthest 1.4 km of beach, which was primary made up of rocky pebbles or gravel. The average number of nests in sections that were primarily sand was 9.57 nests every 100 meters. Between km 0 and km 1 there were 71 (20%) nests found, which was not significantly different (with a p-value = to almost 1) from the average 70.8 nests for the entire 5km beach. From km 1 to km 2 there were 97 (27%) nests, which was significantly more than the expected average (with a p-value $=0.016$ using Chi-square tests). Between km 2 and km 3 there were 126 nests (36%) which is significantly higher than the expected average (with a p-value <0.001 using Chi-Square tests). Between three and four kilometers there were 60 nests (17%), which is less than the expected average but not enough to be significant (p-value$= 0.72$). Between km 4 and km 5 there were zero nests which is significantly less than the expected average (with a p-value < 0.001 using Chi-Square tests). The number of nests per kilometer is shown via Figure 1 and the number of nests per section up to gravel is shown in Figure 2. Exact measurements are provided in Appendix 1.

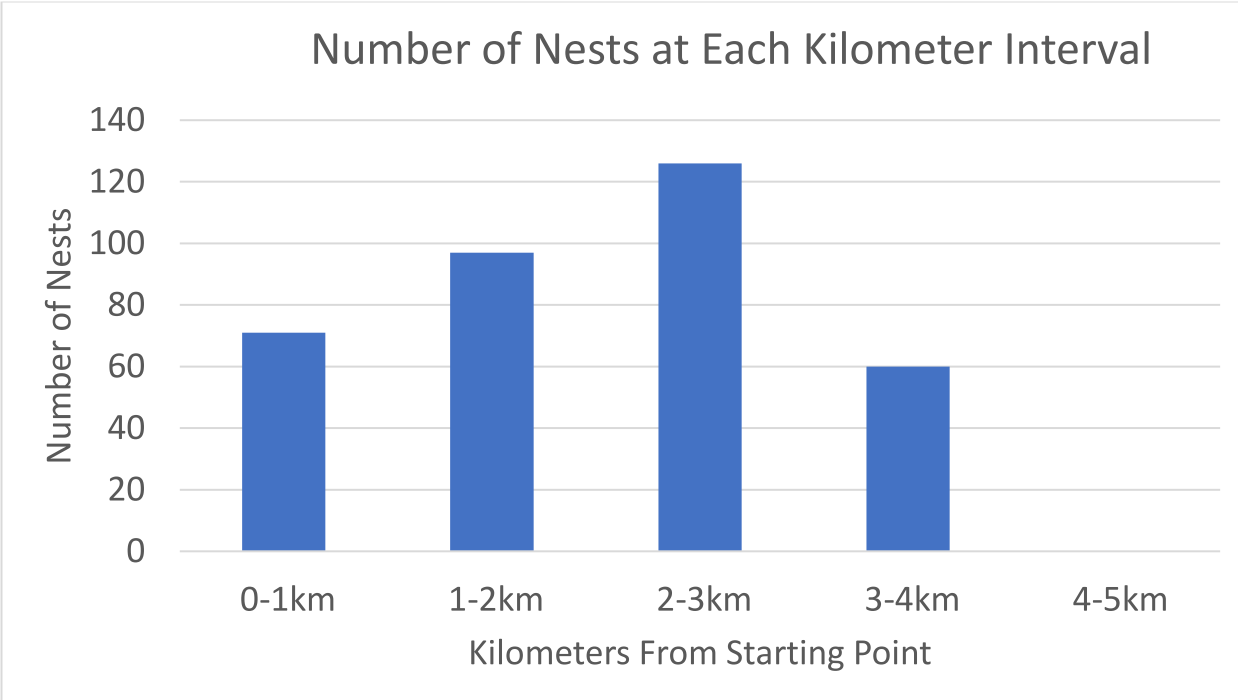

Figure 1. Number of nests at each kilometer interval (10m sections).

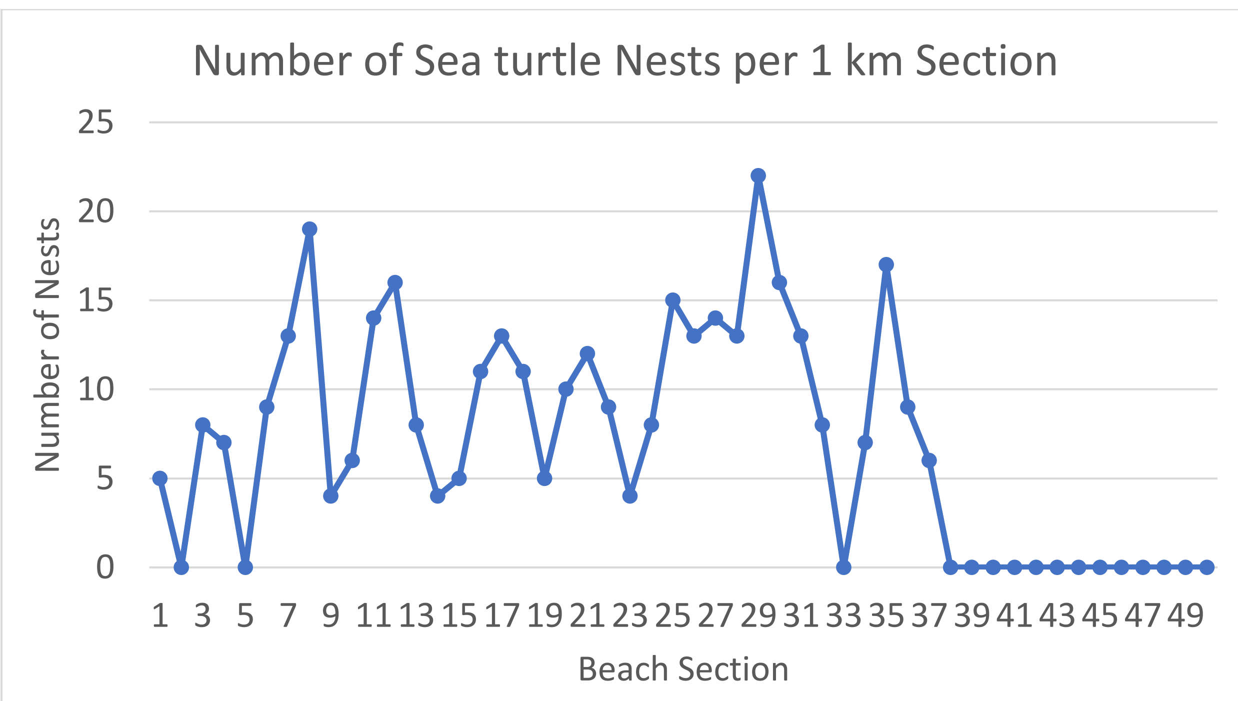

Figure 2. Number of nests at each beach section in Armila

Regarding the vertical location of turtle nests on the beach (*lower*, *medium*, *upper*), there were 277 nests (78%) located in the upper portions of the beach, 70 nests that were located in the middle portion of the beach (19%) and 7 nests (3%) that were located low on the beach. The number of nests found in the upper portion of the beach was significantly more than the other two sections (p-value <0.001 using Chi-square tests).

Table 1. Number of nests based on vertical location of turtle nests

Total nests	Upper	Middle	Lower
354	277	70	7

The first 3.7 kilometers of Armila Beach was composed primarily of sand while the remaining 1.3 kilometers of Armila was composed primarily of gravel and pebbles. There were 348 nests within the sand section and 6 nests found within beaches rocks/gravel section. Thus, the number of nests in sandy sections was significantly higher than sections than sections composed of gravel (with a p-value < 0.001 using a Chi-square test as seen in Figure 3).

Table 2. Number of nests in relation to sediment type

Sand	Gravel
348	6

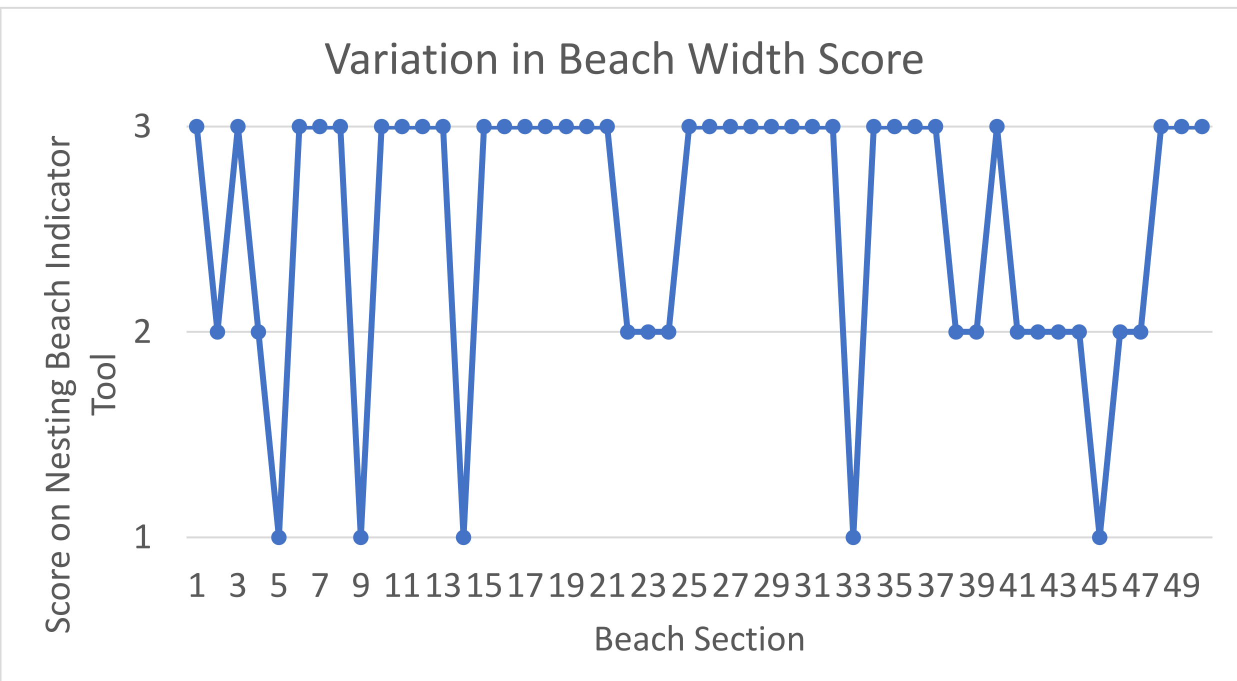

Figure 3. Width score variation throughout Armila, on a 1-3 scale. 1 is 5 meters or below, 2 is between 5 and 15 meters, and 3 is greater than 15 meters

Width was the only other characteristic of the beach that was not uniform throughout Armila. Sections with a width greater than 15 meters had an average of 7.9 nests while sections that had widths less than 15 meters had an average of 4.0 nests per section. The difference between widths of beach was found to be significant (with p-value < 0.001 using Chi-square test), indicating that wider sections of the beach had significantly more nests than narrower sections. Sections of beaches with erosion had an average of 7.7 nests while sections that did not experience erosion had an average of 10.35 nests. The difference in nests was statistically significant (with a p-value=0.009 using a Chi-square test) with eroded sections having fewer nests than non-eroded sections.

Human impacts such as light pollution, development, amount of trash and debris were all rated using the Nesting Beach Indicator tool and then compared between sections. The levels of trash and debris differed throughout the length of Armila beach. For the purpose of analyzing data, trash and debris were compared only in sandy sections nesting took place. The average level of human impact using the tool was 6.82 which factors in variables such as amount of trash, debris, light pollution and development. For areas that had a higher than average human impact assessment, there was an average of 8.13 nests per section. There were more nests found in areas with below average human impact, with an average of 11.13 nests per section. However, there was not a significant difference regarding the number of nests at each site and the level of human impacts (with a p-value=0.13 using Chi-square tests as seen in Figure 4).

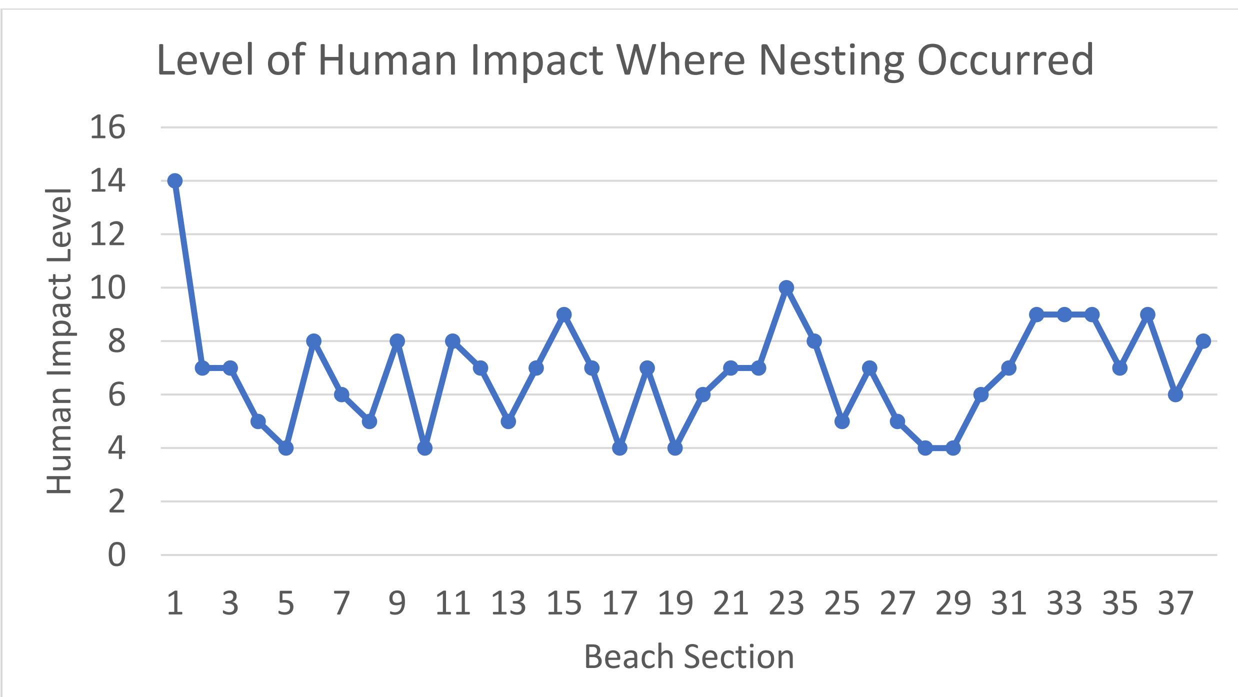

Figure 4. Human impact assessment score at each beach section where nesting occurred.

Discussion

Physical Beach Preferences

The majority of Armila Beach was composed primarily of sand, with a beach elevation greater than two meters, a beach width greater than 15 meters, and a slope that is moderate to steep – all factors which would support previous assessments of Armila (Martinez et al. 2008) and represent ideal nesting habitat for *D. coriacea*, which prefer to nest on beaches that are wide and steep, not in danger of erosion, and are made primarily of sand (Eckert et al. 1997). These factors, coupled with the fact that Armila can be considered a long beach (greater than 1.5 km) and is very minimally impacted by humans, would indicate that Armila is a very suitable beach for sea turtle nesting, especially for *Dermochelys coriacea* (Cousins et al. 2017). This is because *Dermochelys coriacea* generally choose beaches with similar characteristics to nest at throughout the Caribbean (Eckert et al. 1999). It appears that differing physical characteristics for some categories impacted the presence of sea turtle nests at certain areas along the beach in particular substrate type at Armila beach.

From 3.7 kilometers onwards, the sediment of Armila Beach was primarily composed of gravel and the beach also became generally smaller in width, typically ranging between 5 and 15 meters. Even though the amount of debris and garbage was not significantly different than that of the rest of Armila, along with other beach characteristics, there were zero sea turtle nests found in the sections that were primarily composed of gravel and only 6 nests in areas with some gravel. Such a stark contrast would suggest that beach sediment is a critical factor in determining whether sea turtles will nest. All of this would suggest that sediment type is the single most important characteristic for determining the presence of sea turtle nest presence at Armila Beach. These results are consistent with the Nesting Beach Indicator tool where sediment type has the highest percentage of any category (Cousins et al. 2017). These results also suggest that conservation of sandy beach ecosystems is critical for the survival of nesting beach habitats (Defeo et al. 2008).

The only other physical characteristic of Armila that had significant variation was the beach width which was measured from the high water mark. There were not that many sections of beach on the sand sediment side of Armila that had widths less than 15 meters, but all of these sections tended to have fewer nesting sites than sections that were wider than 15 meters. Since there were significantly more nesting sites in beach sections wider than 15 meters than in sections narrower than 15 meters by a wide margin, the results of this study support previous research which also found that wider beaches were preferable (Caut et al. 2006).

Other characteristics analyzed by the Nesting Beach Indicator such as elevation and slope were uniform throughout the entirety of Armila, so their possible impacts could not be measured. Once again, entirely different beaches would need to be compared in order to determine the significance of these factors in affecting nesting site selection for leatherback sea turtles. The same applies for beach length, since Armila is five kilometers in length, every section of Armila was counted as being longer than 1.5 kilometers, and thus, insight on how beach length affects nesting preference cannot be garnered from this study.

Nest Location

Of the three locations along the beach vertically, sea turtles overwhelmingly chose to nest high on the beach, close to the vegetation. Approximately 78% of the 354 sea turtle nests were located in high areas while approximately 20% nested in the medium area of the beach and only 2% of nests were located low on the beach, close to the water. Thus, significantly more turtles chose to nest high up on the beach suggesting that *Dermochelys coriacea* prefer to make their nests on these locations on the beach, closer to the vegetation and safer from water intrusion. This is at least true for *Dermochelys coriacea* at Armila since nesting location may vary from different beaches due to how nesting behavior can change regionally (Kamel and Mrosovsky 2003). After beach sediment type, the vertical location of nests seemed to have the most impact on where sea turtles made their nests. It is important to note that four exposed nests were found during the survey period, and all four of these exposed nests were classified as being low on the beach. The threat of erosion and the exposure of beach nests probably incentivizes sea turtles to nest further up the beach.

Human Impacts

It is important to note that even though Armila is very remote, there were still human impacts seen on its beaches. The most prevalent human impact was the amount of garbage and debris on the beach. The entirety of the five kilometers along Armila Beach contained some garbage. It was clear from observation that this waste was not created by the Armila community but rather that plastic and other waste washed ashore from the ocean. This has important implications for *Dermochelys coriacea* as plastic resembles their primary source of food, sea jellies (Mrosovosky et al. 2008). Thus, the amount of plastic in the ocean around Armila could potentially lead to increased *Dermochelys coriacea* mortality.

Certain parts of Armila Beach also possessed a large amount of debris, mainly in the form of detached logs, but also occasionally furniture. The amount of light pollution, if any, was minimal and development only occurred around the mouth of the Armila River and nowhere else along the five-kilometer stretch west of the community. According to the Nesting Beach Indicator, the amount of garbage and other debris on the beach was enough to have significantly deterred nesting ability. Despite this, there does not appear to be a significant relationship between the amount of litter and debris and the number of nests. Sites that had a large amount of litter and debris still contained sea turtle nests. Therefore, other features such as beach sediment and location were more important in determining where a sea turtle will choose to nest. As these findings suggest, if the beach conditions are optimal for sea turtle nesting, as they are throughout most of Armila, then the presence of trash and other debris does not seem to significantly deter sea turtles even if there appeared to be fewer nests overall in these areas. This finding is not well supported by previous studies (Campbell 2007). There also tended to be fewer nests located closer to the town of Armila, the first section was the only part close enough to be possibly be affected by light pollution and development could have deterred turtles from nesting directly in front of the village. Thus, future development could have negative effects on sea turtle nesting in this area (Price et al. 2018; Cheng et al 2018).

Other Details

Beaches with noticeable erosion also tended to be the beaches where turtle nests were exposed or had their eggs visible at the surface. All the turtle nests that were exposed were found on a beach that had noticeable erosion, showing the potential danger of erosion. Erosion is a natural process that has the potential to accelerate due to human-caused processes, most notably climate change and sea level rise (Feagin et al. 2005; Mazaris et al. 2008). As these two phenomena increase in the future, erosion may intensify which could be detrimental to the survival of sea turtle nests. As it stands now, sites with erosion had significantly fewer nests than sites without erosion when tested with a chi-square test. Armila also contained a large quantity of algae on the lower parts of the beach, which has been known to negatively affect the survival of sea turtle hatchlings (Eckert et al. 1999). Generally, sections of Armila with particularly large amounts of algae tended to have fewer nests but there were not enough sites with large quantities of algae to make a meaningful analysis about how algae may impact the presence of sea turtle nests. Future research could examine this question in further detail.

Potential Sources of Error

One potential problem with this study was that not all areas were assessed simultaneously. There is a high probability that areas surveyed earlier within the study included more nests than were counted as it is possible that sea turtles made nests after the area was surveyed. Areas closer to Armila were surveyed first, with each day of data collection getting farther from the Armila River. There is no easy solution to this problem given that surveying the beach takes time and there was only one researcher for this study. Perhaps a study with multiple researchers could analyze the sea turtle nests on a specified date so as to not bias the data from later sites that could have more nests due to more time passing. Another possible error is that nests could have been miscounted. As sea turtles make tracks and try to not make nesting sites too obvious, it can occasionally be difficult to discern what is and is not a nest in the sand (Couchman et al. 2008). Occasionally, one's best judgment had to be employed as the researcher did not want to dig up the nests to check as that would be intrusive. That said, there was only one researcher, which helped to ensure consistency in the evaluation of process in counting nests. Every effort was made to ensure an accurate count.

Conclusion

Goal of Research

According to the results, the aim of the study, which was to determine what natural characteristics of Armila Beach were associated with and increased number of *Dermochelys coriacea* nests, was successful. The alternate hypothesis, that differences in beach characteristics would result in a difference in the number of nests was partially supported in this study. It was found that beach sediment type, location along the beach vertically (beach width) and amount of erosion were all highly significant features in where sea turtles chose to nest. It was also found that human impacts did not significantly affect the number of nests despite what the Nesting Beach Indicator tool suggested.

Certain parameters such as beach length, slope and elevation could not be accurately analyzed due to lack of variation throughout Armila Beach. This leaves open the possibility of future research comparing Armila Beach with beaches of differing length, slope and elevation in order to determine how these factors influence nest presence. Similarly, there were not enough areas with high algae presence to determine whether it had a significant impact on the presence of sea turtle nests, but this is a topic worthy of future analysis.

This study adds to the existing literature regarding Armila as well as the existing literature regarding *Dermochelys coriacea*. (Martinez et al. 2008; Chaverri and Eckert 2007; Kamel and Mrosovsky 2003). Future research could further examine how sediment type, nest location, erosion and beach width are important to *Dermochelys coriacea*. With this information, successful conservation strategies can be developed to help populations of *Dermochelys coriacea*. Future research can also investigate how these approaches affect the *Dermochelys coriacea* in the Pacific Ocean as their subpopulation is critically endangered (Hutton et al. 2011). In addition, future research could examine how beach characteristics and human impacts affect the survival of the hatchlings themselves. This study examined the number of nests, but how these features, especially debris can affect the success rate of hatchlings reaching the sea is a key area for future research. As anthropogenic impacts continue, the future survival of sea turtles depends upon conservationists properly understanding their nesting habitats.

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Appendix

Table 1. Nest Locations Sections along sections 1-10 out of 50 (in 100m intervals) – 5km

1	2	3	4	5	6	7	8	9	10
9m		223m	303m		502m	601m	704m	809m	912m
15m		239m	313m		522m	609m	712m	813m	920m
22m		241m	325m		550m	630m	721m	859m	933m
53m		266m	334m		554m	631m	722m	899m	947m
56m		279m	340m		554m	643m	729m		989m
		289m	368m		571m	652m	733m		992m
		292m	372m		573m	659m	748m		
		299m			577m	662m	748m		
					586m	672m	754m		
						679m	754m		
						685m	759m		
						685m	768m		
						696m	768m		
							775m		
							780m		
							786m		
							789m		
							791m		
							794m		

Table 2. Nest Locations Sections 11-20 (in 100 m intervals)

11	12	13	14	15	16	17	18	19	20
1003m	1101m	1204m	1325m	1403m	1524m	1605m	1700m	1812m	1913m
1004m	1110m	1215m	1327m	1437m	1550m	1611m	1703m	1863m	1919m
1010m	1119m	1222m	1382m	1480m	1555m	1621m	1717m	1876m	1927m
1024m	1126m	1228m	1391m	1484m	1570m	1629m	1728m	1889m	1932m
1032m	1133m	1234m		1493m	1577m	1633m	1736m	1895m	1936m
1038m	1137m	1259m			1577m	1639m	1744m		1945m
1041m	1147m	1263m			1585m	1644m	1751m		1955m
1057m	1158m	1287m			1590m	1654m	1772m		1963m
1062m	1164m				1592m	1659m	1775m		1974m
1065m	1169m				1598m	1668m	1784m		1983m
1074m	1176m					1674m	1794m		
1095m	1188m					1681m			
1099m	1192m					1693m			
	1197m								

Table 3. Nest Locations Sections 21-30 (in 100m intervals)

21	22	23	24	25	26	27	28	29	30
2002m	2102m	2273m	2329m	2402m	2503m	2607m	2701m	2803m	2903m
2025m	2122m	2282m	2333m	2426m	2508m	2611m	2713m	2813m	2909m
2026m	2130m	2296m	2350m	2430m	2511m	2619m	2730m	2822m	2913m
2029m	2134m	2298m	2359m	2431m	2511m	2626m	2732m	2825m	2913m
2031m	2138m		2362m	2440m	2531m	2634m	2739m	2825m	2917m
2032m	2145m		2377m	2448m	2556m	2646m	2741m	2827m	2922m
2037m	2174m		2390m	2454m	2556m	2655m	2746m	2831m	2927m
2045m	2178m		2392m	2460m	2566m	2658m	2751m	2840m	2930m
2053m	2184m			2462m	2575m	2664m	2771m	2846m	2932m
2069m				2465m	2583m	2670m	2777m	2851m	2937m
2076m				2470m	2595m	2677m	2784m	2854m	2942m
2099m				2474m	2595m	2683m	2790m	2858m	2949m
				2488m	2599m	2690m	2792m	2861m	2973m
				2495m		2696m	2797m	2863m	2982m
				2498m				2866m	2986m
								2869m	2997m
								2873m	
								2880m	
								2884m	
								2889m	
								2892m	
								2897m	
								2899m	

Table 4. Nest Locations Sections 31-40 (in 100m intervals)

31	32	33	34	35	36	37	38	39	40
3010m	3103m		3347m	3404m	3508m	3623m			
3018m	3111m		3352m	3406m	3517m	3646m			
3028m	3143m		3362m	3415m	3524m	3660m			
3031m	3151m		3365m	3421m	3526m	3677m			
3037m	3158m		3383m	3429m	3539m	3689m			
3050m	3164m		3391m	3435m	3545m	3697m			
3058m	3168m		3399m	3439m	3556m				
3062m	3186m			3497m	3574m				
3067m				3457m	3587m				
3074m				3462m					
3082m				3466m					
3090m				3477m					
3092m				3480m					
				3484m					
				3489m					
				3494m					
				3498m					

Table 5. Nest Locations Sections 41-50 (in 100m intervals)

41	42	43	44	45	46	47	48	49	50