# Using multivariate analysis to determine characteristics of sea turtle nest selection along the Florida Panhandle

by

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# Abstract

Sea turtle nesting is a highly monitored event in the state of Florida. From this monitoring, important topics in regards to reproductive success are recorded, such as nesting demographics and site selection location. Although these nesting populations are observed and recorded, hatchling studies have still been the main focus in terrestrial based sea turtle studies. This trend is changing. Observations and studies have determined that despite overall physical trends of site selection, such as wide, open beaches with flat slopes among other characteristics (Miller et al. 2003), site selection is quite varied on both large and small scales, therefore, warranting the need for more research on site selection. Biologists and wildlife managers throughout the world have realized the importance of sea turtle nesting in relation to whole species survival, but require more knowledge on how to handle best practices (Hamann et al. 2010). Okaloosa County managers on the Florida Panhandle are working towards more detailed decisions for management practices. For this project, a wide scale study of Okaloosa County and the surrounding region were looked at in regards to three main questions; what variables (e.g. environmental, urban, etc.) contribute to large and small-scale site selection trends and what does this site selection look like, what variables impact site selection individually, and how do urban variables alone affect sea turtle site selection?

Two methods were used: site selection prediction analysis through a binomial Bayesian general linear model and tree classification. Site selection analysis looked at three distinct prediction types: a comparison between presence and random nests within the whole study area looking at all variables; a comparison in Okaloosa County and Santa Rosa of present nests in comparison to false crawls looking at all variables; and presence and random nests within the whole study area but only looking at urban variables. Tree classification, similarly, looked at a presence – random nest comparison with all variables, as well as a presence - random nest comparison with urban variables.

This complexity in site selection characteristics makes it difficult for management to focus on one particular variable. Yet, this study determines a few main trends: there is a general area between shoreline (high tide) and upper areas with distinct barriers (dunes, roads, urban areas), while within this shoreline area there is a large variability in nest site selection prediction, and finally, urban variables show a complex interaction with and within physical variables. A few select variables are also very important in sea turtle nest site selection.

Overall, nest site selection is highly variable, but some trends, which include urban considerations, are involved more than seen in previous studies, although is becoming more prominent in the literature. This study provides a start for what characteristics may contribute to nest site selection, which managers can use to improve best practices for sea turtle management in the Florida Panhandle and around the world.

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## Introduction

Since the 1970s, sea turtles have become a charismatic species that has received high levels of protection from an increasing amount of threats in the United States (NOAA, 2015). Although, little has been researched since the father of sea turtles, Archie Karr, produced substantial studies in 1942 (University of Florida, 2014; Shanker et al., 2009). Despite extensive knowledge of sea turtles, there are still gaps in knowledge in relation to migration, nesting, foraging, and specific species. Particularly, a group of sea turtle biologists from multiple regions came together to determine five priority research categories for the 21st century, in which one of these incorporated reproductive biology, and specifically the factors and behavior that support site selection (Hamann et al., 2010). Several different methods have been determined throughout the history of sea turtle management by ways of increased studies to understand sea turtle biology, ecology, and migration patterns, while other management techniques such as turtle exclusion devices (TEDs), nest relocation and protection strategies, light ordinances on beaches, and other innovative or eventually unhelpful practices (i.e. head starting) have come and gone in getting humans and sea turtles to live in peace together. However, beaches are one habitat humans and sea turtles share as population increases, more and more humans live near the coast, and sea turtles come to nest. Throughout this history more about sea turtles has been discovered, yet there is still a wealth of information about this species we do not know or understand.

Moreover, sea turtles might be conserved for their charismatic nature. Yet, the species plays a crucial role in the ecosystem in which they promote environmental sustainability, as well as human beach infrastructure. Green turtles are known for their diet of sea grass, although other sea turtles also eat sea grass. Sea grass stays healthy when it is cut short, and perpetuates the growth of sea grass along the benthic floor of the ocean (STC, 2015). Manatees are other grazers, but are also threatened. Sea grass beds have been declining, and could be linked to the declining number of sea turtles, and vice versa (STC, 2015). Sea grass beds support nurseries for small fish, shellfish, and crustaceans we eat, and also increase soil structure, reducing wave action towards the shore. Additionally, dune systems are very nutrient depleted, leading to less vegetation growth since sand does not hold nutrients well. Sea turtle nests and their eggs hold many nutrients. Sea turtles lay around 100 eggs per nest and almost 3 to 7 nests during nesting season which allows for nutrients to get inundated into the dune system (STC, 2015). These nutrients in turn help to increase vegetation, which can increase dune height and protect homes and towns more effectively.

## Known Threats in Florida

In Florida, sea turtles are tied to the state and communities in many different ways. Historically, the father of sea turtle biology, Archie Carr, began his professional career here, who brought the charismatic creature real importance. Sea turtles not only provide benefits to the health of Florida's ecosystem by eating sea grass and improving its growth, but also by adding nutrients to dunes through their eggs which help vegetation to grow and reduce erosion of dunes and therefore inundations to human infrastructure from storms. Besides this, they provide an opening to excite children as well as adults in education through the wonders and mysteries of their own biological and physical histories, providing an attraction to tourists and therefore income to the state. Increasingly, their management is important to the United States, specifically in Florida, since more than 90% of loggerheads nest there, and almost all green and leatherback nests occurs on Florida's 825 miles of beaches in the United States, compared to the entire coastal area of the United States which adds up to 12,383 miles (FOCC, 2010; NOAA, 1975). There is a pivotal connect between humans and sea turtles. Both humans and sea turtles face threats that must be recognized, understood, and managed if this connection is to remain.

In Florida many threats exist which affect both human and sea turtles. For example, sea level rise is not only a human issue, but an environmental issue which disrupts the political and economic nature of human lifestyle. Sea level rise is one of the major threats that has arisen from global climate change through thermal expansion and creates higher volume waters (Deconcini & Tompkins, 2012) and melting of ice sheets, ice caps, and glaciers which has increased freshwater influx to the oceans (Deconcini & Tompkins, 2012). Average global sea level has risen by about 8 inches since 1870 (Deconcini & Tompkins, 2012). Sea level rise can affect human infrastructure, but also increase erosion of beach habitat for nesting. As climate change increases so do storms and their frequency, which only increases the effect of sea level rise and increased flooding in coastal areas (Deconcini & Tompkins, 2012); both result in destruction of human property and sea turtle nests. Evidently, certain threats harm both sea turtles and humans equally, and therefore, integration of management with both groups is mind is necessary.

However, humans also cause their own threats to sea turtle habitat. Over 123 million Americans live in coastal communities and have already begun to feel impacts of climate change on their properties and surrounding environment, and which could economically threaten nearly half of the US GDP (Deconcini & Tompkins, 2012). Many strategies exist to protect coastal development and infrastructure. However, some of these conflict with goals of protecting the environment.

With threats of climate change and sea level rise plaguing coastal areas, sea turtles are particularly at risk both directly, and indirectly through human involvement. Sea turtles come to the United States' east coast and Gulf of Mexico beaches to nest. When they are old enough to reproduce, sea turtles will return to the beach where they hatched regardless of the conditions (Ruppert, 2008). However, if the erosion of that beach is critical, the turtle may lay the nest too close to the water, causing nests to become fatally inundated. Sea turtles may travel to another beach nearby which is less eroded, but these beaches may be less suitable (STC Threats, 2015). In addition, erosion and storms increase escarpments, an area of the beach where a steep vertical bank of substantial height forms or the overall slope of the beach is increased, making it difficult for sea turtles to get to proper nesting areas (New South Wales, 2011).

Although these direct threats are important and many others exist, humans sometimes are the cause of more threats. Although the extent and situation depends on the threat to sea turtles, beach nourishment and coastal armoring are both common management tools used to protect property from sea level rise and erosion issues (Pilkey, 1989). Additionally, infrastructure such as roads and lights and increased population on beaches may cause threatening interactions with turtle nests.

### i. Human Development & Hardening Shoreline

Beach nourishment, a situation where sand from elsewhere is dumped onto an eroding shoreline to widen an existing beach,  (Barber, n.d.) may be seen in a positive light as it would increase beach width, allowing sea turtles to avoid nesting too close to the shoreline, there are issues from this that harm sea turtle nesting success. However, nourishment may result in different sand quality, particularly in sand grain size and color (Gallaher, 2009). Grain size may make it harder for adult sea turtles to dig their nest and may slow down hatchling movement, making them more vulnerable to predation (Gallaher, 2009). Sea turtle eggs are highly vulnerable to rising temperatures as their sex is determined by temperature. If the sand from a nourishment project is darker, sand temperatures will increase, creating a disproportionate amount of females which are influenced by warmer temperatures (PBS, 2015). One last problem is the issue of false crawls, which is when a female turtle either attempts or begins to nest, but eventually abandons the nest before physically releasing eggs (FFWCC, n.d.). Although it is unknown what the exact mechanism is for false crawls, it is possible that a turtle may come on shore and decide that the beach is not suitable for a nest due to nourishment (Stewart & Leitao, 2015). Coastal armoring, particularly seawalls, are safer, more controllable, and stronger from an individual perspective in regards to how well this method can protect property from inundation. However, with increased seawalls, studies suggest that sea turtles nest further from these walls and closer to the shore (C.E. Rizkalla & A. Savage, 2011). Erosion at seawalls creates a change in nesting patterns which has been shown to decrease turtle nests in that area, while the nests that do persist in these areas are more at risk as these areas erode more sand over time leaving nests vulnerable to tides and storm water influx (A.E. Mosier & B.E. Witherington, 2000) Although property is protected, suitable nesting habitat is essentially lost in these areas. Sea turtle nests that do occur here are more at risk of complete fatality, while sea turtles are found to increase false crawls in these areas suggesting these areas are unsuitable for nesting (A.E. Mosier & B.E. Witherington, 2000).

### ii. Lights

Lighting, particularly certain types of light, are known to misdirect or disorient sea turtle hatchlings when they emerge from nests at night, reducing survival. Knowledge of hatchling behavior has long associated their movement with directionality due to the light of the moon, reflecting off the ocean and their behavior is well studied (Rich and Longcore, 2006). However, although it is known to affect and disorient nesting sea turtles, the directionality of their behavior approaching the beach due to these measures is less understood and studied (Witherington 1992, Rich & Longcore, 2006). It is also important to know that different types of light sources affect sea turtle movement, as well as scattering ability, reflection, directivity and direction of the light (Witherington, 1992; Salmon, 2003). In areas where lighting cannot be completely removed, mercury vapor and other broad spectrum lighting are more likely to interrupt nesting sea turtles , while low pressure sodium vapor is less harmful or disruptive (Witherington, 1992). Florida is aware of this problem, and have implemented a model light ordinance (Florida Statutes Chapter 62B- 55, 2010). Additionally, almost all counties have special light ordinances, although some are related to lighting in relation to new construction and not street lights. The only one within the panhandle which does not have a light ordinance is Okaloosa, although its city of destiny does have specific lighting laws. Although this may remove primary and direct sources of light from the beach, it may not remove light completely from beaches. This also does not remove general light pollution from the area which may still disorient turtles (FFWCC Light Ordinance, 2015).

### iii. Human Interaction

There are also a myriad of activities humans may participate in which can harm turtles that they either do not know can harm turtles or do not care. Some possible ways to reduce threats directly are to not touch turtles or interact with hatchlings and their nests because this activity can stress out a turtle or the hatchlings which may reduce nesting ability or survival. Filling in holes is also important, since sea turtles cannot move backwards and therefor a turtle may become stuck. Reducing lighting as discussed, but particularly from houses on beach front property will reduce both hatchlings and mothers from becoming disoriented. Trash may cause a turtle to choke or become entangled which may harm the turtle before nesting or during (Zambello, 2015). Although there are many other issues or problems that exist, these are all preventable or manageable. For example, a sea turtles may nest directly on a private beach under or next to a beach lounger owned by a hotel. Once this is discovered it can be “roped off”, but the survival of the nest is dependent on the lack of human interaction during the incubation process, which may be difficult. These problems occur for two reasons, either because people are ignorant that these problems exist at all, or because they may not care or be willing to change their own actions such as reduce lighting or find a trash can. These problems are difficult to solve, and therefore education or other forms of management need to be used to reduce such behavior. Understanding the movement of turtles on beaches may help explain why turtles are attracted to particular areas and therefore changes can occur to remove threats but allow humans to not change their behavior completely.

Although these problems exist, the degree to which they threaten turtles are manageable. More information is needed on some of these interactions, specifically location based, but overall if management strategies integrate both human and sea turtle threats and needs and find ways for both to coexist in a positive environment, then problems for both could be minimized.

## Integrated Environmental Management

The phenomenon of human-sea turtle interactions has required managers and coastal communities in sea turtle nesting locations come to better solutions on how to control both human and sea turtle populations so both can have the bet positive outcome. Although there are many types of management that exist and which may be used for sea turtle management, Integrated Environmental Management (IEM) is a potential choice in order to combine them in order to combine human and turtle needs in a positive way. Past management strategies for sea turtles have focuses on an ecosystem based management (EBM) approach, which approaches problems from an environmental standpoint where it considers broad interactions such as humans and no single isolated issues. However, integrated management focuses not on any sector, but on a balance and equality between all parties possibly from a standpoint that may improve how humans look at the environmental world in relation to themselves (Christensen et al., 1996, McLeod et al., 2005). IEM can be defined as “a philosophy that is concerned with finding the right balance (sometimes called the 'golden mean') between development and the environment.” (Environpaedia Rethinking Reality, 2007) and has a source of guidelines described by the Department of Environmental Affairs and Tourism in order to make sure that all environmental considerations are considered when a project is suggested and how that fits into its life as well as the process and the policy attributed to it. This concept allows for all elements to be examined from the inception to the end of the project. Although this definition concerns itself with more developmental practices, IEM can also be attributed to entire management practices and how the organization of a problem can be centered on a balance, in this case between environmental success of turtles and human needs. IEM has also had problems with integration in the past, from theory to practice, but has forged ahead with the concept and over time have come to become more accepted as a strategy (Margerum, 1999; Cairns & Crawford, 1991). Overall both management practices are the same, but the way they are received are different, while environment has the upper hand in those applying management with EBM. Therefore, approaching sea turtle management in this integrated way, which may create a balanced strategy.

## Halfway Technologies and Nest Relocation

There are many specific management strategies and “technologies” which have been created to improve sea turtle populations. However, Nat Frazer argues that a lot of these ideas are only halfway technologies (Frazer, 1992). In meaning, in sea turtle research and biology the main problem seen is that their populations are low and that technologies must face this problem in relation to sea turtles, rather than facing some of the larger issues behind the reduction of sea turtle populations and those threats. For example, he claims that not approaching these management strategies from a larger viewpoint, where climate change is actually a large problem to sea turtle populations, and instead focusing on an on the ground approach such as head starting is not a correct method. Although there are some positives in these “halfway technologies” they do not get at the real problem, and sometimes are not as effective at increasing populations as we think. Frazer does applaud turtle excluder devices or TEDs as they improve the most threatened of sea turtle populations, those preparing to nest and increase turtle populations. Most of the reduction in population is due to these issues and therefore recognizing turtle bycatch was an important step. However, nesting sea turtles, particularly the adults, are important to focus on since they are the source of new population generation. Their welfare is less concerning, while the hatchlings are usually the focus. To explain this idea of halfway technologies in the nesting sector of sea turtles, nest relocation will become a focus as it is a common halfway technology on Florida Beaches. Nest relocation is a technique used by volunteers who count and protect nests for survey purposes, but when there is a threat to the eggs and hatchlings from predation, human interaction, or high tides or in order disadvantaged sites (sandy roads used by vehicles, directly at the waterline, or under permanently installed beach umbrellas and the like) the nest are relocated to a “better” location (Margaritoulis, 1988; Silberstein & Dmi’el, 1991; Türkozan, 2000; Ilgaz & Baran, 2001; Sak & Baran, 2001; Taskin & Baran, 2001; Türkozan & Yilmaz, 2007 from Iigaz et al. 2011). This is an important strategy to combat declining reptile populations, specifically sea turtle around the world. (Pfaller et al., 2008 from Iigaz et al., 2011). However, this technique is disputed by scientists as an effective tool. Besides not approaching the problem from a holistic viewpoint as halfway technologies usually are, where not just moving the nest is the issue, but the issues associated with why the nest is moved in the first place is the problem, the “technology” or approach itself is not fully effected and understood. Although Baskale and Kaska (2005) found that relocation, screening, and fencing does increased the hatching success rate of loggerhead turtle due to effective protection and removal from areas which may increase inundation, other have studied other effects which show that nest relocation may not be the best conservation technique for sea turtles in the long run. One study examined, although done on freshwater turtles, showed that the movement of clutches from the original nest to a new location resulted in high mortality rates and other abnormalities compared to non-transplanted clutches (Jaffe & Barreto, 2008). Notably, this does not take into account that nests not moved may result in 100% mortality due to water inundation or other factors in sea turtle nests, since nest positioning too close to the hide tide mark is usually the reasoning for movement. These factors considered, nest relocation may be our only choice in the future if development and erosion continues. The study, however, does not take into account the egg differences between fresh and salt water turtles. Even so, other problems have been found to result from relocation. Even if the relocation itself is successful, in comparison to its previous possibly inundated site, a study in Turkey has found that this movement can result in an altered sex ratio (Iigaz et al., 2011). They realized that although hatchling success can be higher, there proportionality of sex is altered. Additionally, many other studies consider this doomed-egg relation bad as this may distort gene pools (Mrosovsky, 2006), although some studies have found this not to be a problem (Pfaller et al., 2008). In another study by Türkozan and Yilmaz (2007) it was found that hatchlings in relocated nests were heavier and had abnormal scutes than natural ones hatchlings. Therefore, although hatchling success has increased, relocation may increase problems for the entire population or may increase vulnerability and risk during early years (Iigaz et al., 2011).

## Nest Site Selection

Scientists and biologists have a general idea of sea turtle behavior in relation to nesting. After years of observation a common set of sea turtle nesting characteristics have been identified. There is a pattern to nesting and it comes in seven steps:

“(1) emerging from the surf and ascending the beach; (2) excavating the body pit; (3) digging the egg chamber; (4) oviposition; (5) filling in the egg chamber; (6) filling the body pit; and (7) returning the sea” (see Miller et al., 2003 from Iigaz et al., 2011).

Although this process is similar amongst all nesting sea turtles, the locations are generally different. There are a multitude of variables that can affect sea turtles (Van Meter, 2002). However, some have been more distinctly noted over others. Specifically noted in loggerheads, sea turtles prefer nesting on sandy, wide, open beaches which have low dunes while their approach from the sea also includes flat sand (Miller et al., 2003 from Iigaz et al., 2011). It has also been reported that sea turtles normally nest on remote beaches which have complete darkness (Salmon, 2003). However, sea turtles are suggested to also orient themselves on beaches due to tidal flooding, temperature of sand, sand texture, offshore reefs, and vegetation on dunes, artificial lighting, and human activity on beaches among many (Van Meter, 2002). However, these are not highly discussed in detail and analyzed in the literature.

Unfortunately, for sea turtles, a species which come back to beaches from which they were hatched, return to beaches that are populated and usually not dark. Therefore, although remote, dark beaches are preferred, it does not deter nesting completely. Additionally, biotic and abiotic factors have also been studied to affect nesting of embryonic sea turtles such as "salinity, moisture, gas flow, temperature, rainfall, tidal inundation, erosion, sand grain size and type, predation, nest depth and slope" (Hendrickson, 1958; Bustard & Greenham, 1968; Prange & Ackerman, 1974; Fowler, 1979; Limpus et al., 1979; Ackerman, 1980; Mrosovsky, 1980; Stancyk et al., 1980; Blanck & Sawyer, 1981; Miller, 1985; Yerli et al., 1997; Wallace et al., 2004; Özdemir et al., 2008 from Iigaz, 2011), but it is unclear if these associations have also been attributed to the site selection process behavior in the nesting adult turtles. Some general idea of the process of decision making is known in regards to different spatial scales (Salmon, 2003).

Larger scale site selection is known to exist based on magnetic landmarks and using these cues to gauge their spatial positioning. However, the sensory cues are less understood (Lohmann et al., 2001 from Salmon, 2003). At a finer spatial scale, although still generally large in relation to nest location, cues are somewhat understood. Some sites can appear more attractive to nesting females due to ecological characteristics. One is the beaches relationship to shoreline currents which will help hatchling transport to nursery habitat, as well as a favorable approach profile (gradual or low lying bathymetry), few obstructions (no shallow water rocks or reefs) which will remove risk to the female (Salmon, 2003). Very fine scale cues are known also. Assessment of dune, vegetation, beach slope, and elevation are all general cues a nesting turtle might analyze as well as certain sand characteristics like temperature and moisture content (Salmon, 2003).

Additionally, sea turtle site selection may have general characteristics that they are affected by, but are still highly individualistic (Kamel & Mrosovsky, 2004 ).

However, although some cues are known there are more that have not been examined on a worldwide basis and not as specific to fine scale nesting locations. These cues will be integral in understanding why sea turtles are nesting in locations which seem contradictory to the above cues.

## Research Purpose and Framework

Since sea turtles nest on very human populated beaches within Florida, managers are interested in understanding why they are nesting where they nest within these beach areas to better manage future development projects or come up with better management practices which fit these reasons. Although it is understood that sea turtles generally come back to the same beach they hatched at, the dynamics of nesting within a beach is less understood.

The purpose of the project is to understand the species both on the ground in Florida better, while possible also gaining a better understanding of the species as a whole and how they approach nesting and how their behavior reflects this. Knowing what factors affect sea turtle nesting location will help managers to better adapt future human needs plans in order to coincide with sea turtle management and improve species populations. Although nest hatchling success is not a factor in this case, false crawl information will also be analyzed in order to compare nesting success. Although these changes may seem small to the average person, even a small change to use may go a long way in fine tuning regulations and management strategies to what sea turtles need to nest healthily on Florida beaches. Survival of hatchling data is available and can be studied in future analysis's to increase knowledge of sea turtle survival in this area of Florida.

Based upon both past studies and evidence, many variables can intricately affect sea turtles in many differing ways. This can be in both space and time, and in post negative and positive ways in terms of nesting success, hatchling success, and false crawls. Due to this multivariate studies to understand the importance of all these variables will enhance the understanding of sea turtle nesting. This study will look at the success of nesting, rather than the success of hatchlings.

Therefore, this study exists to understand the location that turtles nest in natural conditions. If more understanding of where these nests are made, as well as which result in false crawls, more determination of future innovative management schemes can be made so to reduce relocation strategies which may hurt sea turtle populations more than we are aware at this current time.
Nest site selection in reptiles can affect the fitness of the parents through the survival of their offspring because environmental factors influence embryo survivorship, hatchling quality, and sex ratio. In sea turtles, nest site selection is influenced by selective forces that drive nest placement inland and those that drive nest placement seaward. Nests deposited close to the ocean have a

greater likelihood of inundation and egg loss to erosion whereas nest placement farther inland results in greater likelihood of desiccation, hatchling disorientation, and predation on nesting females, eggs, and hatchlings. To evaluate the role of microhabitat cues in nest site selection in Loggerhead Sea Turtles (*Caretta caretta*), we assessed temperature, moisture, salinity (conductivity), and slope along the tracks of 45 female loggerheads during their beach ascent from the ocean to nest sites in the Archie Carr National Wildlife Refuge in Florida on the beach with the greatest density of loggerhead nesting in the Atlantic. Of the four environmental factors evaluated (slope, temperature, moisture, and salinity), slope appears to have the greatest influence on nest site selection, perhaps because it is associated with nest elevation. Our results refute the current hypothesis that an abrupt increase in temperature is used by loggerheads as a cue for excavating a nest. Moisture content and salinity of surface sand are potential cues but may not be reliable for nest site selection because they can vary substantially and rapidly in response to rainfall and changes in the water table. Sea turtles may use multiple cues for nest site selection either in series with a threshold that must be reached for each environmental factor before the turtle initiates nest excavation or integrated as specific patterns of associations.

## Methods

Using a combination of geospatial analysis techniques, a vast majority of variable types, or indices about possible reason for nesting locations will be collected. Specific calculations for each variable will be conducted.

### Study Area

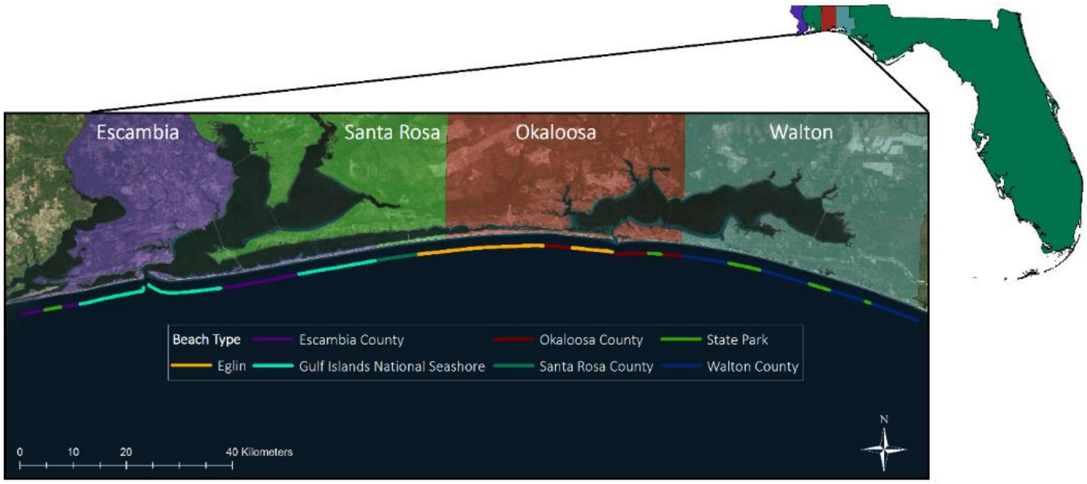


**Figure 1.** STUDY AREA OF SEA TURTLE NEST SITES, along the North Western Florida Panhandle, including four counties.

The study area includes around 150km stretch of beach within the south western portion of the Florida Panhandle of the United States (Figure 1). Several counties are included in this analysis; from east to west these include Walton, Okaloosa, Santa Rosa, and Escambia Counties. Although not all beaches were assessed along this stretch, protocol of this process is followed in Florida through the Fish and Wildlife Service and therefore the process is accurate in terms of sample size. Specific beaches or associations that will be important are South Walton, Eglin Air Force Base and Reserves, Destin, Okaloosa Island, Navarre Beach, Santa Rosa, Perdido Key, Fort Pickens and Pensacola Beach (Table 1). The beaches are a combination of public and private beaches, as well as military reserve land that have different restrictions on human interactions within the areas. Areas of Eglin AFB are the least populated and sometimes involving no development, while areas such as Destin and Pensacola are affected by high population densities and increasing development and both in terms of construction and habitat replenishment. The Emerald Coast lays within this area and are known for their sand which appears sugar white. This combination of white sands against green waters attracts tourists. Additionally, these beaches based previously on physical characteristics also attract nesting turtles, which are threatened by multiple factors, although mainly related human-turtle interactions.

Table 1. SELECTED BEACHES AND THEIR LENGTHS. Variable data types, organized by scale with their respective literature review. Variables in green were not analyzed due to lack of data. Data taken and broken up through Florida Fish and Wildlife Conservation Commission.

| County | Beach | Beach Type | Aggregated Beach Lengths (km) |
|---|---|---|---|
| Escambia | Perdido Key | Gulf Islands National Seashore | 14.6 km |
|  | Perdido Key | Public Access & State Park | 8.7 km |
|  | Fort Pickens | Gulf Islands National Seashore | 12 km |
|  | Pensacola Beach | Public Access | 13.5 km |
|  | Santa Rosa Island | Gulf Islands National Seashore | 13.3 km |
| Santa Rosa * | Navarre | Public Access | 6.4 km |
|  | Eglin AFB | No Public Access | 4.8 km |
| Okaloosa * | Eglin AFB – West | No Public Access | 16.1 km |
|  | Eglin AFB – East | Public Access | 6.6 km |
|  | Okaloosa Island | Public Access | 4.8 km |
|  | Destin | Public Access | 8.5 km |
| Walton * | Walton* | Public Access | 38.9 Km |
|  |  | Total | 109.3 km |

*State parks within, but excluded from total beach length

### i. Study Area Boundaries

A similar process occurred to determine both the final study area distribution. Through 2011 shoreline data (NOAA 2011), analysis of nourishment areas after 2011, roads, and sand which does include sand other than beach sand, all overlaid on 2015 imagery two masks were made; one determined sand only areas, while the other determined a larger scale of the study area to include unlikely nesting sites in order to look at how these areas fair in relation to site selection. The first determined the area in which sea turtles would be likely to nest. The other determined a larger area beyond the beach nesting area to understand the full implications of what areas sea turtles are not deterred by or could be considered possible site selection areas if not for a lack of sand.

### Global Position System (GPS) nest collection

Collection of GPS points from beaches were completed by several groups within the study area which include the South Walton Turtle Watch, Emerald Coast Turtle Watch, Eglin Air Force Base, Gulf Islands National Seashore. All have different data collection techniques, but all must follow standard protocols developed by the FFWCC for Florida's surveying program called the Statewide Nesting Beach Survey (SNBS) (personal communication with Sharon Maxwell and Sara Gray 2016, FWS 2015). The purpose of the SNBS is to collect distribution, seasonality and abundance of sea turtle nesting (FWS 2015).

On the ground collection consists of volunteers or members heading out each morning on foot or ATV along the shoreline each morning from May 1st through September 30th, (about 183 days depending on beach accessibility) (Personal Communication with Sara Gray, Kathleen Gault, and Sharon Maxwell). If a crawl, where turtle tracks are seen, is found the time, species, GPS points, and crawl width and length measurements are taken. GPS coordinates for a nest are taken directly over the egg chamber. Different GPA collection strategies included an assortment of a Trimble Juno with ArcPad software, Garmin GPS units, and handheld GPS phone applications. Some datasets recorded false crawls, when no eggs are laid but an attempt is apparent. Nests were marked with wooden stakes and a wire screen to prevent predation, as well as flagging tape. All crawl markings are physically removed to avoid double counting.

#### i. Geospatial organization of nest points

Data points were collected from each county and important nest data was organized by county, beach, crawl type (nest or false crawl), nest number, date found, described location, species, and latitude and longitude. This data was integrated into ArcMap and nest points were created from latitude and longitude coordinates (Figure 2). Three types of errors occurred; large scale ocean nest error due to GPS functionality or human error, placing a point way out of the normal spatial scale; large scale land error, which is similar to ocean error, where nests are placed unfeasibly inland; and small scale GPS error which is normal when using GPS points and would cause about 2-3 meters of error on the ground. Small scale error can be accounted for during analysis, but large scale errors were removed.

a. Nest Error Removal

To remove ocean errors, a land area polygon through shoreline from 2011 NOAA's Continually Updated Shoreline Product (NOAA 2011) was created and all nests beyond land area were removed. Due to a lack of evidence of sea turtle max distances as well as study area differences, nests due to error were removed by manual extract. Criteria included beyond the original land, beyond highly traveled roads, and nestled within development.

Figure 2. STUDY AREA OF THE FOUR COUNTIES IN THE FLORIDA PANHANDLE AND THEIR NESTING BEACHES. Beaches marked as State Park are missing data due to accessibility, except for Perdido Key in Escambia.

ii. Random Nest Generation

Through ArcMap, random points throughout the study area of the sand only mask were generated through the Create Random Points tool (Figure 3). This point generation is needed to compare observed GPS collected nesting sites to areas that did not observe nesting in the 2015 season.

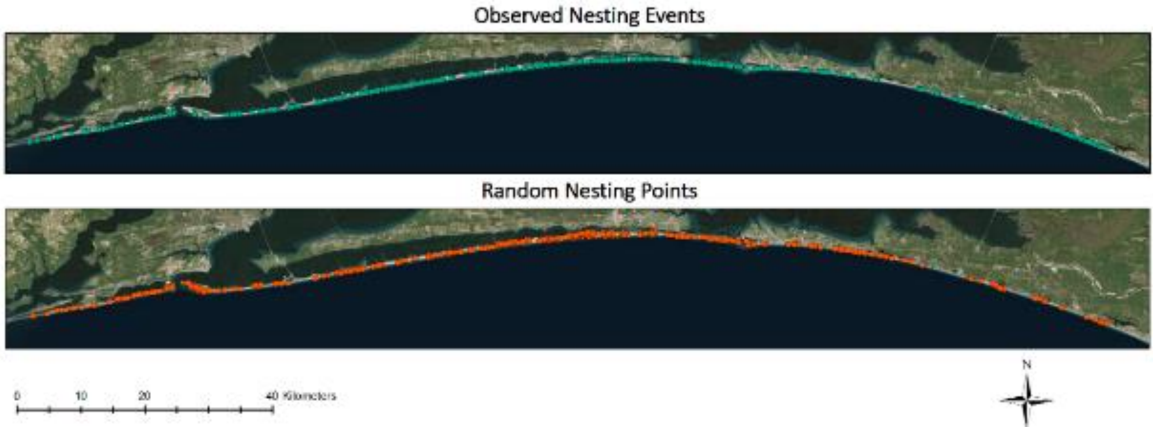


Figure 3. FINAL COLLECTED OBSERVED NESTS, RELATIVE TO GENERATED RANDOM POINTS.

## Variable Collection

Through literature review, as well as observation of sea turtle nesting locations within the study areas, multiple variable types were chosen to analyze nesting site selection preferences. These variables were narrowed down and then organized. Variables were separated by spatial scale into large and small scale variable collection/calculation (Table 2). This is because a sea turtle may approach a specific area of the beach based on a large scale variable, while also selecting a specific location on that beach due to smaller scale variables. Note that some variables can be assessed on both a small and large scale.

### i. Variable Calculation

Multiple variables are used within this analysis. Once variables were collected they were converted into a raster form for value extraction to each nest point during analysis. Each variable was processed into raster form based on its classification. Categorical data had three main components. This data remained intact, serving as a presence-absence dataset with differing factors or was calculated in two ways; into a distance from the closest nest or closest factor type to nest. For example, land use was a variable used while its main attributes remained the same in one layer, in another layer the closest land use to a nest was determined, and in another the distance to the closest land use was determined. Continuous data usually remained intact as its own calculation. Not all variable data will reflect 2015 nests on a temporal scale. However, temporal conditions are close enough to assess the overall areas trends, while both spatial and scaler considerations are taken into account. All data collected is the best data available for this project. Data was coded for analysis purposes (Table 2, see appendix (B) for details).

Below some of the main calculation types that were generated in ArcMap (Table 2) are described in detail:

### a. Categorical : Distance types

Categorical distance was done in two ways as discussed above; nest to variable distance or closest variable to nest. The distance of each nest site to the closest variable was determine using Euclidean Distance tool, while the closest variable factor to nest was determined using the Euclidean Allocation tool.

### b. Categorical: years

In the case of nourishment, the amount of years that had passed since nourishment was calculated and distributed into its respective areas.

c. Continuous Data: Line Use and Calculations

To create differing variable layers from line data inputs, multiple techniques were used.

- Tides

For high tide and low tide calculations, shoreline determinations were hand digitized through the editor tool relying on 2015 imagery. Euclidean distance from these lines were created to determine a layer of distance from the high and low tide lines.

- Beach width

Beach width was created by creating two points north and south of the original and random nests, then using bearing distance to line tool to create a line from each nest point. These lines were intersected onto the sand only beach mask and the distance of the final intersected line was determined. From here polyline to raster was used to create a raster of the full area based upon somewhat evenly distributed lines.

d. Continuous Data: Point Calculations

- Air temperature and precipitation layers were created from weather station sites. Point data was used to create full area layers of estimated land temperature and precipitation through the IDW tool with a power of 2 and a search radius point amount of 12.
- Grain size data layers were also created through the IDW tool with the same tool characteristics
- Permits for future seawalls, dune restoration, and nourishment projects were received in point form. Distance of these variables to the nest was the only logical calculation based upon the data received. For each, a Euclidean distance was performed.

e. Continuous Data: Physical Data Generation

Through bathymetry of the ocean floor and elevation of the land, both slope and aspect of each was generated through their respective tools.

### f. Continuous Data:  Monthly Data to Yearly Averages

Light pollution data, air temperature, and precipitation raster's were originally separated into monthly estimates. The raster's were therefore averaged through raster calculator to create a final yearly average of light and temperature.

**Table 2.** VARIABLE TYPES ORGANIZED BY SCALE AND ASSOCIATED WITH VARIOUS STUDIES. Variables in green were not analyzed due to lack of data.

| **Spatial Scale** | **Variable Type** | Literature |
|---|---|---|
| **Small** | Light-street lights | Miller, Limpus, and Godfrey 2003 |
| | Sand quality, grain size | Garmestani et al. 2000, Mortimer J. 1990 |
| | Sand quality, sand color | Gallaher A.A 2009 |
| | Sand quality, sand content | Garmestani et al. 2000, Kikukawa et al 1999 |
| | Elevation | Miller et al. 2003 |
| | Slope | Miller et al. 2003 |
| | Sea walls | A.E. Mosier & B.E. Witherington 2000 |
| | Nourishment | Miller, Limpus, and Godfrey 2003 |
| | Tidal Distance | Kamel S.J. & Mrosovsky N. 2004 |
| | Dunes | Kamel S.J. & Mrosovsky N. 2004 |
| | Roads | Andrews et al. 2008<br>General question and observation |
| | Land Use | Kamel S.J. & Mrosovsky N. 2004<br>Miller, Limpus, and Godfrey 2003 |
| **Large** | Light – Pollution | Miller, Limpus, and Godfrey 2003 |
| | Elevation | Miller, Limpus, and Godfrey 2003 |
| | Erosion | Miller, Limpus, and Godfrey 2003 , Maison et al. 2010 |
| | Seawalls | A.E. Mosier & B.E. Witherington 2000 |
| | Nourishment | Mortimer J. 1990 |
| | Bathymetry (slope, aspect) | Miller, Limpus, and Godfrey 2003, Maison et al. 2010 |
| | Population | Weishampel et al.2003 |
| | Beach Access | Observation to be assessed, Weishampel et al. 2003 |
| | Hurricanes | Miller, Limpus, and Godfrey 2003 |
| | Weather | Miller, Limpus, and Godfrey 2003 |
| | Parks | Weishampel et al. 2003 |

*This is not a comprehensive list of variables or sources. Some variables not considered in this analysis due to overall lack of importance throughout multiple studies or lack of data.

## Modeling and Statistical Analysis Possibilities

Due to the variety in data collected, multiple analyses were used to create an analytical framework relevant to cover the issue. Specifically, a small analysis on nest data will contribute to an understanding of population and nest distribution, while more importantly, a multivariate analysis of the variables created and their relationship to each nest and to each other will take place. The multivariate analysis encompasses two methods, habitat prediction models using general linear modeling and tree classification of variable importance. Both multivariate analyses encompass a comparison between observed nest selection sites and created nests points within a designated sea turtle nest selection of the study area.

### Population analysis

Population analysis was used to consider 2015 sea turtle nest population distribution and density. Standard point density, using the point density tool in ArcMap, with a 500 km radius around all nest sites (ArcGIS Calculate Density 2015).

Multiple nesting distributions were looked at:

1. Total nesting distribution, including false crawl data
2. Total nesting distribution, removing false crawl data
3. Total nesting distribution, random nest generation data
4. Okaloosa and Santa Rosa nesting data, including false crawl data
5. Okaloosa and Santa Rosa nesting data, only false crawl

### Multivariate analysis

Once all the variables were collected a multivariate analysis combining these multiple observation layers was conducted. There are several different types of multivariate statistics that were used to determine the project goals; three habitat prediction analyses and four tree (variable importance) classifications and are listed below. Site Selection Prediction Models can give an idea of the probability of site selection occurring and what reasons are involved in the process, while tree classification explains what variables are most important in those site selections.

1. A large scale All Variable - Site Selection Prediction Model using Presence (all observed nesting, including false crawls) and Random (generated nest points in a designated area) points for comparison for the entire study area.
2. A small scale All Variable - Site Selection Prediction Model using Presence (observed nesting) and Absence (false crawls) for comparison in the area of false crawl data in Okaloosa and Santa Rosa Counties.
3. A large scale Urban - Site Selection Prediction Model using Presence and Random points for the entire study area.
4. A tree classification of all variables
5. A random forest classification for all variable's
6. A tree classification of urban variable's
7. A random forest classification for urban variables

This multiple analysis is important in understanding the reasoning behind why each variable matters.

### i. Combining Nesting Data and Variable Data

First, data from each variable related to each observation nest and random nest point was collected through the Sample tool in ArcMap. This allowed for the creation of a table with each variable and its respective value related to each nest. In r studio, observation nest values and random nest point values were combined, while a new column was added where observation nests were coded 1 as species present and random nest points were coded as 0 for species not present.

### ii. Habitat Classification

Habitat classification, or in this case, site selection prediction area was done to determine best potential locations of sea turtle nesting habitat in the study area. There were multiple ways and steps to conduct this analysis.

#### a. Presence – Random Model

It is also assumed that all the covariates are related, also that they are not collinear, do not interact with each other, and have not chosen too many covariates for our data to support

There, first, collinearity of variables compared to each other were tested. If any variables were highly correlated (>.07), then one was removed from the analysis. Additionally, variables that appeared less important than others through literature review were removed in order to improve the predictability of the final model. Independence was assessed to determine proper assumptions that the habitat classification model requires through a chi-square test of independence. The final variables chosen were then run within a Bayesian general linear model to account for un-normal data distributions as well as a small data source for some categorical factors. For example, a nest may have been present within the land use designated as coastal shrub, while no other nests were found there. This variable is still included within the analysis, but a normal GLM would have trouble comparing such small values. Bayesian GLM weights the values of all continuous variables and categorical variables factors variable so that all values can be compared despite small datasets. This was a binomial logistic regression, as it was comparing 0 and 1 or species non-presence vs species presence. (Duke University-Rockfish Habitat Modeling, 2015). This way species non-presence points and their variables are compared statistically to the original species presence observations and their values to build the model to predict habitat locations based on variable comparisons. A best model was created after reducing the original model variables, based on lowest AIC, highest deviance explained, and variable significance (p<.05). A site selection prediction map was created suing the coefficients supplied within R Studio.

### c. Presence - Absence Model

In addition, false crawl data was supplied for the Okaloosa and Santa Rosa counties. To provide a more distinct and scalar analysis for the Okaloosa region, comparing false crawls to observed nest locations was ideal. A total of 44 false crawls were collected from the original study. Therefore, 44 observed nests were randomly selected from the Okaloosa and Santa Rosa area for direct comparison. Similarly to the above two habitat classifications, the observed and false crawl nests and their variables were combined into a table. False crawl nests were given a species value of 0 and observed nests a species value of 1. These were also compared in a binomial Bayesian general linear model. Once a best model was determined, a site selection map for Okaloosa and Santa Rosa County was created.

### c. Urban Model

Once the original analysis was run, it was determined that due to a lack of studies comparing urban area variables with sea turtle nest site selection, a  tailored binomial Bayesian GLM model looking at only urban variable types was used. This included some variables removed from the total model. Once a best model was found, a site selection prediction map based on urban variables was created.

### iii. CART & Tree Classification

Therefore, another option is to run a statistical analysis which determines what variables are most important in determine sea turtle locations. General linear regression approaches can be supplemented with alternative methods, specially known as tree regressions (Statistical Sciences, 1993 from Garmestani et al., 2000). Tree regressions or classifications can separate variables based on different scales or types of variables, such as oceanic or terrestrial variables as well as large scale vs. small scale variables (Garmestani et al., 2000). Some of the variables inputted cannot be directly compared since sea turtles may be affected by these scales and types differently. For example, large scale variables in terms of what area of the beach they choose and then once on the beach, the decision process due to small scale variables could be more likely to cause a nesting event. Tree classification consists of repeatedly binary splitting which separates these multiple variables into subsets, where each split is examined and the best split response is chosen. Response variability at each split increases in predictability, in this case, it will produce subsets of variables which best predict likelihood of sea turtle nests. This statistical analysis is able to look at complex relationships, over he more simplified regression that would be run in the habitat classification. The tree regression model derived by the process described above can be used to identify environmental characteristics that are most likely to be important to turtles in determining a nesting site.

### a. Full Classification Tree

Using the classification tree method, all variables were used within a model in R Studio under the rpart package ( Therneau et al., 2015). The original models x val relative error plot was created and the lowest was determined in order to prune the classification tree to reduce over fitting. Once pruned, the tree was used to map out importance of each variable spatially into ArcMap. Additionally, species (0, 1) predictions by nest, based upon the model, were created and compared to the original data in order to reveal true positive, true negative, false positive, and false negative rates. Additionally, a receiver operating characteristic curve was created to further estimate the predictability power of the model and determine if the model can discriminate between the two species types. The area under the curve was calculated to determine a precise determination of the predictability power of the model (Hopley and Jo van Schalkwyk, 2011).

b. Urban Tree

Similar to the habitat classification, urban variables were sectioned out of the original variable data set to be compared on their own. The same process as the total tree analysis was used.

c. Random Forest

Additionally, although tree classification is effective on its own, only one tree is generated. Random Forest was used as a separate technique for both the total tree and urban tree. This method grows multiple trees and then chooses the tree based upon the best variable for each branch and returns the importance of each variable. The more importance variables are determined, and the true positive (TP), true negative (TN), false positive (FP), false negative (FN) are returned (Stephens T., 2014).

## Analysis and Key Findings

### Nest Collection Information

A total of 316 nesting sea turtles we observed during the 2015 season. Of these 316 nesting sea turtles, 91% were loggerhead sea turtles (Table 3). After removing inaccurate GPS nest locations, 285 of the nests were retained. Of these 285 nests, 240 were true nesting attempts, while 45 were false crawls within Santa Rosa and Okaloosa (Table 4). Distribution of these 285 nests can be seen in Figure 2, and the differences between true nests and false crawls can be seen in Figure 4 and 5. False crawl data was not collected in Walton County, while false crawl data was not received from Escambia County in time.

Table 3. SEA TURTLE NESTING ABUNDANCE BY SPECIES.

N/A means the species could not be determined by the tracks.

| | Loggerhead | Green | Kemps Ridley | Leatherback | N/A | Total |
|---|---|---|---|---|---|---|

|  |  |  |  |  |  |  |
|---|---|---|---|---|---|---|
| **Amount of Nests** | 288 | 20 | 5 | 2 | 1 | 316 |
| **Percent** | 91.1% | 6.33% | 1.58% | .63 % | .32% |  |

Table 4. NEST AND CRAWL TYPE DISTRIBUTION WITHIN STUDY SITE. Only 285 nests were used in the final analysis. False crawl data described as NA describes data as either unattainable in time from the county, or not recorded by the county. Walton does not record false crawls, while Escambia didn't provide data in time due to data still being organized.

| **County** | **Beach** | **Nests** | **False Crawls** | **Total** |
|---|---|---|---|---|
| **Escambia** | Perdido Key (Public & State) | 11 | NA | 11 |
|  | Perdido Key (GINSS) | 17 | NA | 17 |
|  | Fort Pickens | 10 | NA | 10 |
|  | Santa Rosa Island | 35 | NA | 35 |
|  | Pensacola Beach | 16 | NA | 16 |
| **Santa Rosa** | Navarre | 4 | 1 | 5 |
| **Santa Rosa & Okaloosa** | Eglin AFB | 65 | 36 | 101 |
| **Okaloosa** | Okaloosa Island | 5 | 3 | 8 |
|  | Destin | 13 | 5 | 18 |
| **Walton** | Walton | 64 | NA | 64 |
| **Totals** |  | **240** | **45** | **285** |

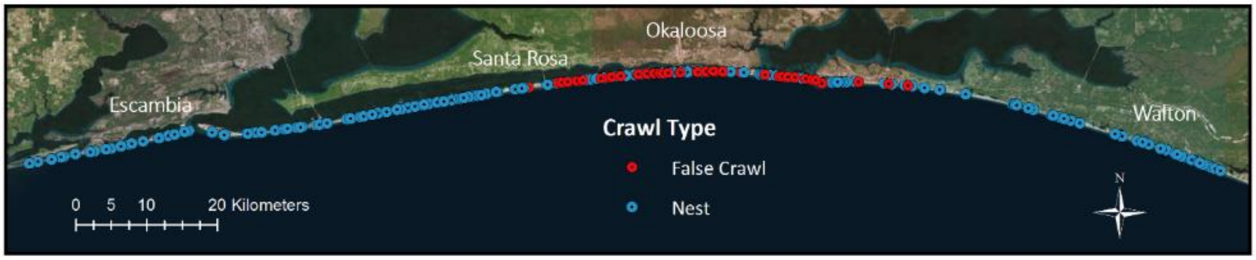


Figure 4. Distribution of Nests separated by Observed nesting and false crawls in the total study area.

**Figure 5.** Observed False Crawl and Observed Nest Locations within Okaloosa County and Eglin Air Force Base in Santa Rosa County. Only one false crawl observation was seen in Santa Rosa County beaches, so was removed from any analysis. This figure is a zoomed in portion of the total study area seen in figure 3.

## Population Analysis

A population density analysis was used to look at spatial nesting population tendencies of 2015 sea turtles that came ashore. When observing all 2015 nests, including false crawl data, nesting sites reached a highest density of 4.1 nests per square kilometer (Figure 6). This high density of nests were clustered in 4 key areas; Eglin AFB- East in Okaloosa County, Eglin AFB – West in Okaloosa

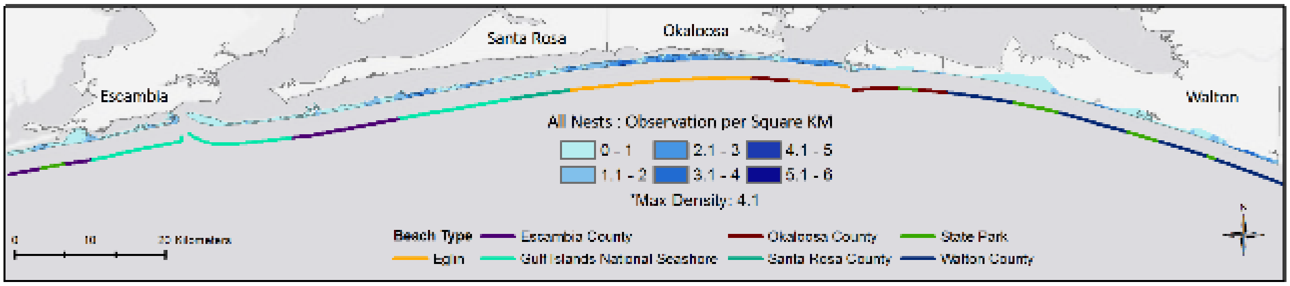


Figure 6. POPULATION DENSITY OF OBSERVED NESTS THROUGHOUT STUDY AREA. Beach type is included for reference.

County, a small area of Escambia called Santa Rosa Island which is part of the Gulf Islands National Seashore, and the eastern most area of Walton County. Aside from the Walton County cluster, all high density areas are associated with some form of barrier from human impact.

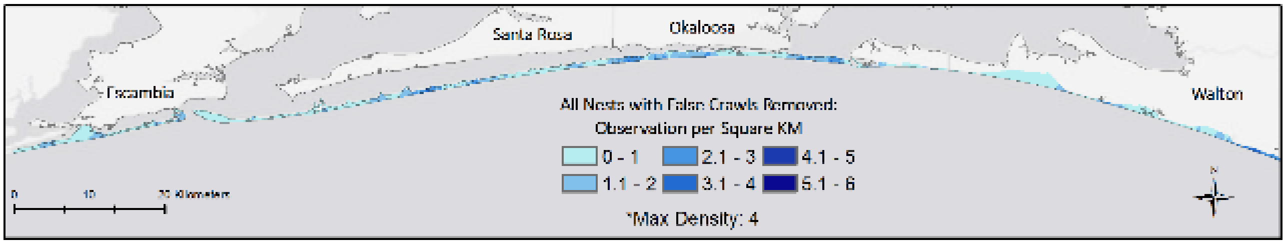


Figure 7. POPULATION DENSITY ANALYSIS WITH NO FALSE CRAWL DATA.

Additionally, when false crawls were removed these higher density areas were not altered (Figure 7). Random nest points were also analyzed for comparison purposes (Figure 8). Highest clustering here occurred on a magnitude of 6 nests per square km and was within the Eglin AFB west area, although high densities of over 3 nests per square km occur more often than in the true observed nest areas.

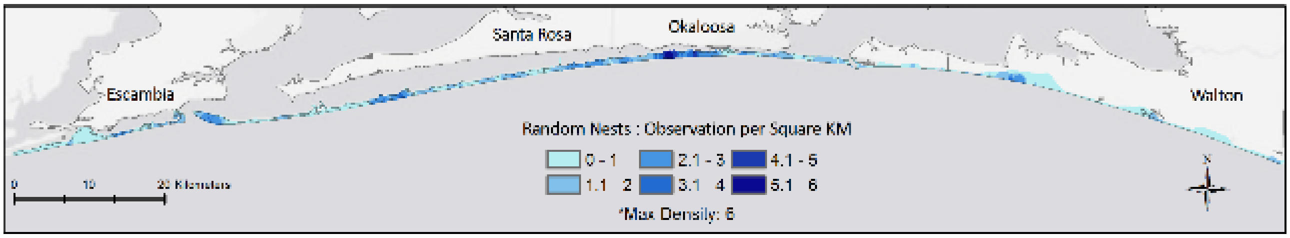


Figure 8. POPULATION DENSTIY OF RANDOM GENERATED NESTS

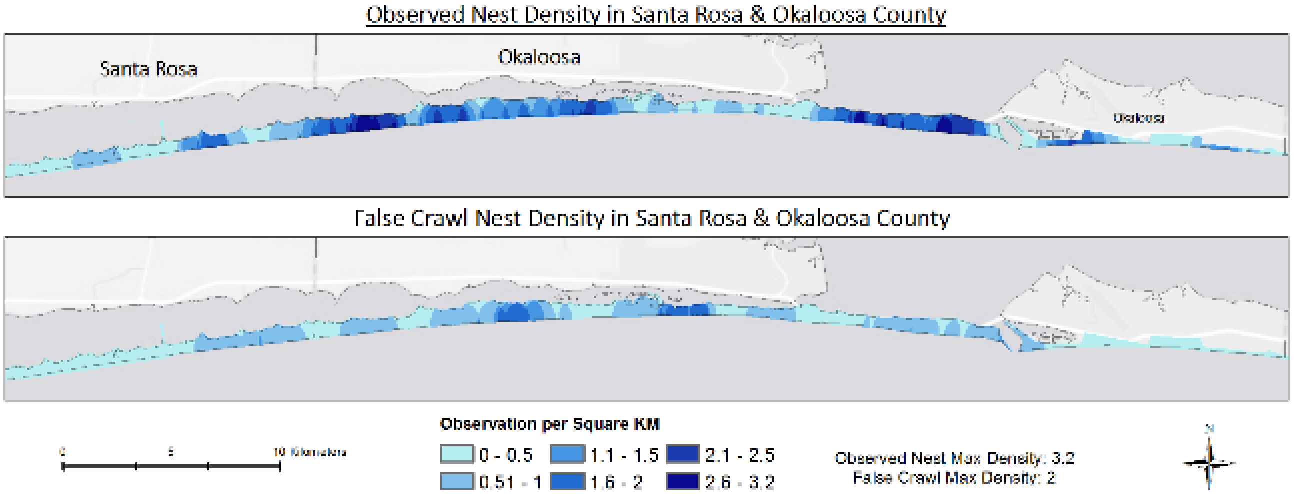


Figure 9. OKALOOSA AND SANTA ROSA COMPARISON OF FALSE CRAWL AND NEST DENSITY.

When looking at false crawl nests compared to true nests in the Santa Rosa, Okaloosa County region, the densities are different. Overall, false crawls tend to be less dense and more spread out (max of 1.91 attempts per square km) then true nests (max of 3.18 nests per square km) (Figure 9). Additionally, where false crawl sites due cluster, they both differ and overlap from true nests. False crawl sites cluster in an area westerly, where true nests also cluster. However, in an easterly area of false crawl nests, these do not appear to associate with true nest density. The spread of false crawls may have smaller scale impacts, or independent reasons for the false crawl. However, the area of non-overlap may be an important site to focus on, on the ground.

## Multivariate Analysis

### i. Variable Reduction & Analysis

To begin the analysis of the variables per nest, some variables were removed due to lack of data, no occurrence, or determined insignificant from multiple literature reviews. These include street lighting, sand color, hurricane events, currents, and beach access (Table 5). Correlation of all variables to each other helped to remove variables from the main large scale – all variable analysis to reduce overfitting. Variables removed in this process included nourishment site distances, distance to artificial reefs, house abundance, distance to critical erosion sites, and distance to dune restoration sites (Table 5). Additionally, some variables were removed through high insignificance in the model when run originally.

Table 5. LARGE SCALE VARIBLE SIGNIFICANT CORRELEATIONS.

| **Variable 1** | **Variable 2** | **Correlation** | **Variable Removed** |
|---|---|---|---|
| Distance to Closest Nourishment Site | Beach Width | .761 | Distance to Closest Nourishment Site |
| Closest Distance to Artificial Reef Type | Precipitation Average | .794 | Closest Distance to Artificial Reef Type |
| House Abundance by Block | Population Abundance by Block | .822 | House |
| Distance to Closest Nourishment Site | Distance to Critical Erosion Site | .795 | Distance to Erosion Site |
| Distance to Seawall Permit Point | Distance to Critical Erosion Site | .724 | Distance to Erosion Site |
| Distance to Dune Restoration Permit Point | Distance to Critical Erosion Site | .703 | Distance to Erosion Site |
| Distance to Closest Nourishment Site | Distance to Seawall Permit Point | .950 | Distance to Closest Nourishment Site |
| Distance to Closest Nourishment Site | Distance to Dune Restoration Permit Point | .932 | Distance to Closest Nourishment Site |
| Distance to Dune Restoration Permit Point | Distance to Seawall Permit Point | .977 | Distance to Dune Restoration Permit Point |

Different starting variables for both small scale pa and urban variables. This removal process of variables remained the same for small scale site selection prediction, with their own correlations performed due to a different scale. The urban variable removal was the same, except erosion distance remained in while nourishment distance was removed (two other nourishment characteristics remained).  The full variable tree also reduced inputs through this process. The urban models were also reduced looking at correlations, however this process was less stringent as the tree allows to look at the differences between these variables despite high correlation. Variables were reduced through running the model and looking and removing the most non-significant variables. Through this process, final variables were determined specifically for each analysis (Table 6).

All models still had a significantly high amount of variables use for testing, but this multiple variable layer analysis is important in understanding the reasoning behind variable importance to nesting sea turtles.

### ii. Site Selection Prediction Analysis: Large Scale - Presence/Random (PR)

The resulting site selection distribution of the full variable, large scale model was determined by the Bayesian GLM logistic regression. This resulted in a 9 variable model. This was the best model based upon the highest residual deviance, consistent with the lowest AIC (Table 7). The model includes categorical data of land cover type, nourishment source, and continuous data of bathymetry, slope of bathymetry, distance from high tide, distance from roads, distance from urban types, population abundance, and elevation (Table 8) and resulted in a percent deviance explained of 37.7%. The original high number of variables and then reduction of the model explains this. However, the original deviance explained of 39.8% notes that possible explanation of sea turtle site selection is due to many small factors or that model reduction may be necessary to explain site selection predictability on this large scale.

All variables are considered significant ($p < .05$) or within reason, except for those within categorical data (Table 8). Factors of significance include beaches other than swimming beaches, sand other than beaches, offshore and storm over wash nourishment source, and the east pass ebb shoal nourishment source. Additionally, bathymetry, slope of the bathymetry, elevation, distance to high tide, population, distance to roads, and distance to urban areas are all significant in probability of sea turtle site selection (Table 8). These associations with nest selection sites are either positive or negative (Table 8, Figure 10).

Table 6. VARIABLE INPUTS BASED ON MODEL

| **Model Type** | **Variables included** |
|---|---|
| **PR Site Selection** | Average Light Pollution + Average Air Temperature + Average Precipitation + Distance to High Tide + Beach Width + Distance to Closest Urban Area+ Land Cover Type + Distance to Wetland Type + Road Type + Distance to Closest Road + Population Abundance by Block + Nourishment Source + Distance to Closest Seawall Permit + Elevation + Slope of Land + Aspect of Beach + Bathymetry + Slope of Approach + Aspect of Approach + Grain Size |
| **PA Site Selection** | Average Light Pollution + Average Air Temperature + Distance to High Tide + Total Land Use + Population + Source of Nourishment + Wetland Type + Distance to Seawall Permit + Distance to Urban Area + Distance to Closest Road + Closest Road Type + Elevation + Slope of Land + Aspect of Land + Bathymetry + Slope of Approach + Aspect of Approach + Grain Size |
| **Urban PR Site Selection** | Average Light Pollution + Beach Length + Beach Width + Total Land Use + Distance to Closest Urban Area + Road Type + Distance to Closest Road + Population + Nourishment Source + Years since Nourishment + Distance to Seawall permit + Grain Size + Erosion Type + Urban Density. |
| **Full Classification Tree & Random Forest** | Land Cover Type+ Light + Air Temperature + Precipitation + High Tide Distance + Beach Length + Beach Width + Total Land Use + Distance from Urban Areas + Closest Urban Type + Land Cover Type + Land Use Combined + Distance to Hydrology + Hydrology + Closest Hydrology Type + Wetlands + Distance to Wetland + Road + Closest Road Type + Road Distance + Population + House Abundance + Urban Type + Nourishment Source + Nourishment Distance + Nourishment Year + Seawall Distance + Dune Distance + Artificial Reef Type + Artificial Reef Distance+ Elevation + Elevation slope + Elevation aspect + Bathymetry + Bathymetry Slope + Bathymetry Aspect + Erosion distance + Erosion Type + Grain Size |
| **Urban Classification Tree & Random Forest** | Average Light + Beach Width + Total Land Use + Distance from Urban Areas + Closest Urban Type + Land Use Combined + Road + Closest Road Type + Road Distance + Population + House Abundance + Urban Density + Nourishment Source + Nourishment Distance + Nourishment Year + Seawall Distance + Erosion distance + Erosion Type + Grain Size |

Table 7. MODEL STATISTICAL ANALYSIS RESULTS: PRESENCE RANDOM MODEL

| **Statistical Result** | Original Model | Best Model |
|---|---|---|
| Null Deviance | 790.19 on 569 degrees of freedom | 790.19 on 569 degrees of freedom |
| Residual Deviance | 476.02 on 532 degrees of freedom | 492.46 on 549 degrees of freedom |
| Percent Explained | 39.8% | 37.7% |
| AIC | 552.02 | 534.46 |

As population, elevation, and beaches other than swimming beaches increase or exist, nests are more likely (Figure 10). While as bathymetry, slope of the water approach, offshore and storm over wash sand, east pass ebb shoal sand, sand other than beaches, distance from high tide, distance from road, and distance from urban areas increase, nests are less likely to occur (Figure 10). Distance to high tide, distance to road, distance to urban areas, and population have very small effect compared to the other characteristics. In conjunction with an imagery map (Figure 11) the distinction of each characteristic significant variable can be seen of the east pass area to understand each variable in relation to its environment, on a higher resolution of the east pass inlet for fine scale explanation of its effect on the surrounding environment (Figure 12).

Overall distribution of predicted site selection tends to vary throughout the study area, which is to be expected (Figure 14). Additionally, nest site selection tends to focus in a region of the beach beyond the tide line and towards the dunes or urban areas. Gulf Islands National Seashore, near the inlet (Figure 14 I) shows nesting along this gradient, however is low in overall site selection compared to other areas. The area between Eglin Air Force Base and Okaloosa Island shows that although nesting site selection predictability is higher in Eglin air force base (darker red), the non-beach sand which is the area in darker blue reduces sea turtle nesting significantly, while urban factors such as population may increase site selection as this area has a wider swath of high predictability, despite this area having less actual nesting area. The east past inlet area shows a similar normal predictability distribution, but Eglin on the left and Destin on the right show a similar non beach sand to urban distinction as Eglin and Okaloosa Island. The Walton water

Table 8. VARIABLE STATISTICAL ANALYSIS RESULTS : PRESENCE RANDOM MODEL

Final Model Equation:

species ~ Distance to High Tide + Distance to Closest Urban Type + Land Cover Type + Distance to Closest Road + Population Abundance+ Nourishment Source + Elevation + Bathymetry + Slope of Approach

| **Variable** | **Factor Description*** | **Estimate** | **Pr(>\|z\|)** |
|---|---|---|---|
| (Intercept) | | -0.0003 | 0.99979 |
| Bathymetry | | -0.1543 | 0.009415 |
| Elevation | | 0.581822 | 1.35E-09 |
| Distance to High Tide | | -0.00982 | 0.003385 |
| Land Cover Type | Community Recreational Facilities | -0.55062 | 0.767534 |
| | Beaches other than swimming beaches | 2.915048 | 0.003322 |
| | Auto Parking Facilities | -1.93461 | 0.24988 |
| | Sand other than beaches | -1.92943 | 0.044382 |
| | Mixed scrub-shrub wetland | -1.34269 | 0.417662 |
| | Military | 1.246594 | 0.312985 |
| | Swimming beach | 1.414953 | 0.133793 |
| | Medium Density, Under Construction | 0.258416 | 0.900591 |
| | Parks and Zoos | -0.86731 | 0.615843 |
| Nourishment Source | Offshore and Storm Over wash | -0.86005 | 0.046478 |
| | Offshore | -0.85303 | 0.106438 |
| | Inlet | 0.554639 | 0.300726 |
| | East Pass Ebb Shoal | -0.92846 | 0.035639 |
| Population | | 0.003499 | 0.002948 |
| Distance to Closest Road | | -0.00197 | 0.056883 |
| Slope of Approach | | -0.42013 | 0.055059 |
| Distance to Urban Areas | | -0.00035 | 0.008858 |

*if a categorical variable

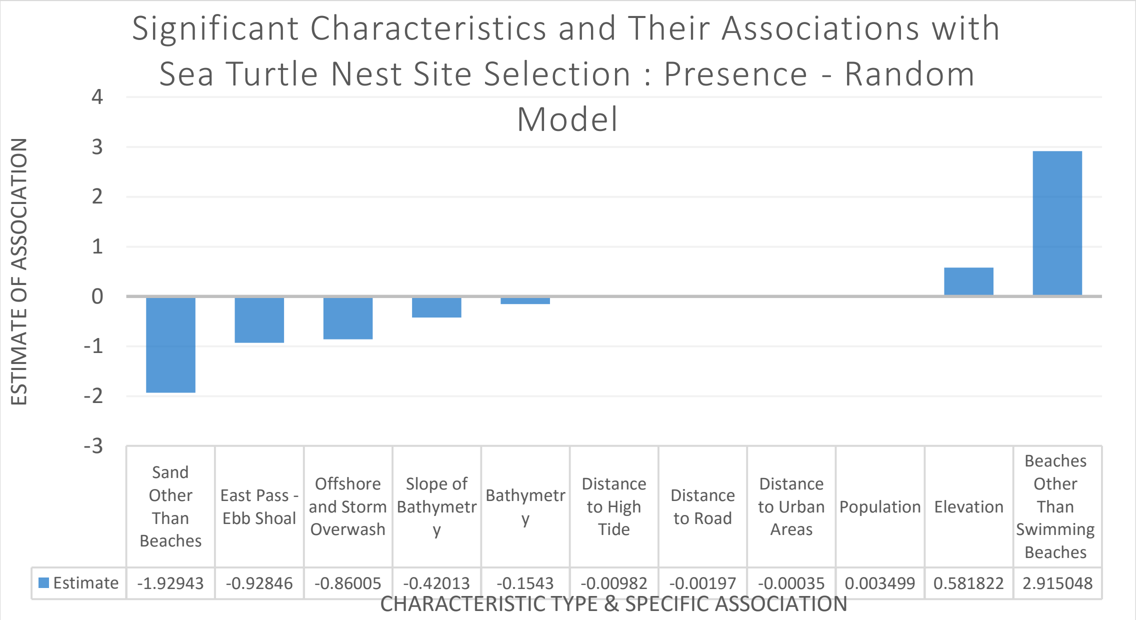


**Figure 11.** VISUAL REPRESENTATION OF POSTIVE AND NEGATIVE ASSOCIATED VARIABLES WITH SITE SELECTION.

outflow area (Figure 15) shows the importance of elevation. The Walton area is higher in elevation compared to other areas (Figure 15) and therefore has a high predictability rate for sea turtles. Where the higher predictability occurs, the more likely nesting site selection will occur in Walton County. However, 50% site selection prediction does show a general spread of nesting in the area, but is focused in Walton, the west end of Escambia, and the mid Okaloosa area (Figure 16). Overall, despite a general trend of nesting beyond the tide, but before beach sand drops off, there are some areas of interest. Throughout the predictability changes in the area of the beach between the tide and beach sand end. This can give solid inferences in this area on where sea turtles may nest.

Figure 10. ZOOM IN OF DESTIN AND EGLIN AFB IMAGERY WITH EAST PASS. Destin is on the right, Eglin AFB is on the left

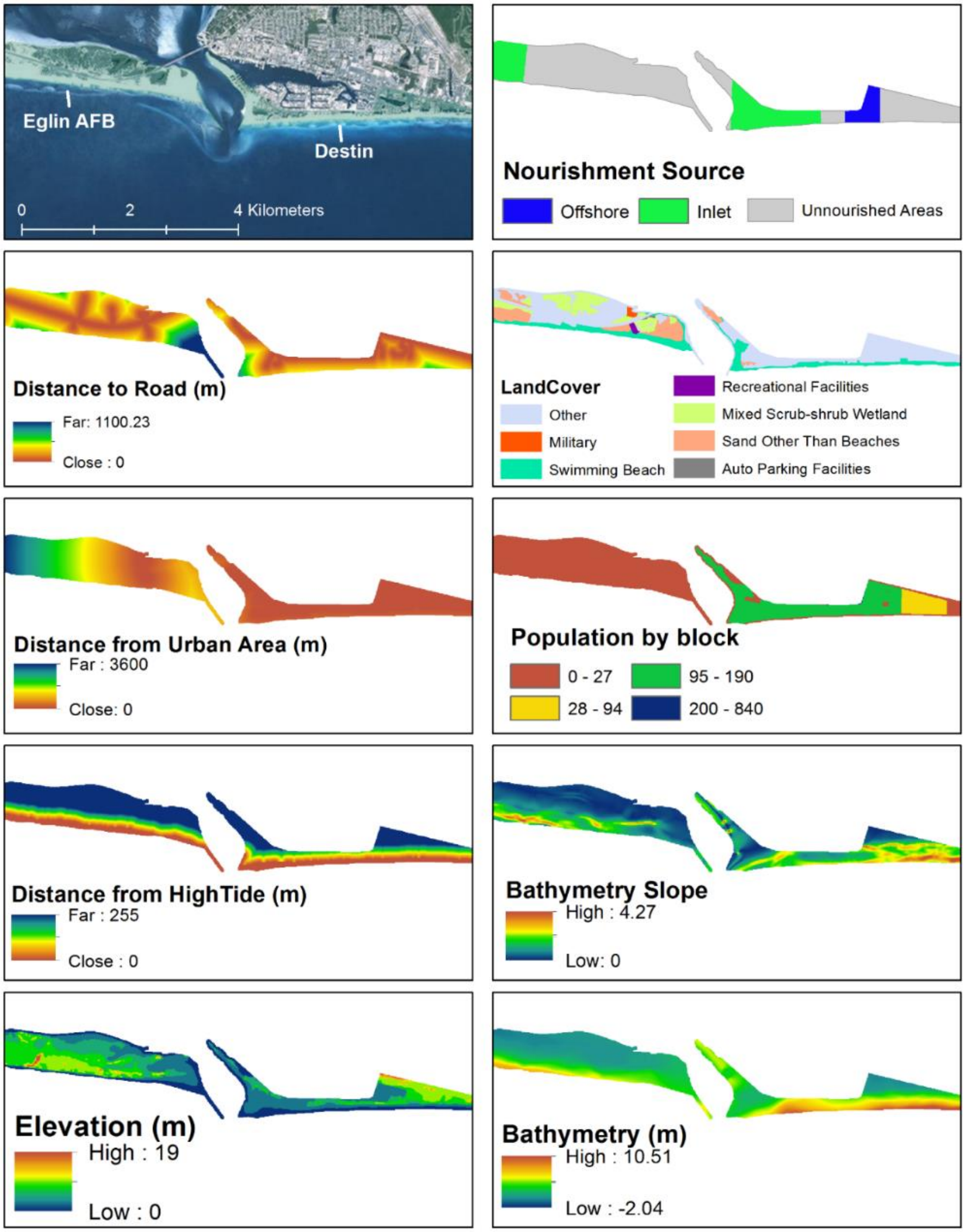


Figure 12. SIGNIFICANT VARIABLE DISTRIBUTIONS OF LARGE SCALE PRESENCE RANDOM MODEL FOR A SELECTED REGION WITHIN THE STUDY AREA. See Figure 10 for imagery comparison. Other variables could be included in the best model, but not be significant.

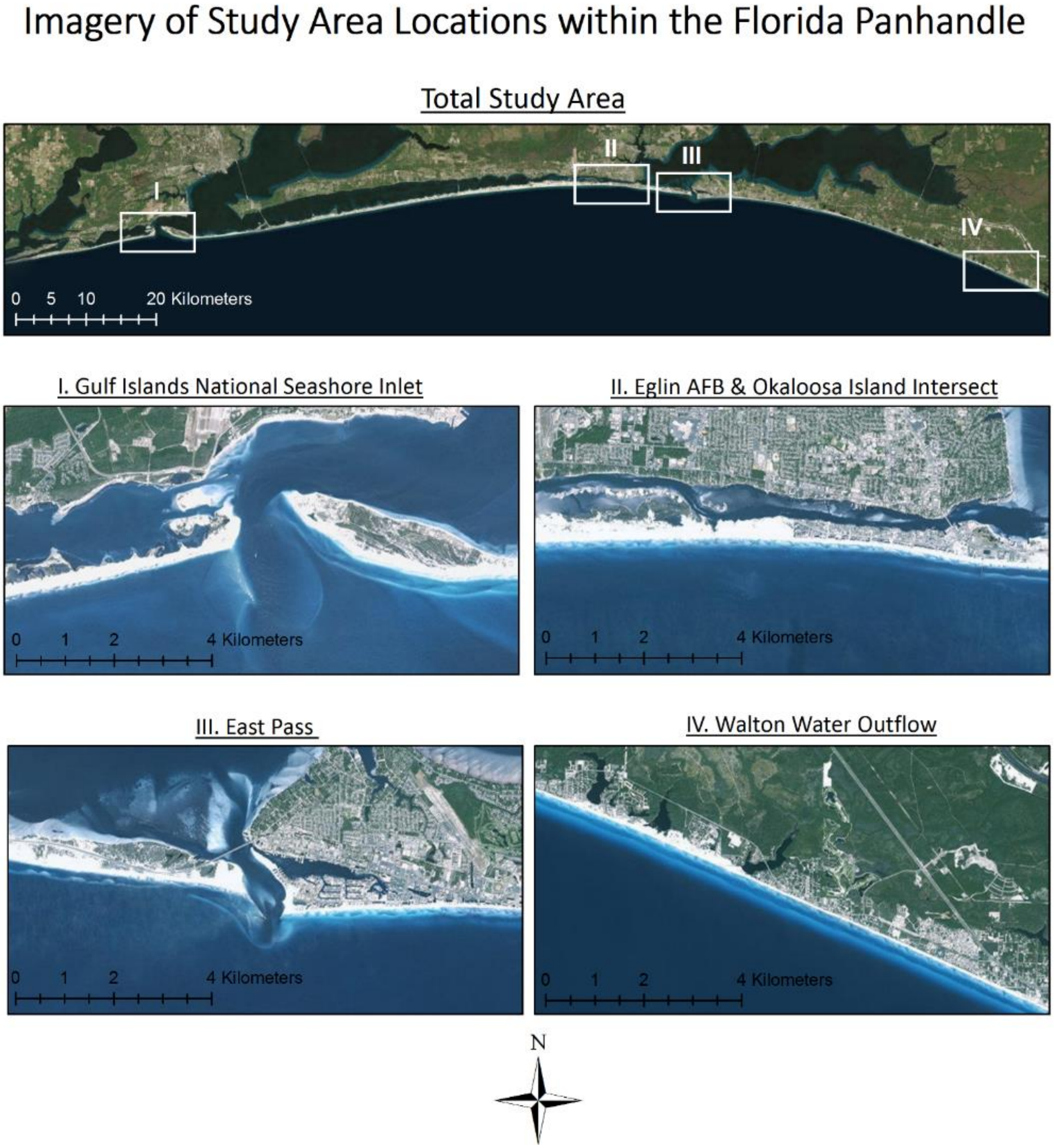


Figure 13. TOTAL ZOOM IN OF SPECIFIC STUDY AREAS - IMAGRY MAPS FOR COMPARISON PURPOSES. Areas of white are beach and sand area, while lighter blue indications shallow water, and areas of darker capacity indicate urbanization. Vegetation is a similar shade of urbanization, but less linear in observation**.**

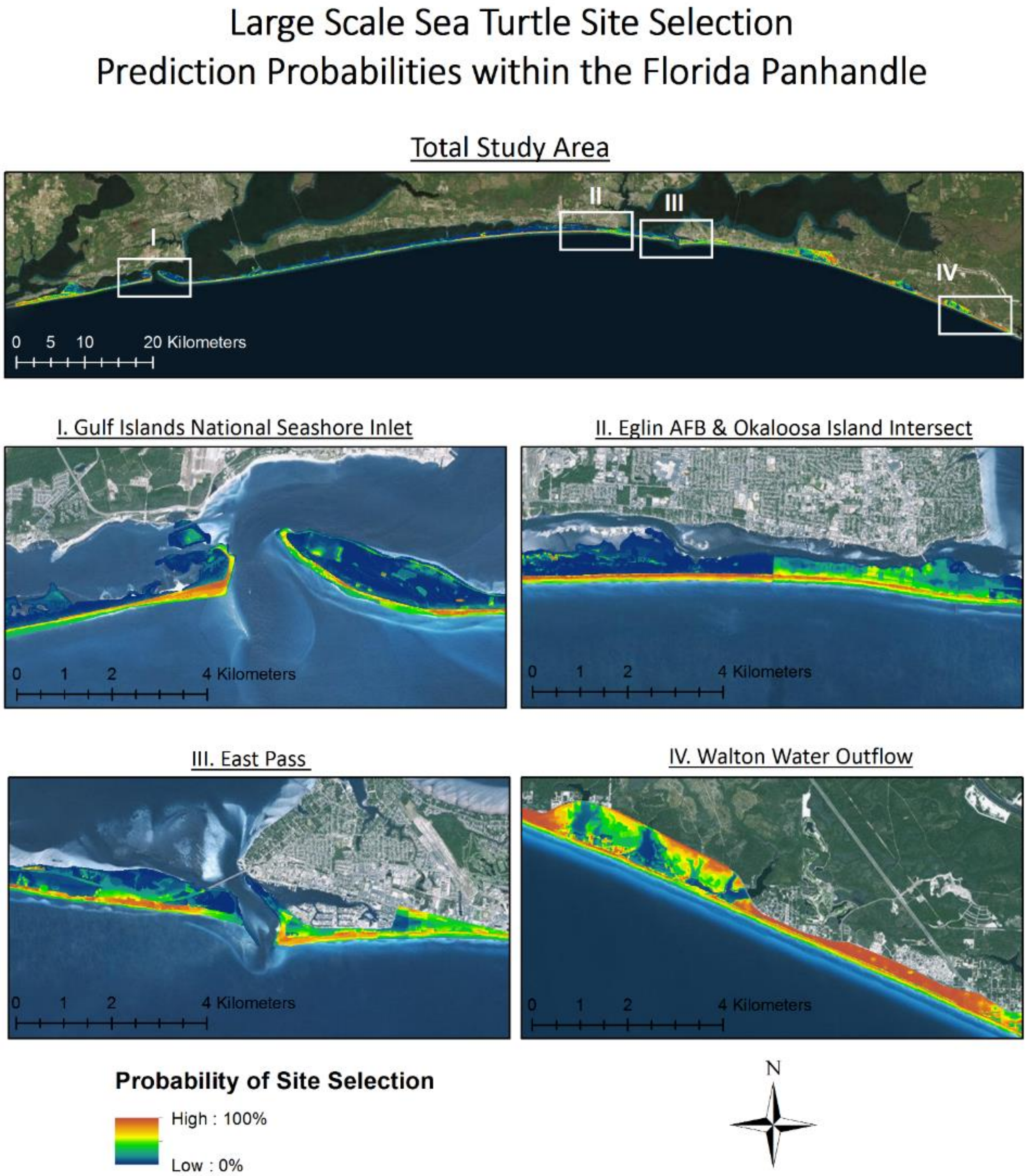


Figure 14. SITE SELECTION DISTRIBUTION OF THE WHOLE STUDY SITE AND SELECTED ZOOM IN MAPS FOR FINE SCALE OBSERVATON. High probability is in darker red, while low probability is in blues.

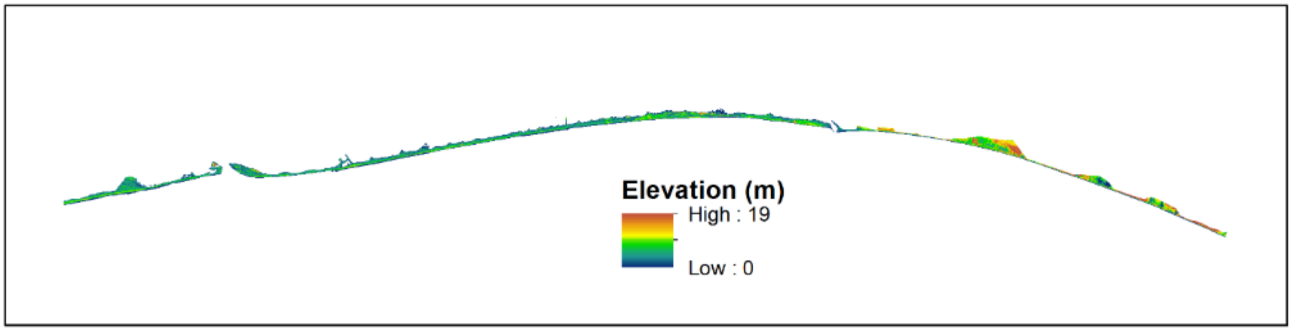


Figure 15. LARGE SCALE DISTRIBUTION OF ELEVATION IN STUDY AREA. . Background removed to focus on elevation change. Higher portion of shoreline is below 10 m in elevation. Walton County, the area to the right, is significantly higher in elevation.

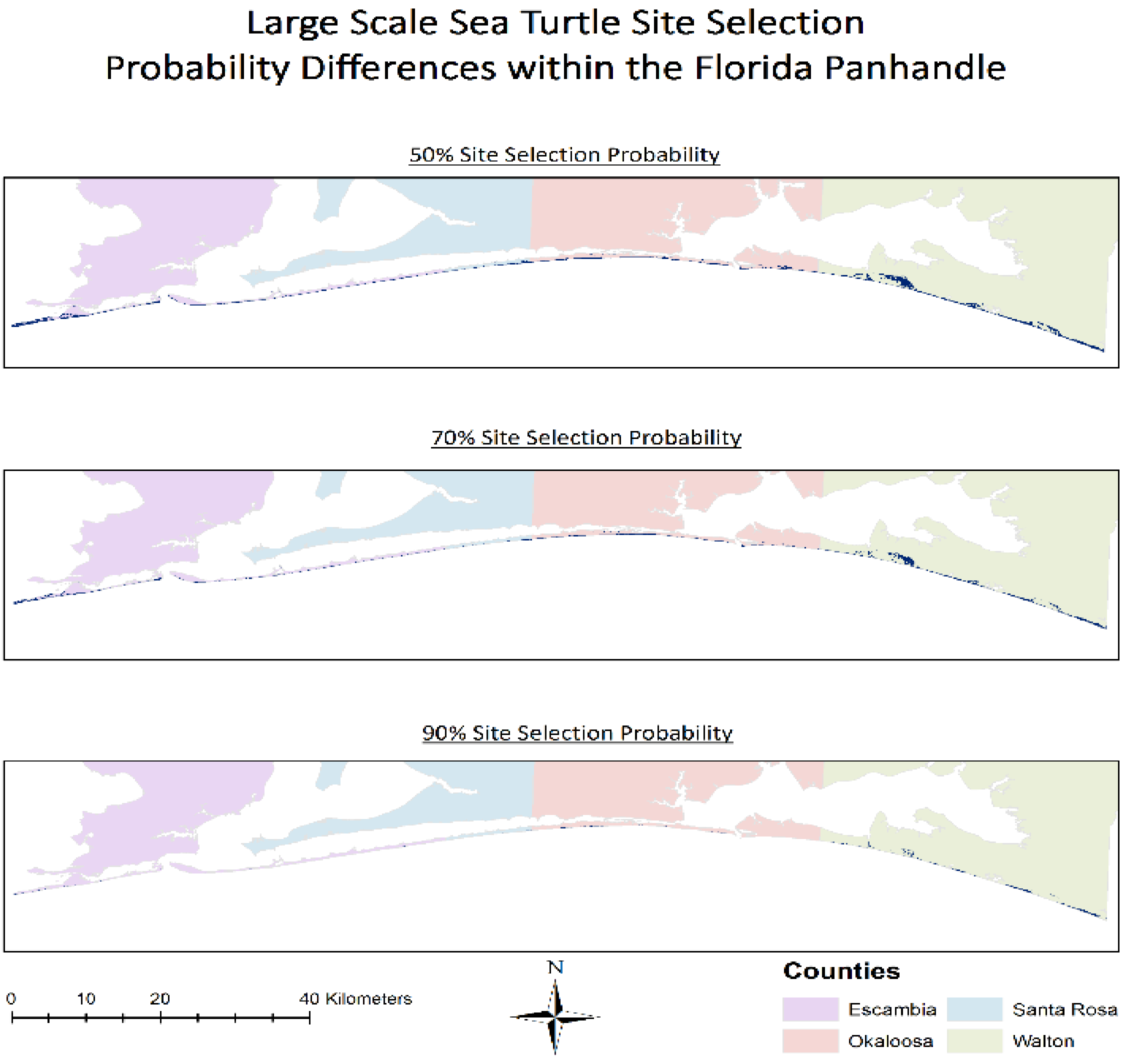


Figure 16. AREA OF 50, 70, AND 90 % PROBABILITY OF SITE SELECTION. As probability increases, area of site selection decreases.

### iii. Site Selection Prediction Analysis: Small Scale - Presence/Absence (PA)

Site selection prediction models using presence random binomial comparisons are highly influenced by the structure of the environmental conditions. In this study, random nests are not necessarily distinguished from nesting and therefore cannot be considered absence points. Although a model considering random points is statistically significant, a model looking at true absence points may improve information in such a study. Therefore, using false crawl data as absence points ("bad" nesting site) in comparison to absence points, can allow for this. As false crawl data was only received for Okaloosa and in high enough sample size in the Eglin portion of Santa Rosa, the study area was restricted to this location. Using the same modeling technique, the best model was determined and six characteristics were presented as important for site selection within this region of the panhandle; distance to high tide, land uses, wetland type (although restricted to only estuarine and marine deep water), source of nourishment, type of road closest to nest, and grain size. This model determined 34.4 % percent deviance explained, suggesting again, that small input of other variables are important, but not significant , although the original deviance of 39.23 % also suggests that again, random nesting can occur (Table 9).

Table 9. STATISTICAL ANALYSIS RESULTS: PRESENCE ABSENCE MODEL

| **Statistical Result** | **Original Model** | **Best Model** |
|---|---|---|
| Null Deviance | 122.00 on 87 degrees of freedom | 122.00 on 87 degrees of freedom |
| Residual Deviance | 74.14 on 60 degrees of freedom | 80.00 on 72 degrees of freedom |
| Percent Explained | 39.23% | 34.43% |
| AIC | 130.14 | 112 |

Table 10. VARIABLE STATISTICAL ANALYSIS RESULTS : PRESENCE ABSENCE MODEL

Best Model Equation :

species ~ Distance to High Tide + Total Land Use Type + Wetlands Type + Nourishment Source + Road Type + Grain Size

| Variable | Factor Description* | Estimate | Pr(>\|z\|) |
|---|---|---|---|
| (Intercept) | | -0.09153 | 0.94473 |
| Distance from High Tide | | 0.05806 | 0.00186 |
| Total Land Use | Beaches other than swimming beaches | -0.6021 | 0.525061 |
| | Communications | -0.86227 | 0.629379 |
| | Sand other than beaches | -5.34499 | 0.023308 |
| | Swimming beach | 0.427661 | 0.653654 |
| | Ocean | 0.114283 | 0.914584 |
| Wetlands Type | Estuarine and Marine Deepwater | -0.97481 | 0.128424 |
| Nourishment Source | Offshore | 1.527727 | 0.469761 |
| | Inlet | 1.403586 | 0.133982 |
| | East Pass Ebb Shoal | -0.5605 | 0.727446 |
| Road Type | Road or Street, Class 3 | -0.73884 | 0.272859 |
| | Secondary Route, Class 2, Undivided | -0.99841 | 0.5245 |
| | Road or Street, Class 3, Divided by centerline | 1.527727 | 0.469761 |
| | Primary Route, Class 1, Divided by centerline | 2.329372 | 0.043049 |
| Grain Size | | 0.106144 | 0.279332 |

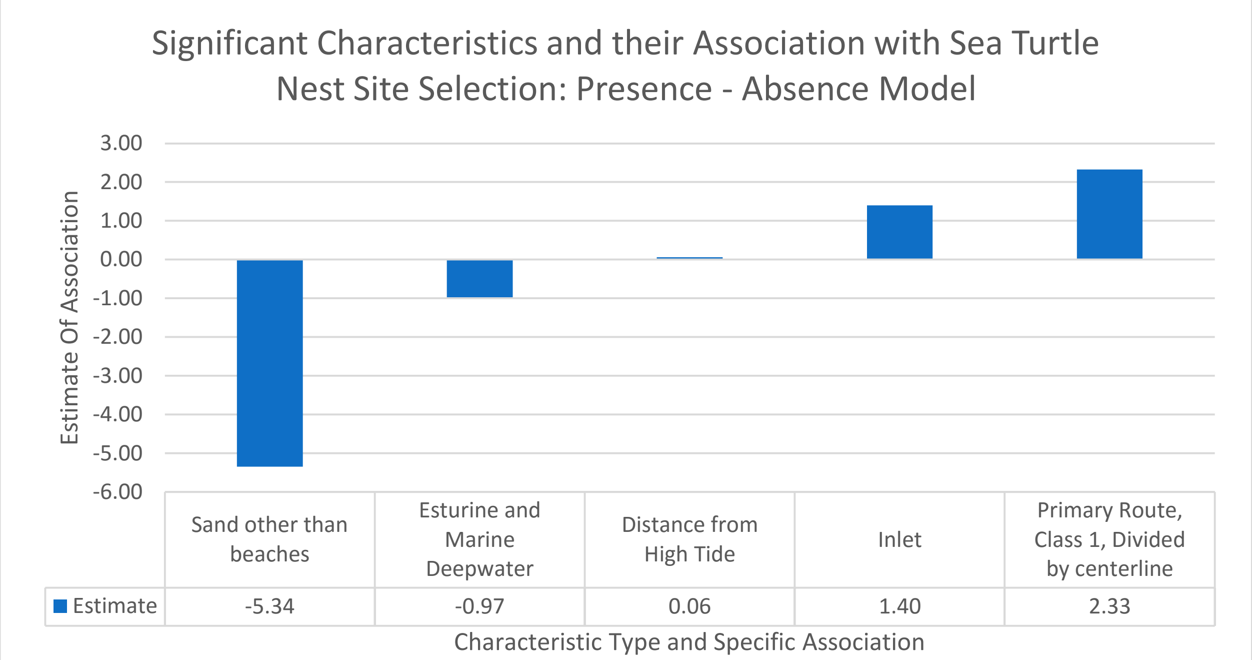


Figure 17. VISUAL REPRESENTATION OF POSIIVE AND NEGATIVE ASSOCIATED VARIABLES WITH SITE SELECTION.

Of those six variables, grain size was the only variable not within a statistically significant consideration (Table 10). Of the five left, distance from high tide, primary route (road type), and sand other than beaches were highly significant (p < .05) while the wetland–estuarine and marine deep water and inlet nourishment source was considered vaguely significant (p < .15) in comparison the overall distribution.  Sand other than beaches, similarly to the presence – random prediction is highly negatively related to nesting (Figure 17). Sand other than beaches is distributed further from the shoreline and may hinder nesting, although physical reasons could also exist since this distinction is seen in both models. However, beaches other than swimming beaches is not found to be significant in this area. Distance from high tide, is once again important as it distinguishes that distance from water is important, however, its estimate is low and does not contribute to the model in comparison to other variables. Primary route road is linked highly to sea turtle nesting in a positive way, which could indicate some factor either drawing turtles to them. Although street light data was not acquired for this study, the roads could be serving as a proxy for this variable, as light ordinances are only used in Destin in Okaloosa. However, another factor could affect nesting prediction also. Although only vaguely significant, inlet source is shown to have a positive association to nesting prediction. Grain size was not significant and therefore the reasoning for inlet nest prediction increase is not due to an effect of grain size. Possible associations should be investigated in this area. Note, in comparison to the large scale map that elevation does not play a large role in this area. This shows the importance of large vs small scale distributions of sea turtle nesting. Based upon variable maps of the area elevation is more evenly distributed, land use distinctly different between beach sand and other sand, and inlet source and primary roads highly focused in the Destin area. These variable distinctions can play crucial roles in sea turtle nesting protection beyond natural protection of nests (Figure 18).

The final distribution map shows that despite the high distinction between beach sand and other sand, zoomed in areas of Eglin Air Force base show that distance from water is playing a crucial role in this habitat predictability (Figure 19). Although, as I mentioned, high tide distance appears low in importance, its values increase as distance increases adding a higher important to distance over other sand type as a negative relationship. Unfortunately, this is an inaccurate assumption the model assumes, as there is a distance at which turtles will no longer travel and therefore should be incorporated into future studies to remove that influence. Additionally, it can be shown that Eglin's shoreline of prime nesting is not distinct (does not alter predictability) across the shoreline length, although width wise, increases in nesting predictability, decreases and then increases again. The reasoning behind this could be many, seeing at these variables overlap and therefore the best association is that land use, within that low probability region overlaps with high tide in a way that makes these areas distinct. Interestingly, the areas of Destin and the east portion of Eglin show complete variability in nesting predictability patterns. Eglin in this area is not restricted to human use, while Eglin in the map (Figure 19) does not, which may change infrastructure and site selection. A large portion of Destin has very low nesting predictability, which seems associated with grain size (negative association – as grain size increases nests decrease) which is still included in the habitat predictability. Overall this habitat distribution can point out variables of interest on a small scale level, but also locational based areas of interest to focus on. However, seeing as on the ground observation and habitat predictability seems mismatched, these predictability mas must be assessed on a variable by variable basis. Meaning, in conjunction with its associated variable map and what those maps mean in relation to sea turtle biology.

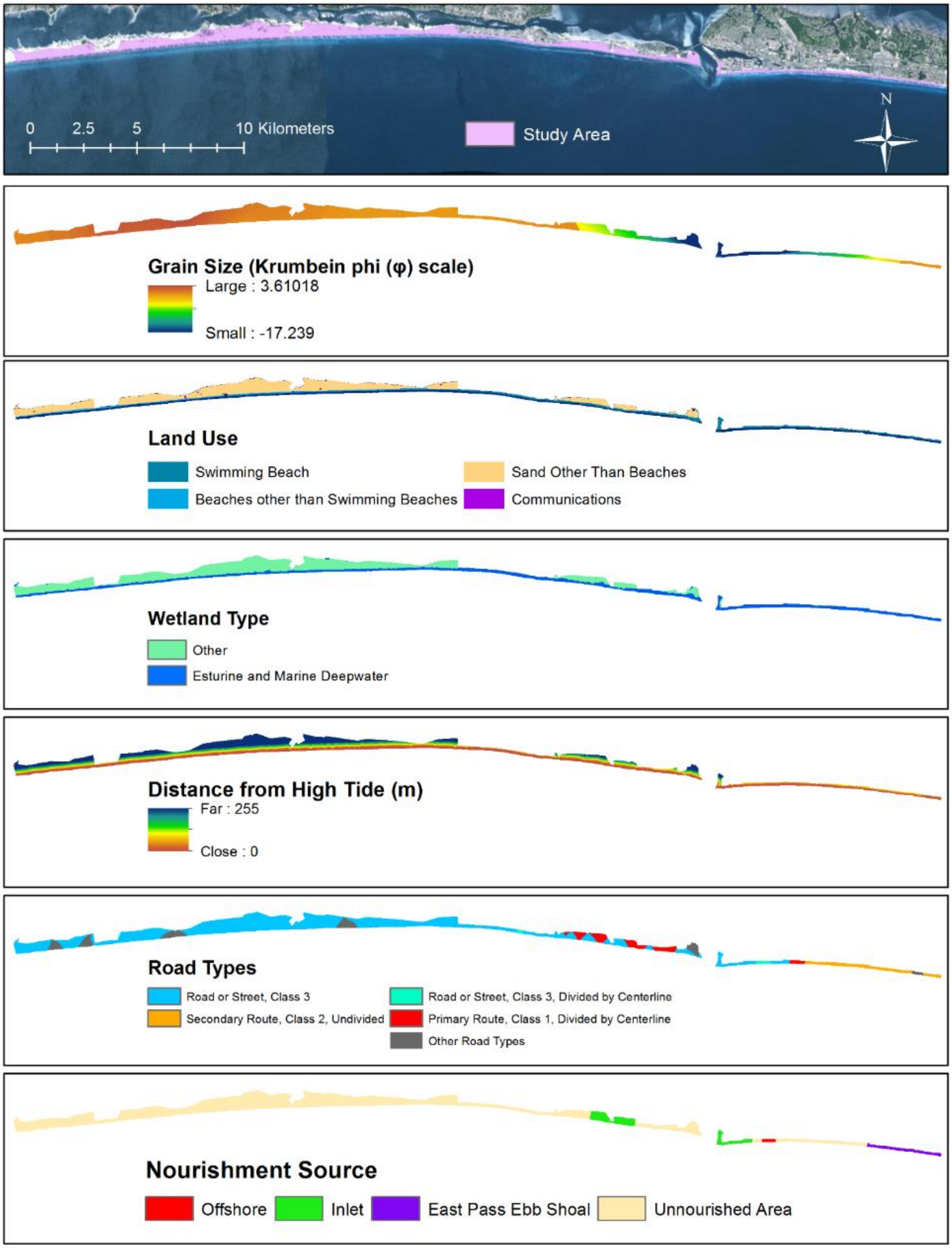


Figure 18. SIGNIFICANT VARIABLE DISTRIBUTIONS OF PRESENCE ABSENCE MODEL FOR SELECTED REGION WITHIN THE STUDY AREA. See Figure 17 for site selection comparisons.

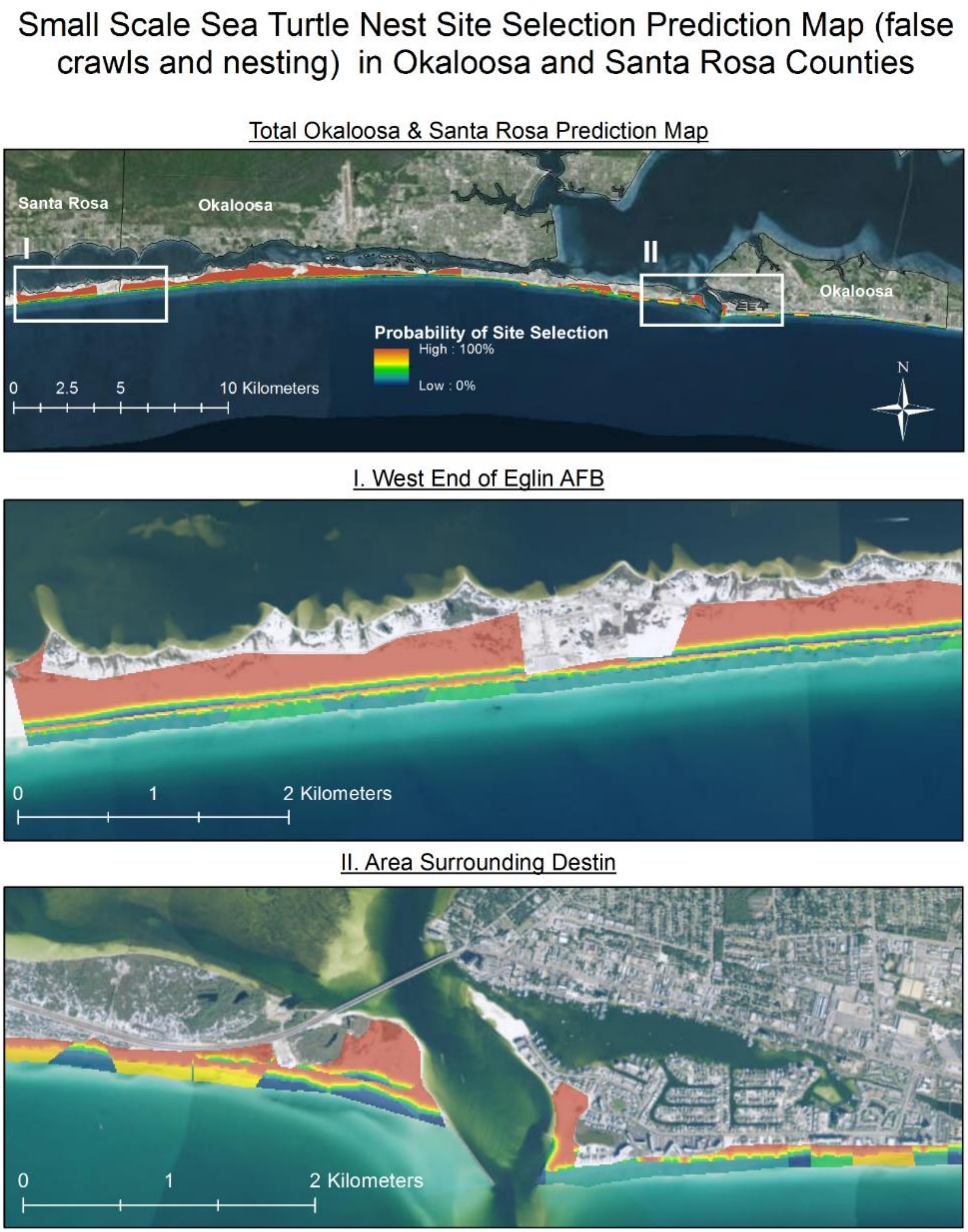


Figure 19. PROBABILITY OF SITE SELECTION OF AREAS IN EGLIN AFB AND DESTIN WHERE FALSE CRAWL DATA WAS COLLECTED.

### iv. Urban Sea Turtle Site Selection Prediction: Large Scale – Presence/Random (PR)

To understand urban variables without interacting physical variables, as well as other variable types non-urban related, an urban site selection model was run using only urban variables. The final best model, using AIC ranking determined a six variable model with a percent deviance explained of 32.3% (Table 11). The deviance explained in this analysis is expected, as it has been determined both by past studies, and the PR model that physical variables are important factors in sea turtle nest site selection. The urban variables significant in site selection include beach width (included as urbanization such as land use and erosion can effect this variable), land use, distance to urban areas, road type closest to nest, population, and years past since nourishment. Note that distance to urban areas and land use can be similarly as urban areas were selected out from land use and reclassified into a distance, however they assess differences as distance refers to how close an association may be, while urban type may imply that the type is affecting the nest regardless of distance.

Table 11. STATISTICAL ANALYSIS RESULTS: URBAN VARIABLE SITE SELECTION MODEL

| **Statistical Result** | **Original Model** | **Best Model** |
|---|---|---|
| Null Deviance | 790.19 on 569 degrees of freedom | 790.19 on 569 degrees of freedom |
| Residual Deviance | 523.29 on 531 degrees of freedom | 534.92 on 544 degrees of freedom |
| Percent Explained | 33.8% | 32.3% |
| AIC | 601.29 | 586.92 |

Of the six variables, three were classifications which included factors, land use, years since nourishment, and road type. For land use a total of 11 factors were associated with nests, but only two were highly statistically significant ($p < .05$), sand other than beaches and beaches other than swimming beaches (Table 12). Auto Parking was also vaguely significant ($p < .15$). For road type, with 7 factors, two were highly significant (trail, other than four wheel and a primary route divided by centerline), while secondary route, undivided road was still significant with a p value of .08. (Table 12). Years since nourishment has four factors in which 5 years, 8 years, and 9 years were all statistically significant (Table 12). The association of each variable can be seen in Figure 20. When observing the variable maps however, this may be due to the isolation of each year to a general location and may have a multitude of reasoning for why that area was statistically significant in differences between nesting and random points (Figure 21).

Table 12. VARIABLE STATISTICAL ANALYSIS RESULTS: URBAN VARIABLE SITE SELECTION MODEL

Best Model Equation:

species ~ Beach Width + Total Land Use + Distance to Closest Urban Area +Road Type + Population Abundance + Years since Nourishment

| **Variable** | **Factor Description*** | **Estimate** | **Pr(>\|z\|)** |
|---|---|---|---|
| **(Intercept)** | | 1.428978 | 0.077978 |
| **Beach Width** | | -0.00307 | 0.000694 |
| **Total Land Use** | Medium Density, Fixed Single Family Units | 0.979545 | 0.552008 |
| | Community Recreational Facilities | -1.85406 | 0.273354 |
| | Beaches other than swimming beaches | 2.17985 | 0.003007 |
| | Communications | 0.409628 | 0.833025 |
| | Sand other than beaches | -3.061 | 1.78E-05 |
| | Auto Parking Facilities | -2.44757 | 0.138726 |
| | Mixed Scrub-Shrub wetland | -2.02272 | 0.200402 |
| | Swimming Beach | -0.91482 | 0.182479 |
| | Medium Density, Under Construction | 0.45353 | 0.810213 |
| | Parks and Zoos | -2.20548 | 0.158382 |
| | Embayment's opening directly to gulf or ocean | -1.6342 | 0.3366 |
| **Distance to Urban Area** | | -0.00043 | 0.001649 |
| **Road Type** | Road or Street, Class 3 | 0.423008 | 0.223357 |
| | Secondary Route, Class 2, Symbol Undivided | 0.659163 | 0.075984 |
| | Trail, Class 5, Other than four wheel drive vehicle | 2.136925 | 0.006262 |
| | train, class 5, four wheel drive vehicle | 0.52129 | 0.327938 |
| | Road or street, class 3, symbol divided by centerline | 0.347535 | 0.717336 |
| | primary route, class 1, divided by centerline | 1.572021 | 0.007309 |
| | primary route, class 1, divided, lanes separated | -0.11427 | 0.959731 |
| **Population** | | 0.005534 | 6.88E-07 |
| **Years since Nourishment** | Nourishment done 2 years ago | -0.83627 | 0.43345 |
| | Nourishment done 5 years ago | 1.500597 | 0.022079 |
| | Nourishment done 8 years ago | -1.50103 | 0.000643 |
| | Nourishment done 9 years ago | -1.41596 | 3.02E-05 |

*if categorical variable

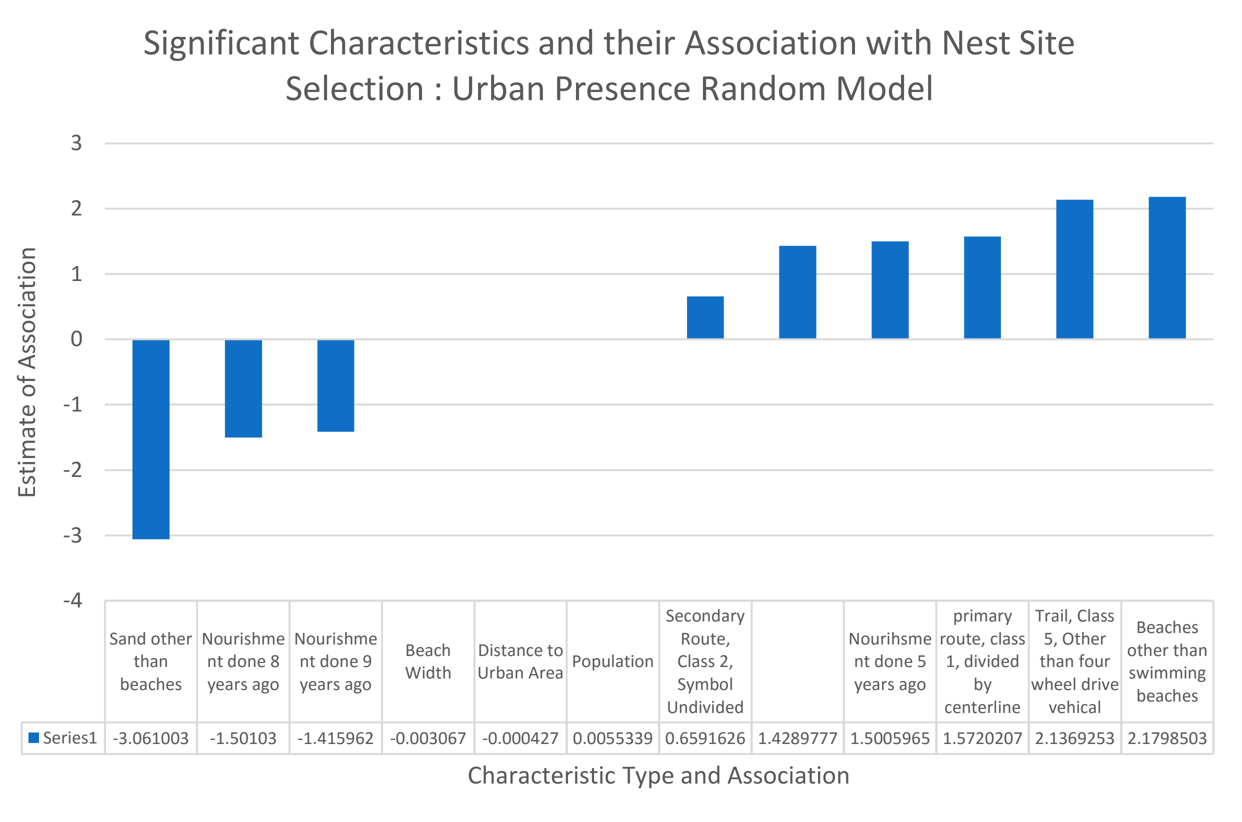


**Figure 20.** VISUAL REPRESENTATION OF POSIIVE AND NEGATIVE ASSOCIATED VARIABLES WITH SITE SELECTION.

Of the factors that were significant, beach width, distance to urban areas, and population were also significant (Table12). When each estimate of each variable of significant is plotted, the association to nesting site selection can be seen. As seen previously, sand other than beaches shows high negative association to site prediction, while beaches other than swimming beaches shows high positive association. Nourishment done 8 and 9 years ago shows negative association with nesting predictability, while nourishment done 5 years ago has a positive association. Based upon previous assumptions, these areas (based on variable maps) may have other conflicting issues. However, nourishment done 5 years ago may improve beach width which may improve turtle nesting, while nourishment done longer may indicate that a beach is more eroded over time as nourishment also indicates a highly eroding system. However, beach width which is also significant disproves this assumption. Beach width has a negative association, meaning that as beach width increases, nests decrease. This is a small negative relationship (-.003), but still negative. Understanding this relationship may be an important factor, as erosion and beach width, a highly volatile system, plays an important role in increasing threat to nests. However, figure variable map, does imply a small inconsistency of beach width. Although the beach was mapped with both observed and random nests in mind, this nests were distributed haphazardly and then extrapolated and therefore may not reflect a completely accurate depiction of beach width (Figure 21). Distance to urban areas reflects a small negative association with nesting, which shows that sea turtles may not nest near urban locations. However, nest selection is positively associated with population. This is a similar distinction as within presence – random and presence – absence models.

Although mapping this prediction does not necessarily imply nest site selection probability, it does show the distribution of nest predictability in relation to urban variables. Meaning, although some areas may have low probability, does not mean that area is not high in nest selection. The map is highly dissimilar from the PR and PA maps (Figure 22 compared to Figure 14 and 19). Note that figure 19 is not comparable by extent to figure 14 and 22, although maps II, III, and IV are similar spatially. Similarities and differences will be discussed after initial exploration of the maps.

The urban predictability map depicts the high variability in nesting probability, both high and low. The west end of Escambia (Figure 22 I) depicts how larger beach areas work in absence of other physical variables. The larger hump region shows that sea turtles would nest near the back beach if able based on urban characteristics. They also prefer that area along the shoreline in general, while the rest is predicted to be less selected. Note that beaches other than swimming beaches are involved in this process and may not necessarily explain urban variables, but is involved in land use so was included.  Figure 22 II can be compared to the high distinction between Eglin and Okaloosa Island as in figure 14. However, the areas of site selection is more distinct, showing that there are 5 large areas beyond the beach line where sea turtles may be “attracted” or not deterred by urbanization. Exploring these areas and the variables associated with this map may help to find answers to higher predictability. Note again that nest site selection predictability in lower in Okaloosa city, on a wider scale, but has higher predictability on a more refined scale along the beach in Eglin (Figure 22 II).The highest variability can be seen in Figure 22 III were east Eglin and Destin meat. This is due to the high variability in Eglin here where roads are common and showing high association. Once again higher area of nest prediction can be seen in Destin and these areas may be important focuses on how urban variables are associated with nesting and if they are inherently good or bad. Walton shows overall high nest site selection predication. Walton, however, is known for having low density / low population of humans and therefore the forms of urbanization here may imply that there is a level of urbanization which influence site selection (or do not deter it), while other areas have more conflicting urban areas that turtles may associate less with. These conflicting areas prove most difficult, but understanding which variables due influence site selection is the first step.

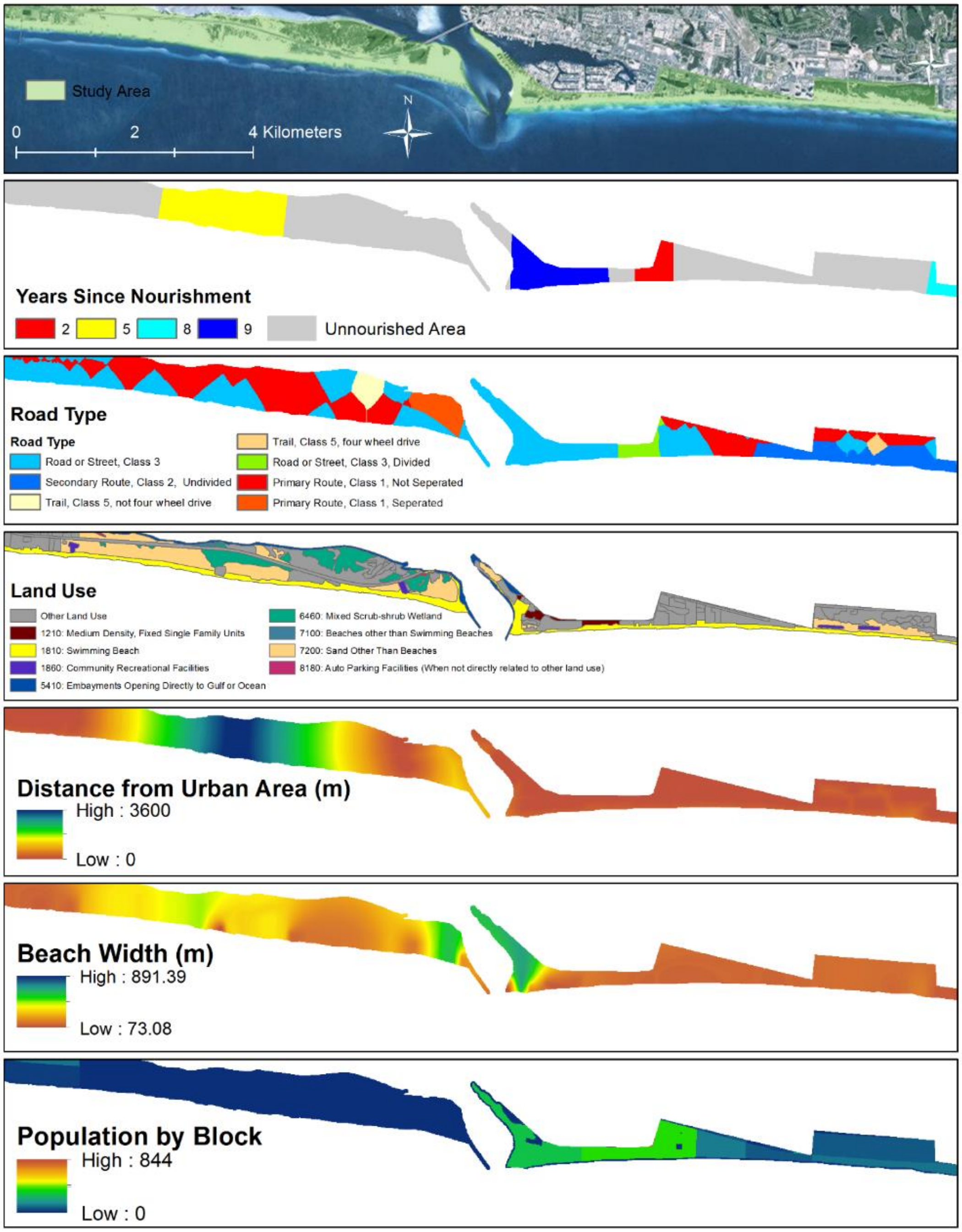


Figure 21. SIGNIFICANT VARIABLE DISTRIBUTIONS OF URBAN MODEL FOR SELECTED REGION WITHIN THE STUDY AREA. See Figure 21 for site selection comparisons.

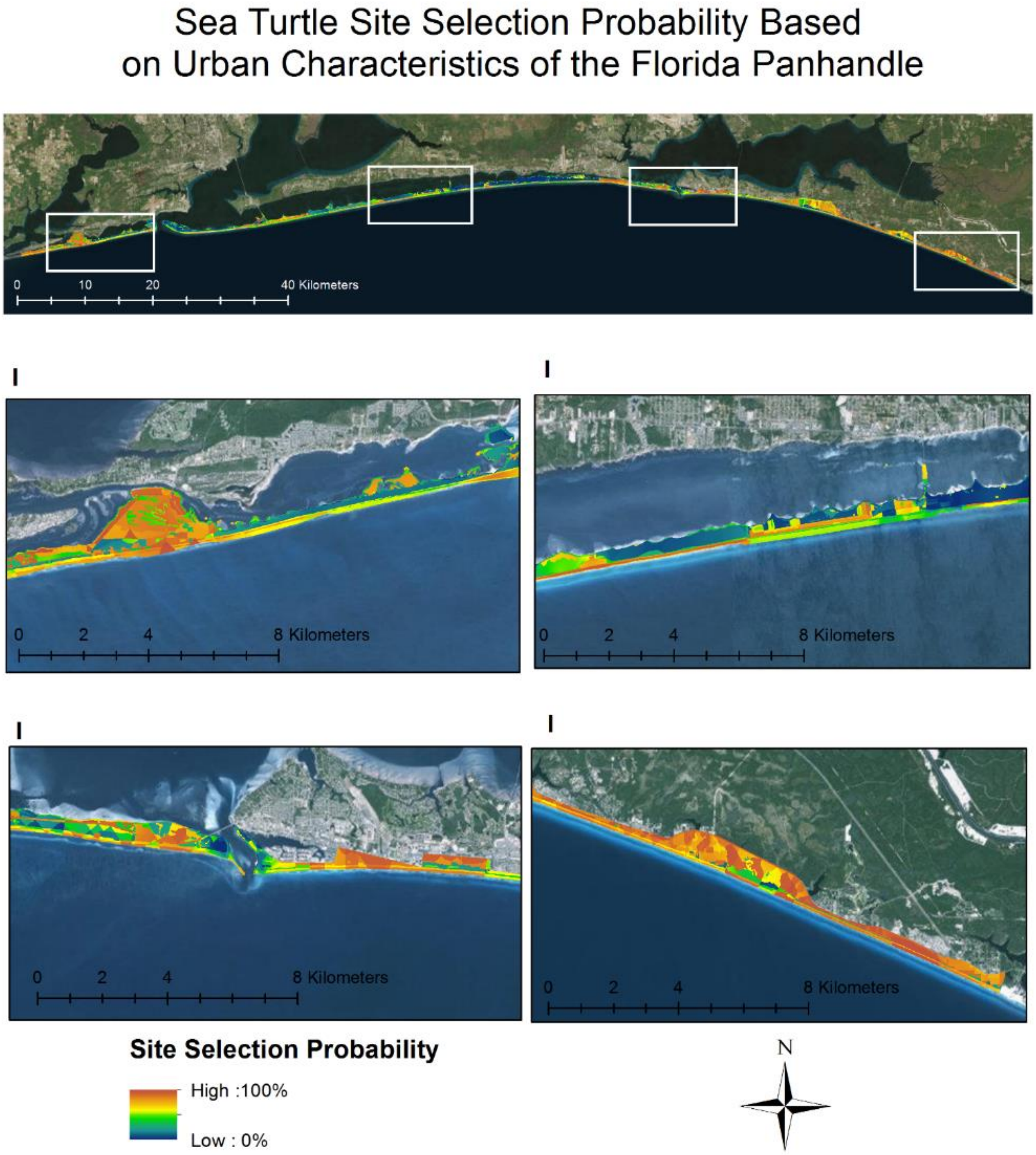


Figure 22. PROBABILITY OF SITE SELECTION OF AREAS IN EGLIN AFB AND DESTIN WHERE FALSE CRAWL DATA WAS COLLECTED.

### a. Limitations of Site Selection Predictability

There are a few limitations of habitat predictability maps. The first is the concept of what predicting habitat, or in this case, site selection means. Although modeling can predict areas in space and time of what those sites look like, this space and time is limited by species and their ecology at that point in time only. Therefore, these models can only be understood in the time scale of 2015. More so, some data sources are not updated to 2015 and therefore cause temporal complications. However, these are sources of information that are fairly regular and do not change significantly over time.

Additionally, based upon the species, prediction mapping can be very limited in explanation. Sea turtles have many possible factors of influence, even of ones known. Many presented in this model that were not previously studied in detail show that many other factors could be involved in site selection,  have a role, or serve as an indicator for another variable not used (street lights on roads).

Variables are not assessed in terms of attraction or deterring a species. Instead, they are understood in terms of why an area is more like to have turtles or not. Therefore, additional studies of variable and turtle behavior need to be observed in more detail. For example, site selection may positively associate with roads of certain types, but turtles may have originally nested there and therefore ae just not deterred by the change, or are attracted to these areas now. This cannot be distinguished without further research. Due to this, and due to the first limitation, variables may affect turtles differently over time, or new variables may come into play (increase in sea level rise rates).

Variables used work in conjunction with each other. Although variable maps alongside estimates of association can be observed, it is difficult to see the distinct differences in what variables are causing site selection. Although this is important in understanding how variables may work together and influence each other, to understand each variable on its own, other methods must be explored. Here is where we look at tree classification, to understand which variable has the highest impact and in what combination can this be explored.

However, since habitat classification in this situation is based on a number of variables, which for sea turtles, is wholly not understood still, this map will be purely potential habitat. In the future, a more distinct habitat classification map can be made if variables are more understood in relationship to sea turtle nesting.

I would analyze the importance of particular variables (land use in terms of a habitat map) through classifying each variable first in determining important areas in sea turtle nesting. This map will be created in order for managers to see on the ground visualization of the “environmental” variables that these turtle nests are surrounding themselves with based on the best scientific knowledge available.

v. Full Variable Tree Classification Analysis

The full variable tree classification analysis was run with all variables distributions in mind. The tree was pruned with the lowest x error of .36 with an n-split number of .014.

Out of the multitude of variables assessed (Table 13), 7 were included in the pruned tree as the most statistically significant, 3 of which were categorical (land cover, wetlands, and artificial reef type) l and 4 that were continuous (elevation slope, distance to urban areas, beach width, and distance to seawall). Tree classification determined statistically the best break and each node and split left for more prominent random nest factors of variables or values less then or greater than a variable (Table 13, Figure 24). The range of each continuous variable and the values associated with observed nests and random nests can be seen in table 13.

Four final branches of the tree were observed. The first incorporates land cover types with multiple factors (Table 13) although these are mostly associated with random nest sites (132 of 285 compared to only 9 of 285 nest sites) and elevation slope greater than 9.16 (Figure 24). This branch is highly unlikely to determine site selection, as of the 9 nests that are related to the land use types, only 4 have elevation slopes > 9.16. This is also interesting since sea turtles prefer low slopes, and 5 of the 9 nests (a higher proportion), actually prefer lower elevation slopes, as do random nests though.

Additionally branches show an initial node with association with nesting in relation to land cover type. Branch four associates with land cover types of medium density, fixed single family units,

Table 13. TREE CLASSIFICATION IMPORTANT VARAIBLES AND DETAILS

**Best Model Equation:**

**species ~ Land Cover Type + Elevation Slope + Wetlands + Distance to Urban Areas + Beach Width + Artificial Reef Type + Distance to Seawall**

| Variable Type | **Variable Attributes : Amount & Range** | **Observed Nests (1)** | **Random Nests (0)** |
|---|---|---|---|
| Land Cover Type | 58 Types | Medium Density, Fixed Single Family Units<br>Beaches other than swimming beaches<br>Tidal Flats<br>Swimming Beach<br>Medium Density, Under Construction | Community Recreational Facilities<br>Auto Parking Facilities<br>Sand other than Beaches<br>Mixed Scrub – Shrub Wetland<br>Parks and Zoos |
| Elevation Slope | 0 - 29.42 | >= 9.16 | < 9.16 |
| Wetlands | 7 Types | No Wetland<br>Freshwater Forested / Shrub Wetland<br>Estuarine and Marine Wetland | Estuarine and Marine Deepwater |
| Distance to Urban Areas | 0-3600 | < 90.82 | >= 90.82 |
| Beach Width | 73.08 - 891.40 | >= 132.675 | < 132.675 |
| Artificial Reef Type | 18 Types | Module Plastic Cones<br>Ship Steel<br>Barge Steel<br>Steel Tank Turrets<br>Modules Concrete Ghettos (2 locations)<br>Army Tank M-60<br>Barge Steel & Ship Scrap<br>Modules Concrete Walters<br>Limestone Units<br>Ship Steel Tug<br>Concrete Culverts<br>Bridge Rubble Concrete | Concrete Culverts<br>Special Concrete Modules |
| Distance to seawall | 0 - 12359.80 | < 187.395 | >=187.39 |

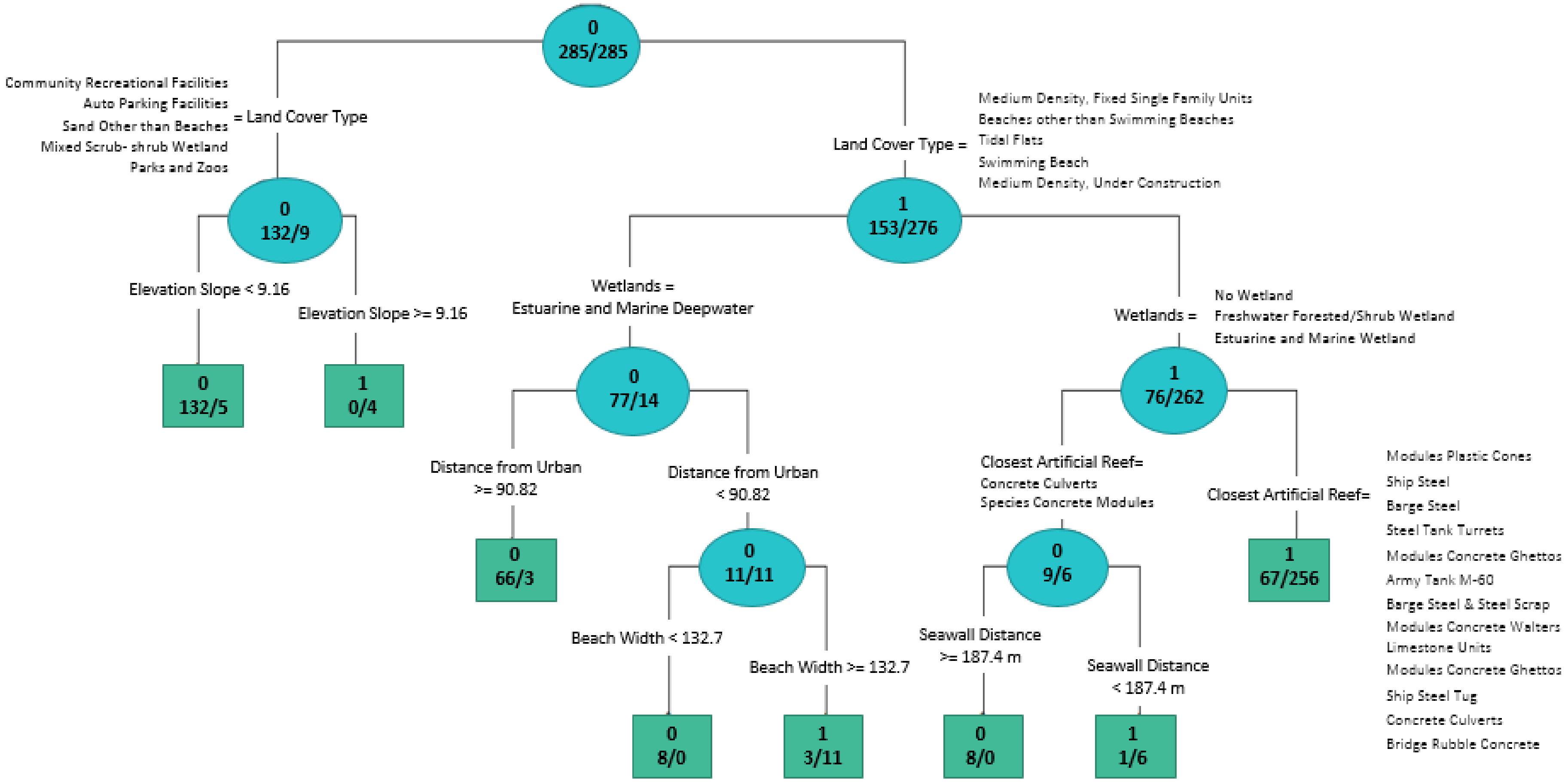


Figure 23. FULL VARIABLE CLASSIFICATION TREE. Important factors and distribution of ranges are noted in relation to its branch. A 1 indicates more association with observed nesting and a 0 indicates more association with random nests. Numbers in boxes indicate the number of nests with that variable association from the previous branch, with observed nest amounts on the right and random nests on the right.

beaches other than swimming beaches, tidal flats, swimming beaches, and medium density, under construction areas as well as estuarine and marine deep-water in the wetlands category, a distance less than 90.82 m from urban areas, and a beach widths greater than 132.7 m. The only variable which associates with itself more with the random nests is the estuarine and marine deep-water areas. This is logical, as these areas are inundated with water more than others, although it describes areas of complete inundation, land use data was from 2004 and therefore the shoreline may have altered somewhat, therefore this area can only be described as possibly being inundated 100% if the shoreline change did not alter since that date. Based on this branch though, there seems to be a mixture, as seen in the habitat prediction models of urban variables association both positively and negatively to nesting sites, alongside important physical variables such as beach width. Land cover types is particularly important to note, since these are mixed, while distance to urban areas may imply that the beach width and the proportion of overall density of human infrastructure is high, so turtles don't necessarily associate with urban distances, but with an overall choice will choose a further distance from tide. However, tide is not significantly shown in this tree, so beach narrowness may also associate with this. Urban variables may not imply negative associations specifically, but they can associate with other interactions (higher human abundance, higher erosion) which could be seen as a harmful association, not seen directly from these models. The third branch includes the same land cover types as branch two, but then also includes wetland distinctions of freshwater forested and shrub wetlands, estuarine wetlands, as well as no wetlands as an indication of site selection, while it branches of more towards random nests for closest artificial reefs including concave culverts and special concrete modules. However, within the nest observance left, all 6 were less than 187.4 meters within a seawall, while non-observed nests were distinctly much further. Although this final last portion of the tree only incorporates a few nests, it is highly distinct from the random nests and may suggest that sea turtles nesting tend to nest as close to sea walls as possible, which may be more due to the fact that seawalls are placed in higher eroded areas. Although width did not come out as significant for this branch, beach width for the second branch does suggest sea turtles prefer large width beaches, or as far from the tide as possible, which could explain the closeness to seawalls. However, more information is needed about the area to determine this association. The final branch describes all site selection characteristics that associate itself with nesting. These include the same land cover types and wetland types mentioned in branch 2 and 3, but includes a number of artificial reef types (Figure 24). Overall, the chance of a sea turtle associating itself to the beach with an artificial reef is high, and even higher for particular artificial reefs. All branch map associations can be seen in Figure 25.

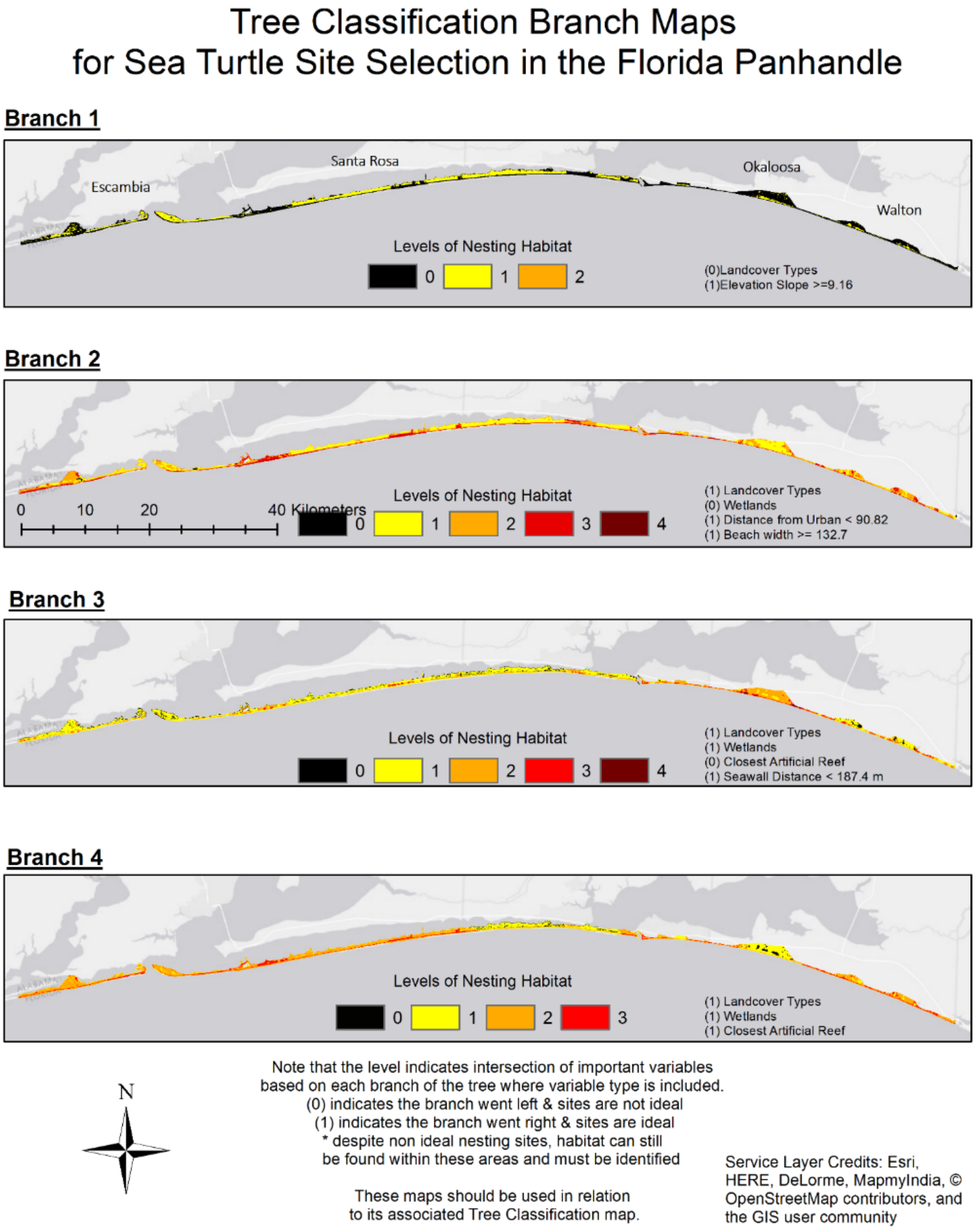
These branches associated maps can be seen with each characteristic overlapped upon each other, creating levels of spatial distribution. Branch one is difficult to assess, since it was more associated with random points. However, the rest show more accuracy in mapping of the area and all show similar site selection areas. This may suggest that a number of differing characteristic combinations cause sea turtle site selection, with land cover types serving as the most pertinent of that association. The areas in red and dark red show the most chance of site selection based on its respective characteristics. This mean that certain areas of the Panhandle can look at their location based on the maps, assess what variables (branch combination) may cause the highest levels and use those variables to determine proper management. Each particular variable distribution can be seen in Figure 26.

Table 14. FULL VARIABLE CONFUSION MATRIX

| | **Predicted Random** | **Predicted Nest** |
|---|---|---|
| **Observed Random** | 214 (True Negative) | 71 (False Positive) |
| **Observed Nest** | 8 (False Negative) | 277 (True Positive) |

To understand the predictability of the tree, and to tests its statistical significance, the tree was then used to determine a predicted set of numbers for each of the random and observed nests and hen compared with the original data to determine a true negative rate of 214 and therefore a false positive of 71 out of the 285 predicted nests (Table 14). This explains that the prediction rate high for random nests, although it is understandable that 71 of the 285 were false positives, meaning were predicted as observed nests instead, since the random points were not necessarily absence points and could have indeed been positives or actual nesting sites. Importantly, the true positive rate is much higher, meaning that not as many of observed nests were predicted as non-nesting, showing the tree accurately represents the distribution of turtles in relation to the variables.

Additionally an roc was constructed depicting an area under the curve of .88 depicting a high predictability value for the tree (Figure 27).



Note that the level indicates intersection of important variables
based on each branch of the tree where variable type is included.
(0) indicates the branch went left & sites are not ideal
(1) indicates the branch went right & sites are ideal
* despite non ideal nesting sites, habitat can still
be found within these areas and must be identified

These maps should be used in relation
to its associated Tree Classification map.

Service Layer Credits: Esri, HERE, DeLorme, MapmyIndia, © OpenStreetMap contributors, and the GIS user community

Figure 24. TREE CLASSIFICATION FOR ALL VARIABLE TREE SEPERATED BY DIFFERENT BRANCHES. Levels of nesting habitat indicate the amount of important variables which overlap in those areas. Branches can be seen in Figure 24.

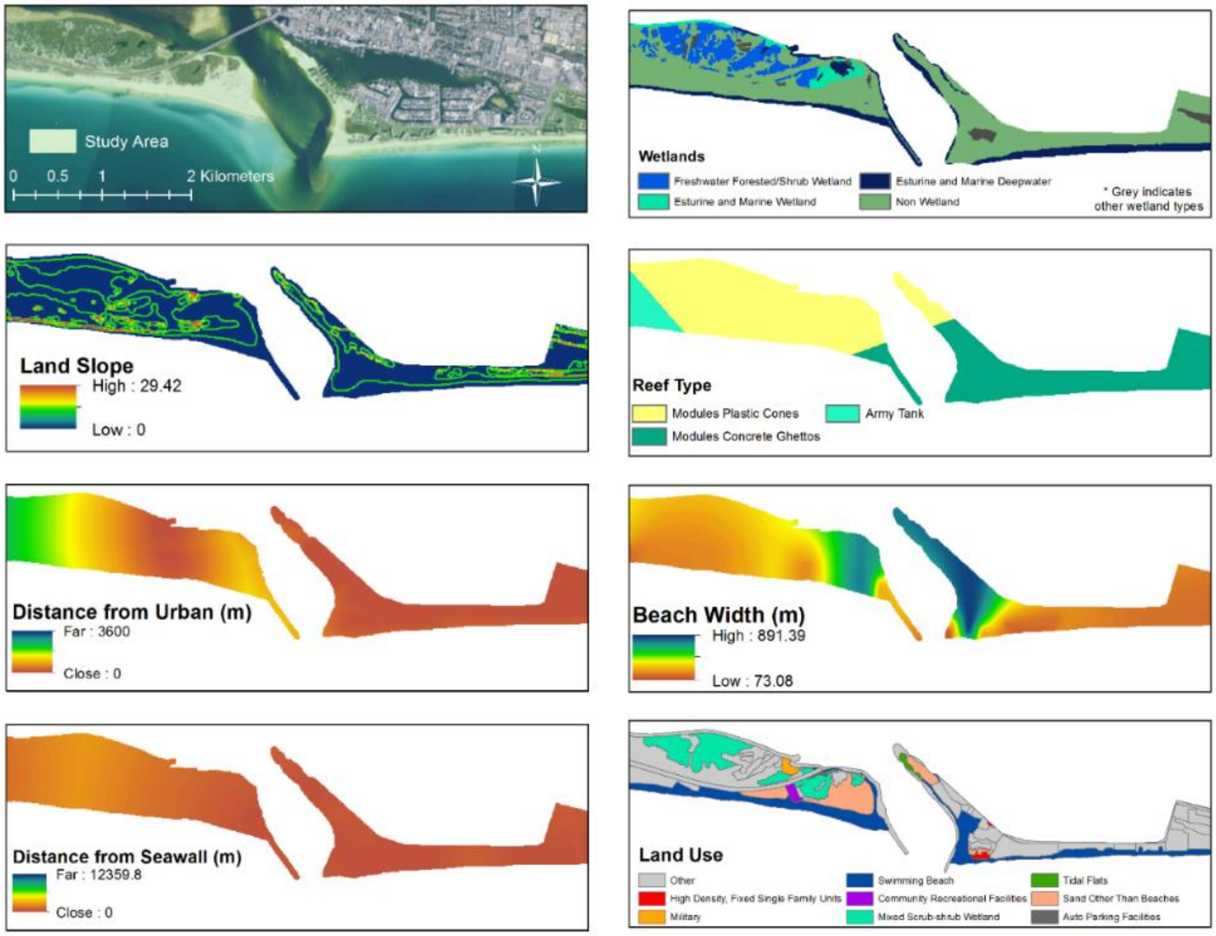


Figure 25. SIGNIFICANT VARIABLE DISTRIBUTIONS OF URBAN MODEL FOR SELECTED REGION WITHIN THE STUDY AREA

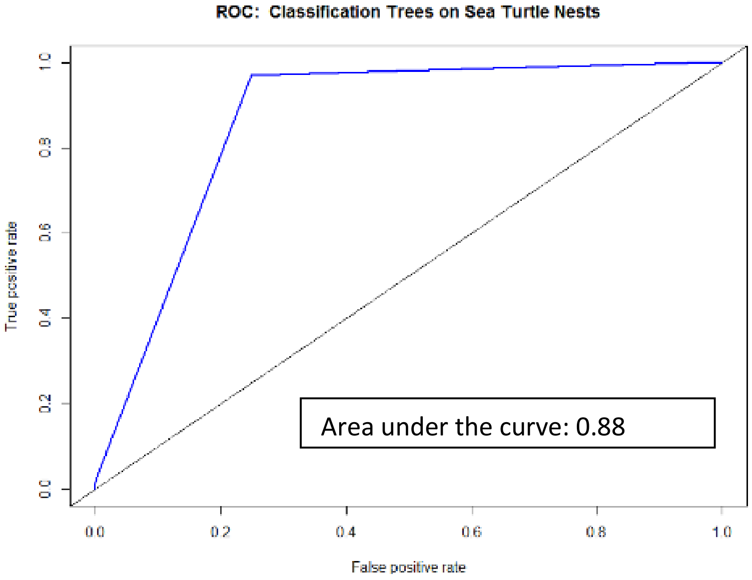


Figure 26. RECEIVER OPPERATING CURVE FOR FULL TREE CLASSIFICATION showing the statistical significance of the model.

### vi. Full Variable Random Forest Analysis

A random forest was performed on the same variable collection as the full tree model. Although no tree is created, the variable in rank of mean decrease accuracy and mean decrease ginis returned (Table 15, Table 16). Additionally an estimate of error rate returned was 14.74%. In both cases, it in confirmed that land cover types is the most important in determining sea turtle site selection, which is logical as this incorporates sand, which is necessary for nesting (Table 15, Table 16). Interestingly, average light pollution, air temperature, precipitation, distance to high tide, and beach length does get returned as the next most important in terms of site selection, despite it not being important in the tree. Therefore, the association should be looked at more in depth. As the trees are getting produced multiple times, the tree originally generated may not incorporate these as the first factor of importance within land cover types and that is the reasoning for the difference. This table can additionally be used to determine which variable types should be managed first (or if low on the rank, should not be considered at all as needing management which may save resources). For example, based upon this list, distance to erosion does not seem to associate with sea turtle site selection. Although there may be problems with erosion and nests, there is another variable which is more important with site selection. Note, as erosion changes, this may change so managers need to be open to moving parameters.

Similarly with the tree, a prediction data set was calculated based on the average tree and compared with the original data. Of the 285 random nests, 226 with true negatives and 59 were false negatives, with an error of 20.7%, while out of the 285 observed nests, 260 were true positives with 25 false positives with a 9% error rate, meaning that a high proportion of the predicted observed nests were correctly organized as a observed nest based upon the parameters of the tree (Table 17).

Overall, both the regular full variable tree and random forest are both statistically sound, but have differing results. However, depending on the circumstance, both can be used to sustain sea turtle populations and protect nesting in the future.

Table 15. FULL VARIABLE CONFUSION MATRIX FOR RANDOM FOREST STATSITCAL ANALYSIS

| | **Predicted Random** | **Predicted Nest** | **Classification Error** |
|---|---|---|---|
| **Observed Random** | 226 (True Negative) | 59 (False Positive) | 20.7% |
| **Observed Nest** | 25 (False Negative) | 7260(True Positive) | 8.77% |

Table 16. RANDOM FOREST VARIABLE STATISTICAL ANALYSIS FOR MEAN DECREASE ACCURACY.

| Variable | Description | Mean Decrease Accuracy |
|---|---|---|
| HighTideDi | Distance from High Tide | 26.969424 |
| WETLANDRAS | Wetlands | 20.168311 |
| Elevation | Elevation | 18.033349 |
| LANDUSECOM | Land Use Combined | 17.074395 |
| EROSIONDIS | Distance from Erosion | 16.150419 |
| TOTALLANDU | Total Land Use | 15.487715 |
| WetlandDis | Distance from Closest Wetland | 15.01291 |
| HYDROLOGYE | Distance from Hydrology | 14.878942 |
| URBANECLUD | Distance from Closest Urban Area | 14.850519 |
| BathyM | Bathymetry | 14.830966 |
| LANDCOVERT | Land Cover Type | 12.944333 |
| Shape_Le_1 | Beach Width | 12.746438 |
| LANDCOVTr | Land Cover Type | 12.528363 |
| AvgLight | Average Light Pollution | 12.280418 |
| PrecipAvg | Yearly Precipitation Average | 12.017475 |
| SlopeBathM | Slope of Approach | 11.138309 |
| ARTIFICIAL | Artificial Reef Type | 10.932223 |
| HYDROLOGYR | Hydrology | 9.822608 |
| NOURISHMEN | Distance from Nourishment | 9.78663 |
| HOUSERAST | House Abundance by Block | 9.785606 |
| SEAWALLPER | Distance to seawalls | 9.748179 |
| POPULATION | Population by Block | 9.37188 |
| GRAINSIZEI | Sand Grain Size | 9.011784 |
| ROADSDISTA | Distance from Road | 7.931804 |
| DUNEPERMIT | Distance from dunes | 7.507013 |
| ARTIFICI_1 | Distance from Artificial Reefs | 7.486049 |
| MeanSurvLe | Beach length | 7.322872 |
| URBANTYPE | Urban Type | 6.621966 |
| BathAspeM | Aspect of Approach | 6.557606 |
| AirTAvg | Average Yearly Air Temperature | 6.115922 |
| ELEVSLOPE | Slope of Land | 5.837927 |
| HYDROLOGYT | Hydrology Type | 5.787282 |
| ROADTYPERA | Road Type | 5.689707 |
| ELEVATIONA | Aspect of Land | 4.923818 |
| NOURISHM_3 | Years since Nourishment | 4.430473 |
| NOURISHM_1 | Nourishment Source | 3.953786 |
| FINALURBAN | Urban Density | 1.980395 |
| EROSIONTYP | Type of Erosion Rating | 1.958402 |
| ROADRASTER | Roads | -1.518731 |

Table 17. RANDOM FOREST VARIABLE STATISTICAL ANALYSIS FOR MEAN DECREASE GINI

| Variable | Description | Mean Decrease Gini |
|---|---|---|
| HighTideDi | Distance from High Type | 34.41445 |
| LANDUSECOM | Land Use Combined | 19.29268 |
| WETLANDRAS | Wetlands | 14.17984 |
| Elevation | Elevation | 13.02037 |
| EROSIONDIS | Distance from Erosion | 10.77531 |
| BathyM | Bathymetry | 10.51924 |
| WetlandDis | Distance from Wetlands | 10.16682 |
| HYDROLOGYE | Distance from Hydrology | 10.01419 |
| TOTALLANDU | Total Land Use | 9.90447 |
| URBANECLUD | Distance from Urban Areas | 9.746774 |
| Shape_Le_1 | Beach Width | 9.719969 |
| LANDCOVERT | Land Cover Type | 8.527007 |
| SlopeBathM | Slope of Approach | 8.285997 |
| LANDCOVTr | Land Cover Type | 8.255736 |
| ROADSDISTA | Distance from Road | 7.77912 |
| BathAspeM | Aspect of Approach | 7.579165 |
| ARTIFICIAL | Artificial Reef Type | 7.168016 |
| PrecipAvg | Average Year Precipitation | 7.040891 |
| GRAINSIZEI | Sand Grain Size | 6.849792 |
| NOURISHMEN | Distance from Nourishment | 6.776066 |
| ELEVSLOPE | Slope of Land | 6.368961 |
| DUNEPERMIT | Distance from Dune | 6.300638 |
| AvgLight | Average Light Pollution | 6.259956 |
| ELEVATIONA | Aspect of Land | 6.238274 |
| SEAWALLPER | Distance from Seawall | 6.170061 |
| HYDROLOGYR | Hydrology Type | 6.105671 |
| HOUSERAST | House Abundance by Block | 4.558409 |
| URBANTYPE | Type of Urban Area | 3.889913 |
| MeanSurvLe | Beach Length | 3.817571 |
| POPULATION | Population | 3.285683 |
| ARTIFICI_1 | Distance from Artificial Reef | 3.001173 |
| ROADTYPERA | Road Type | 2.119782 |
| AirTAvg | Average Air Temperature | 1.63678 |
| HYDROLOGYT | Hydrology Type | 1.189803 |
| NOURISHM_1 | Nourishment Source | 1.04039 |
| NOURISHM_3 | Years since Nourishment | 0.918445 |
| EROSIONTYP | Erosion Type | 0.826979 |
| FINALURBAN | Urban Density | 0.539539 |
| ROADRASTER | Road Type | 0.122196 |

### vii. Urban Variable Classification Tree Analysis

Based upon the determination that urban variables should be looked at more in depth, an additional tree classification was run for urban variables only. After running the original urban variables, used during the site selection modeling process, a tree was determined. The tree was then trimmed on the lowest x error which was .46, which resulted in a CP of .014.

The pruned tree classified 9 significant urban variables, land use with 11 factors, urban types with 13 factors, distance to sea walls, distance to erosion, house abundance by block, distance to urban areas, average life pollution, and beach width, all with their own respective ranges and distributions between observed nests and random nests (Table 18).

Similar to the previous tree, these variables are associated with each other in differing ways by branches.

Branch one in Figure 28 first incorporates land use types which include community recreational facilities, sand other than beaches, auto parking facilities, mixed scrub-shrub wetland, parks and zoos, embayment's opening directly to gulf or ocean. These land use types are more associated with random nests sites (134 of the 2285 random nests compared to 16 of 285 observed nests). Of those 16 observed nests left, 9 of them are associated with a distance of seawall's less than 208 meters (Table 18).

The second branch (Figure 28 and Figure 29) includes the other land use types which are associated with nesting. These include military, medium density, fixed single family units, and beaches other than swimming beaches, and communications, medium density, under construction, showing a variety of urban against non-urban areas. This then includes erosion distance which is >= 59.16 in which 267 of the 269 observed nests remaining do not nest close to erosion. This branch then chooses land use to associate more with random nests, although is still associated with observed nesting. This segment then branches off to associate random nests to house abundance which is less than 74.5 showing that sea turtle site selection is associated with more housing which may be more related to how most areas have a significant amount of housing. Eight urban types are then also associated, but more so to random nests (Figure 29, Table 18) and then a distance less than 86.41 radiance 10-9 W/cm2 sr, and finally an average light less than 18.84 radiance 10-9 W/cm2 sr. This is a large contribution of variables which seem to work in conjunction to each other. Although important, this branch is complicated and may indicate over complexity that is too difficult. Figure

30 does show the seven levels and the areas of highest association with these variables, so these places do exist so this branch is useful.

The next branch associates sea turtle site selection with observed nests due to specific land use variables noted in branch two, while it also includes erosion distance of observed nests, total land use, house abundance, but then associates more with urban types (Table 18) which is associated more with observed nests where it then also associates with beach widths less than 508.6, giving a general idea of how far sea turtles tend to travel for site selection. This is less complex then branch two, and includes more observed nesting site selection, which is therefore a good branch in looking at site selection. However, not a large portion of some of these variables have a large amount of nests related to nesting observance (Figure 30) so that makes this combination less helpful and should be looked at when determining management decisions. Meaning that those variables should not be as focused on. Spatially, points of high interest in relation to these variables can also be seen which is helpful for management decisions of area.

Branch four includes land use associated with observed nest, erosion distance greater than or equal to 59.16, a total land use of I which splits both ways, and a house abundance greater than or equal to 74.7. As mentioned earlier, this may be due to the fact that overall this study area has high house abundance and therefore this may just be more telling that observed nesting will always be near high housing. Although statistically this is important and descriptive for managers, the spatial mapping is less helpful (Figure 29) as it does not give a good depiction of high site selection as very few levels of 4 (the highest level of this branch) exist, while only one level tends to persist (figure 30). Individual variable maps can be seen in Figure 30.

Table 18. STATISTICAL ANALYSIS OF URBAN TREE CLASSIFICATION

species ~ Average Light Pollution + Beach Width + Total Land Use + Distance from Closets Urban Area + Closest Urban Type + Combined Land Use + Roads + Closest Road Type + Distance to Closest Road + Population + House Abundance + Urban Density + Nourishment Source + Distance to Closest Nourishment + Years since Nourishment + Distance to Closest Seawall Permit + Distance to Erosion Area + Erosion Type + Grain Size

| Variable Type | **Variable Attributes : Amount or Range** | **Observed Nests (1)Association** | **Random Nests (0) Association** |
|---|---|---|---|
| **Total Land Use** | 61 total<br>: 11 associated with nest types | 10: military<br>12: medium density, fixed single family units<br>58: beaches other than swimming beaches<br>63: communications<br>81: Swimming beach<br>93: medium density, under construction | 21: community recreational facilities<br>66: sand other than beaches<br>69: auto parking facilities<br>78: mixed scrub-shrub wetland<br>105:parks and zoos<br>109: embayment’s opening directly to gulf or ocean |
| **Urban Type** | 30 total:<br>12 associated with nests types | 2=institutional,<br>5=High Density, Multiple Dwelling Units, Low Rise,<br>10 = community recreational facilities,<br>14= military,<br>24 = campgrounds | 1=low density, fixed single family unit,<br>4=Commercial and Services,<br>6=High density fixed single family units ,<br>8= Medium Density, Fixed single family units ,<br>15= High Density, Multiple Dwelling Units, High rise ,<br>16= Medium Density, under construction,<br>22 = parks and zoos,<br>25= commercial services under construction |
| **Distance to Seawall** | 0 – 12359.8 m | =<208.06 | > 208.06 |
| **Distance to erosion area** | 0-10781.67 m | =>59.155 | < 59.155 |
| **House Abundance by block** | 0-3160 houses | => 74.5 | < 74.5 |
| **Distance to Urban Areas** | 0-3600 m | <86.41 | =>86.41 |
| **Average Light Pollution** | .30 – 75.4 radiance 10-9 W/cm2 sr | <18.85 | =>18.85 |
| **Beach Width** | 73.08-891.4 m | <508.64 | =>508.64 |

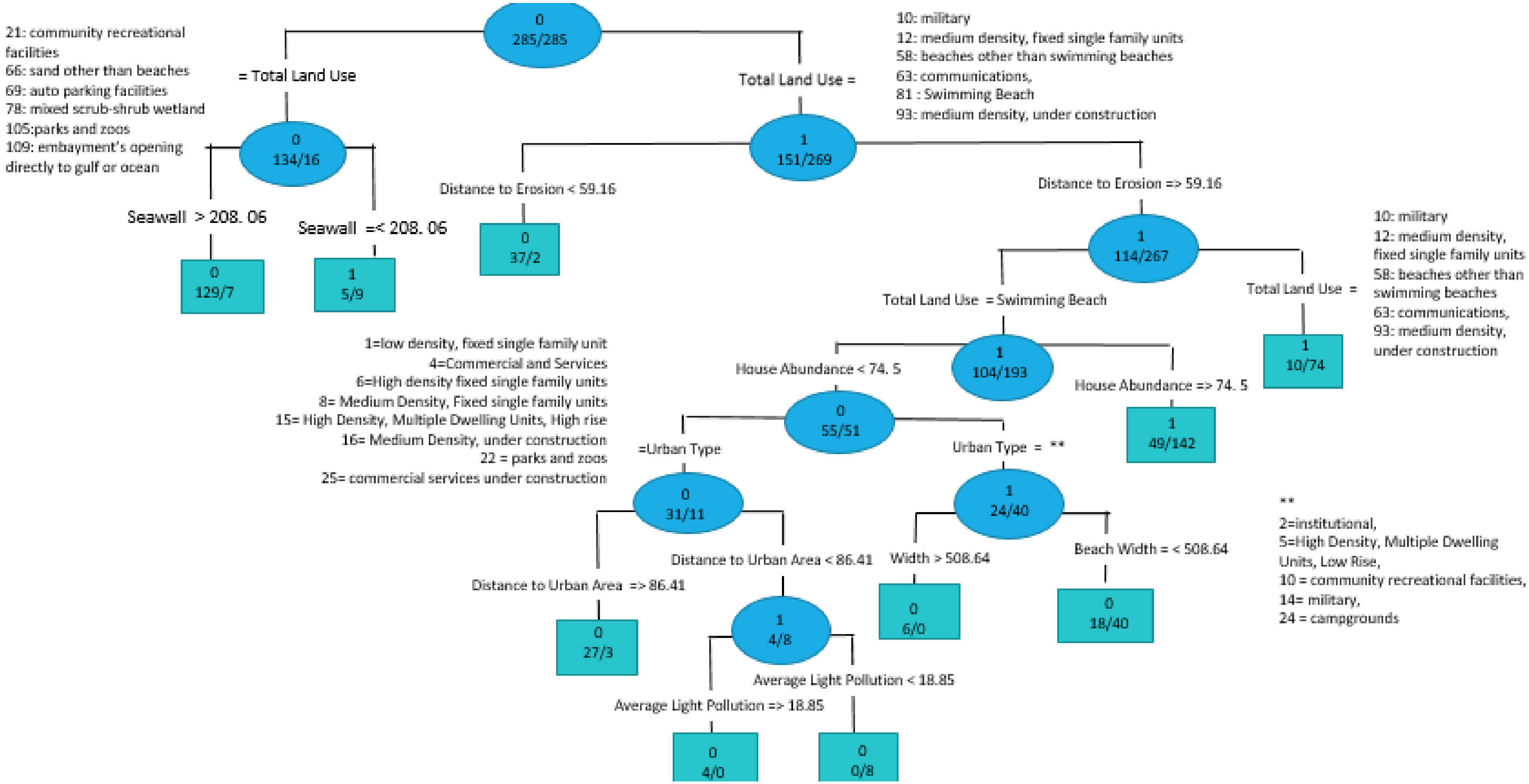


Figure 27. TREE CLASSIFICATION FOR URBAN VARIABLES. This includes five significant branches.

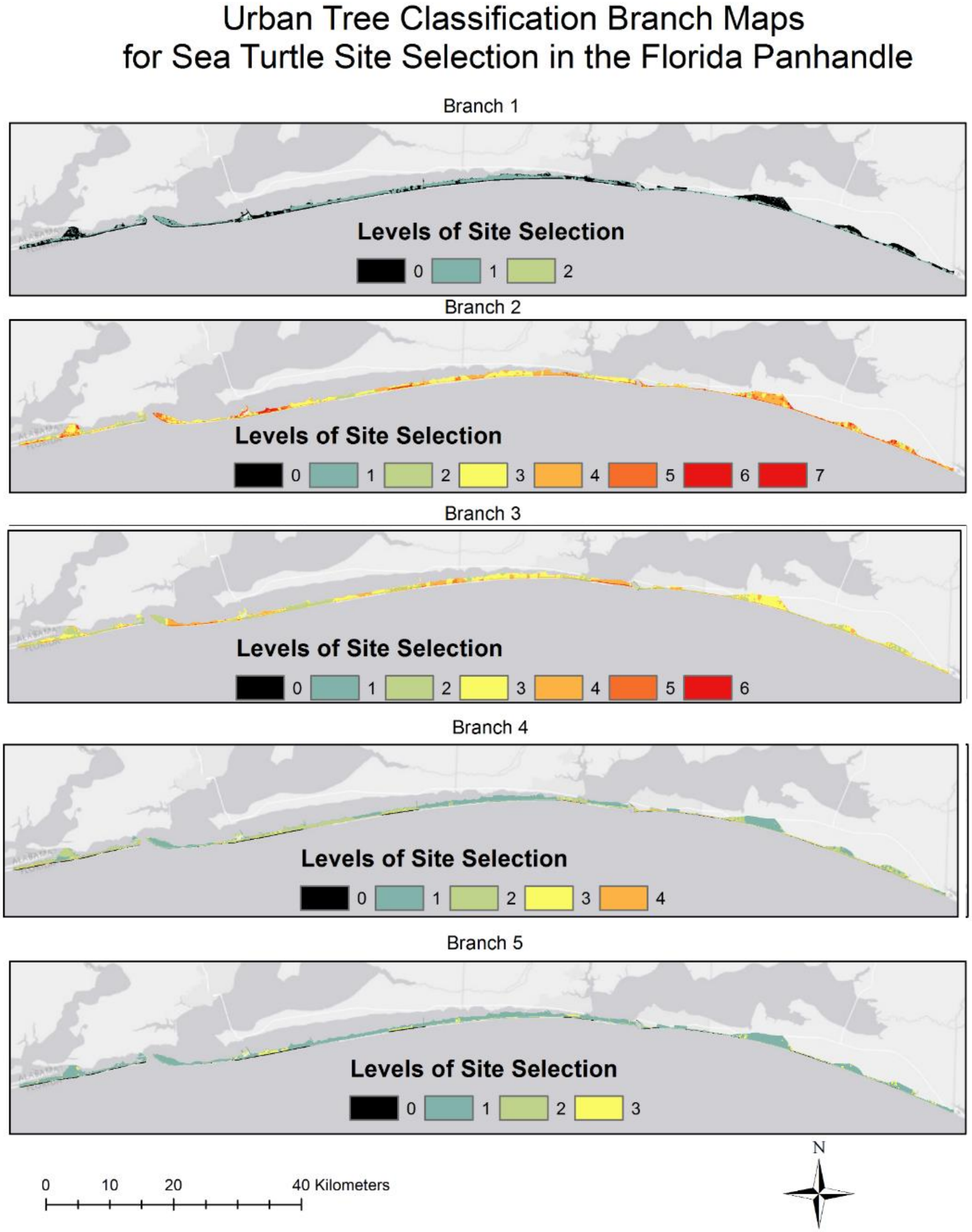


Figure 28. TREE CLASSIFICATION FOR ALL VARIABLE TREE SEPERATED BY DIFFERENT BRANCHES. Levels of nesting habitat indicate the amount of important variables which overlap in those areas. Branches can be seen in figure 28.

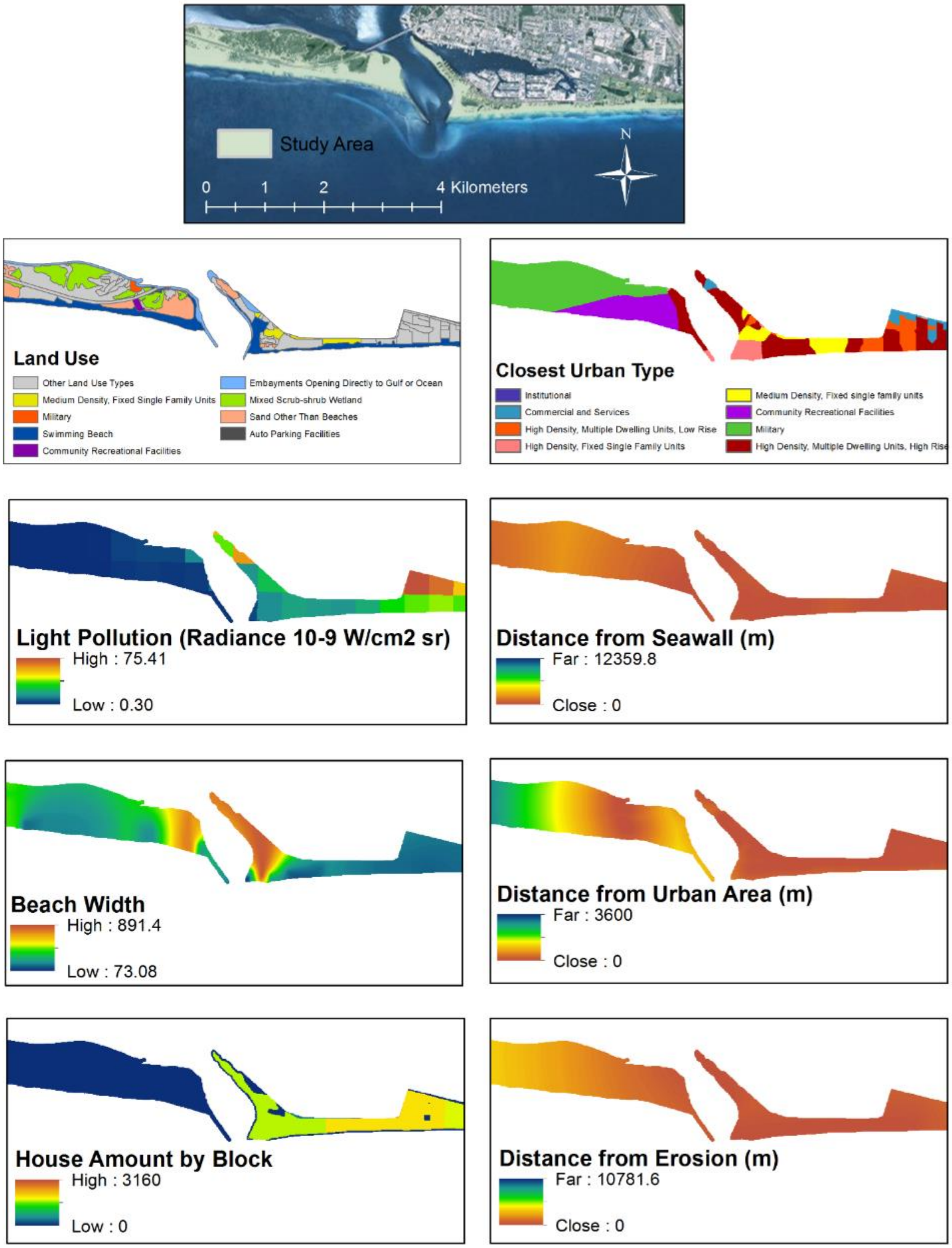


Figure 29. SIGNIFICANT VARIABLE DISTRIBUTIONS OF TREE CLASSIFICATION FOR SELECTED REGION WITHIN THE STUDY AREA

A confusion matrix determined a true positive detection of 273, with only 12 false negative while the true negative rate was 206 of 285, with a 79 false positive rate (Table 19). Similarly to the original tree, the false positive rate is expected to be high, since random nest points are not necessarily absence points. This determines that the tree model is statistically significant and the variables are useful in determining site selection. Additionally, the ROC was created (Figure 31) and an AUC was determined to be .83, so overall there high statistical significance.

Table 19. URBAN VARIABLE TREE CONFUSION MATRIX

| | **Predicted Random** | **Predicted Nest** |
|---|---|---|
| **Observed Random** | 206 (True Negative) | 79 (False Positive) |
| **Observed Nest** | 12 (False Negativure) | 273 (True Positive) |

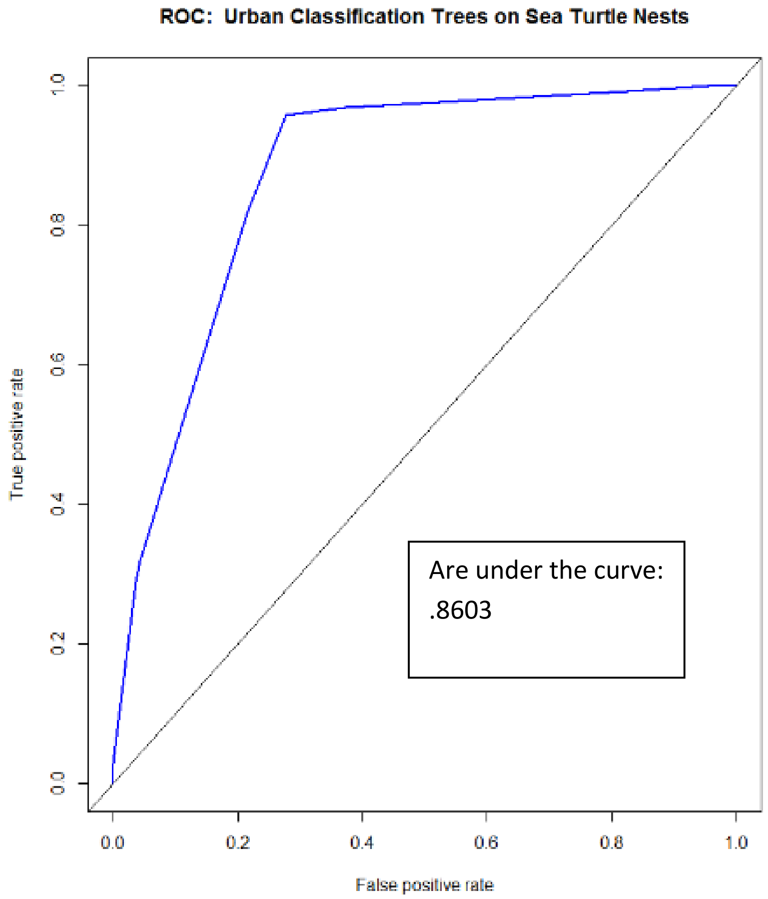


Figure 30. ROC of urban classification

### viii. Urban Variable Random Forest Analysis

Random forest of urban variables used the same variables as the urban tree classification, and was run on 500 trees. The estimate of error rate was at 18.95% which is higher than previous analyses, but still significant.

The average of trees of urban variables returned a confusion matrix with a random nest classification error of 24.9% and an observed nest error of 13% (Table 20). This follows the same logic as the other confusion matrixes as the random nests have more error since they can be actual nests, while the observed nest error is lower since those are actual nests. This gives significance to the overall model.

Table 20. URBAN VARIABLE RANDOM FOREST CONFUSION MATRIX

| | **Predicted Random** | **Predicted Nest** | **Class Error** |
|---|---|---|---|
| **Observed Random** | 214 (True Negative) | 71 (False Positive) | .2491 |
| **Observed Nest** | 37 (False Negative) | 248 (True Positive) | .1298 |

In this model, for the mean decrease accuracy the top ten in order of importance are total land use, distance to erosion, distance to urban density, land use combined, beach width, nourishment source, average light pollution, house abundance by block and distance to sea walls (Table 21, Table 22, Figure 33). By far, total land use makes the highest impact on nest site selection for similar reasons that land cover in the full variable model does. These particular variables can be of focus depending on the area for management, and in conjunction with site selection prediction areas, and tree classification combinations, decisions can be made. From this areas of interest can be pointed out and then managed, or oppositely, an area can be chosen and decisions can be made from the results found in this study.

Table 21. RANDOM FOREST URBAN VARIABLE STATISTICAL ANALYSIS FOR MEAN DECREASE ACCURACY

| Variable by Code | Description | Mean Decrease Accuracy |
|---|---|---|
| TOTALLANDU | Total Land Use | 34.95673 |
| EROSIONDIS | Distance from Erosion | 25.55904 |
| URBANECLUD | Distance from Urban Area | 24.43967 |
| LANDUSECOM | Land Use Combined | 24.4069 |
| Shape_Le_1 | Beach Width | 19.64303 |
| NOURISHMEN | Nourishment Source | 17.37322 |
| AvgLight | Average Light Pollution | 17.30311 |
| HOUSERAST | House Abundance by Block | 15.7787 |
| SEAWALLPER | Distance from Seawall | 15.11698 |
| ROADSDISTA | Distance from Road | 14.83742 |
| POPULATION | Population by Block | 14.83218 |
| URBANTYPE | Closest Urban Type | 14.28602 |
| GRAINSIZEI | Sand Grain Size | 11.23832 |
| ROADTYPERA | Road Type | 10.72071 |
| NOURISHM_1 | Nourishment Source | 7.08669 |
| NOURISHM_3 | Years since Nourishment | 4.911201 |
| EROSIONTYP | Erosion Type | 4.807635 |
| FINALURBAN | Urban Density by Block | 3.247909 |
| ROADRASTER | Road Type | -3.48558 |

Table 22. RANDOM FOREST URBAN VARIABLE STATISTICAL ANALYSIS FOR MEAN DECREASE GINI

| **Variable by Code** | **Description** | **Mean Decrease Gini** |
|---|---|---|
| TOTALLANDU | Total Land Use | 40.38657 |
| EROSIONDIS | Distance to Erosion | 27.87609 |
| LANDUSECOM | Land Use Combined | 27.35537 |
| URBANECLUD | Distance to Urban Area | 23.35193 |
| Shape_Le_1 | Beach Width | 22.96957 |
| ROADSDISTA | Distance to Road | 19.73922 |
| URBANTYPE | Closest Urban Type | 19.12737 |
| NOURISHMEN | Nourishment Source | 18.77919 |
| SEAWALLPER | Distance to Seawall | 17.63164 |
| GRAINSIZEI | Sand Grain Size | 15.37784 |
| AvgLight | Average Light Pollution | 15.17331 |
| HOUSERAST | House Abundance by Block | 10.12661 |
| POPULATION | Population by Block | 7.693945 |
| ROADTYPERA | Closest Road Type | 7.028768 |
| NOURISHM_1 | Nourishment Source | 3.374228 |
| NOURISHM_3 | Years Since Nourishment | 2.667802 |
| EROSIONTYP | Closest Type of Erosion | 1.752845 |
| FINALURBAN | Urban Density | 0.88854 |
| ROADRASTER | Road Type | 0.344391 |

### Final Considerations

Finally, since yearly data is currently not available for this project for all the beach locations. Two separate data sources should be run within the models decided upon above, if time. The first will include comparison of all the beaches and nests for 2015 to determine the important variables for that year. However, this is limiting the data and ignoring bias as 2015 was known to be a generally good year. Over time, nest amounts fluctuate and may be influenced by differing situations on a yearly basis. The model in 2015 can test short time scale differences, but annual time scale differences are also important. To get a better analysis, Okaloosa County has provided 2012 to 2015 and therefore this county can be tested with a better control of time and nest fluctuation. This will be done last, as more data is required to be collected for this analysis and may not be practicable. However, it should be suggested that this project be continued to further the understanding on sea turtle nesting locations.

## Discussion

### General

This study analyzes the nesting population and its small scale site selection distribution within the Florida Panhandle, exempting Bay County of all nesting sea turtles. The attributes of why sea turtle site selection is occurring in this areas was the main purpose and much can be learned from an analysis of this size.

In the past, sea turtle site selection analysis has focused on main physical variables and characteristics in relation to nesting, those being sandy, wide open beaches, with low dunes and a flat approach (Miller et al., 2003 from Iigaz et al., 2011). Some also suggest that remote and dark areas are preferred (Salmon, 2003). However, these areas are less common in most coastal areas where sea turtles nest in Florida. It has also been reported that sea turtles normally nest on remote beaches which have complete darkness. Population density from 2015 in this area of Florida supports this. However, nesting populations still aggregate elsewhere, showing that although (no data was collected on this) turtles nest regularly in these areas of wide, non-populated beaches, with low slope and high elevation,  that is not the only criteria in nest selection and may actually involve many variations of preferred site selection. This difference in preference for nesting sea turtles give scientific precedence, over just the political and management questions, for this type of analysis. Additionally, from a human perspective, this variable nesting pattern is understandable. Turtles, like humans, may have their own general trend, but some may have other trends that were not previously studied, or were just not as prevalent with previous site selection studies. Although site selection studies have occurred since they focus on looking at similar trends as before, leaving some important variables out that have to do with changing landscape like land use, while others only look at one variable in regards to nesting such as sea walls. This study, which involves a more multivariable approach addresses these problems and assess what more needs to be done in bringing all these factors together.

Three prominent observations come from this analysis when observing the overall trends on the study which include an overall shoreline trend, a distributive variable observance within this shoreline trend, and a complex interaction between urban variables regardless of integration of physical parameters.

An initial trend marks a distinct area of the beach of nest selection, which sensibly describes the area of the beach which appears around. Essential habitat is focused in the area after high tide and before any form of barrier such as dunes, roads, or urbanization. This is seen almost completely throughout the entire study area. A study looking at nesting leatherbacks in French Guiana also found that nest site selection was repeatable relative to the highest spring tide line, similar to high tide analysis (Kamel and Mrosovsky, 2004).However, this was based upon nesting turtles and studies of them coming back to shore multiple times (Kamel and Mrosovsky, 2004). Therefore, this study is difficult to compare, but does show that sea turtle may have a heritable behavior in site selection and therefore studying individuals and their replication in nesting may improve management.

Additionally, areas of differences are due to variable importance's affecting site selection probability, and may influence areas differently. Overall, beach area distinction is the most focused. To truly determine this, a look at the mean distance traveled from the ocean should improve this area of turtle site selection.

In relation to this beach nesting, there are areas of variability within this. This is similarly supported by the French Guiana nesting leatherback population, which was determined to have individual preferences compared to other nesting turtles, creating a general lack of predictability in (Kamel and Mrosovsky, 2004). Therefore, this may create the odd distribution and variation in shoreline and variable analysis. However, overall, trends are taken from this. Urban areas may have more breadth to nesting with lower predictability of site selection, but low populated areas have a smaller width of site selection, but a much higher probability. This is not true for the entire area, but can be seen throughout the Panhandle, while variability in nesting is seen in areas throughout the world (Maison et al., 2010).

Additionally, a change in nesting activity could be affected by increasing climate change conditions, which questions whether their nest selection may also be affected (Dawicki, 2013). Based upon the importance of variables such as erosion, seawalls, and beach width, this may need to be a main focus in the future, as climate change poses multiple threats to sea turtle nests including inundation of nests from increased storms and sea level rise, increased nourishment due to erosion where sand may disrupt hatchling survival and possibly nesting locations, and increased heat which changes overall gender distribution (New South Wales, 2011; D. Barber, nd: A.A. Gallaher, 2009). This may require foresight in acknowledgment. This additional variability, however, shows that not all shoreline is good for nesting. Nesting is therefore much more complicated than the general idea of wide beaches and low slope determined in the past. For example, one study which did focus on multiple anthropogenic variables, specifically a golf course construction, in the West Indies, looking at leatherback nest distribution (Maison et al., 2010). This determined that aspect, meaning the direction the beach was facing determined differing nest selection abundance based upon erosion of those beaches (Maison et al., 2010). Overall, a lot of variables go into the distribution of nest site selection and can be variable over time.

Finally, there appears to be an overall trend in nesting distribution, in which land use, land cover, and urban factors play a part all came from the data dataset and are similar/ reduced to produce the final (Van Meter, 2002). Although this is significant over the course of large scale, small scale and multiple analysis types, it is logical, relating back to original understandings of sea turtle nest selection of wide open beaches previously discussed (Miller et al., 2003 from Iigaz et al., 2011). These types are also inherently related to nesting sites as the nest must be within one of the many factors, while are close to certain aspects of land use, cover, and urban areas regardless of where they choose to nest. Whether these are highly influencing nest selection, or just have high associations is questionable. However, in relation to urban variables, enough interchange of other urban variables between models can be seen that urban variables at least do play a large part while it is understandable that sand is a large promotor of turtle nests, when sand other than beach sand is not. Testing of sand types, may influences turtle nesting, as the sand other than beach sand may be more of a deterrent on a small scale, static in time basis then a highly popular urban area which is larger in scale and variable in time. This pinpoints a factor of sea turtle selection, that choices of selection may be more influenced, on a cost-benefit scale, on small scale choices as turtles may perceive nests on this scale and not necessarily absorb surrounding features.

Although not distinct, it is proven that sea turtles are more likely to false crawl near seawalls (A.E. Mosier & B.E. Witherington, 2000). Therefore, the positive attraction may conflict with false crawl reasoning’s. Since only a small area of the study looked at the difference of false crawls and observed nesting, it may be important to look into this interaction more. However, an overall increase in human interaction and variables on much smaller scales should be addressed in the upcoming years if more is to be learned of their nesting patterns in regards to these interactions.

Additionally, much can be said in observation with small scale analysis, but should be done with nest site selection studies and on the ground observances. For example, one study in Ten Thousand Islands, looked at multiple variables and determined more physical variables affected those nesting turtles, such as beach width and slope which can be a focus for that area (Garmestani et al., 2000). However, along the panhandle, urban variables may be more important to focus on.

### Management Suggestions

Sea turtles additionally are highly variable creatures, with general trends, but less distinct drivers for nesting. Depending on the area, different patterns can emerge, while each characteristic driver may cause differing site selection choices. This requires managers to look at multiple angles of a species, their behavior, and their ecosystem preferences to fully protect and conserve species, particularly ones who are highly vulnerable.

Comparative mapping studies to not just generate maps of site selection, but to compare maps on a small scale with overlaid maps from differing studies or analyses. Generating similarities and differences between these maps may help to narrow down the most important focused variables. Assuming variables across analysis through observation is not enough, but analysis of these maps may confirm or deny variables of focus for managers. This can be used in literature review analysis through generating maps from previous studies in small scale areas also, to discover commonalities. This will improve the ability for managers to focus on the most important or repetitive drivers of site selection with a statistical reasoning.

There is also a world focus on ecosystem based management. However, for species such as sea turtles, who not only associate nests with physical variables in relation to the environment, but also with urban variables Integrated Environmental Management. Although it is not distinguished that a specific management type is used within the Florida Panhandle, integrated environment management, which includes the human sector and environmental sector equally may improve future strategies, reducing social outcry from this highly touristy area.

Additionally, Managers also have focused on lighting in relation to sea turtle conservation, particularly for hatchlings, although false crawls have been known to occur with nesting females in highly lit areas. The area of Florida, except for a small segment within Okaloosa County is protected by light ordinances (FL FWS – light ordinance, 2015).  Light does not seem to show up within the analysis though as causing any association, meaning that it has little affect in comparison to other variables. Therefore, managers should understand or focus on differing in relation to more important variable types such as land use and urban areas, as well as beach width in conjunction with safer nourishment standards looking at studies which analyses grain size, color, and other distinct forms of sand which sea turtles and their hatchlings are not negatively affected by in terms of nesting and survival respectively.

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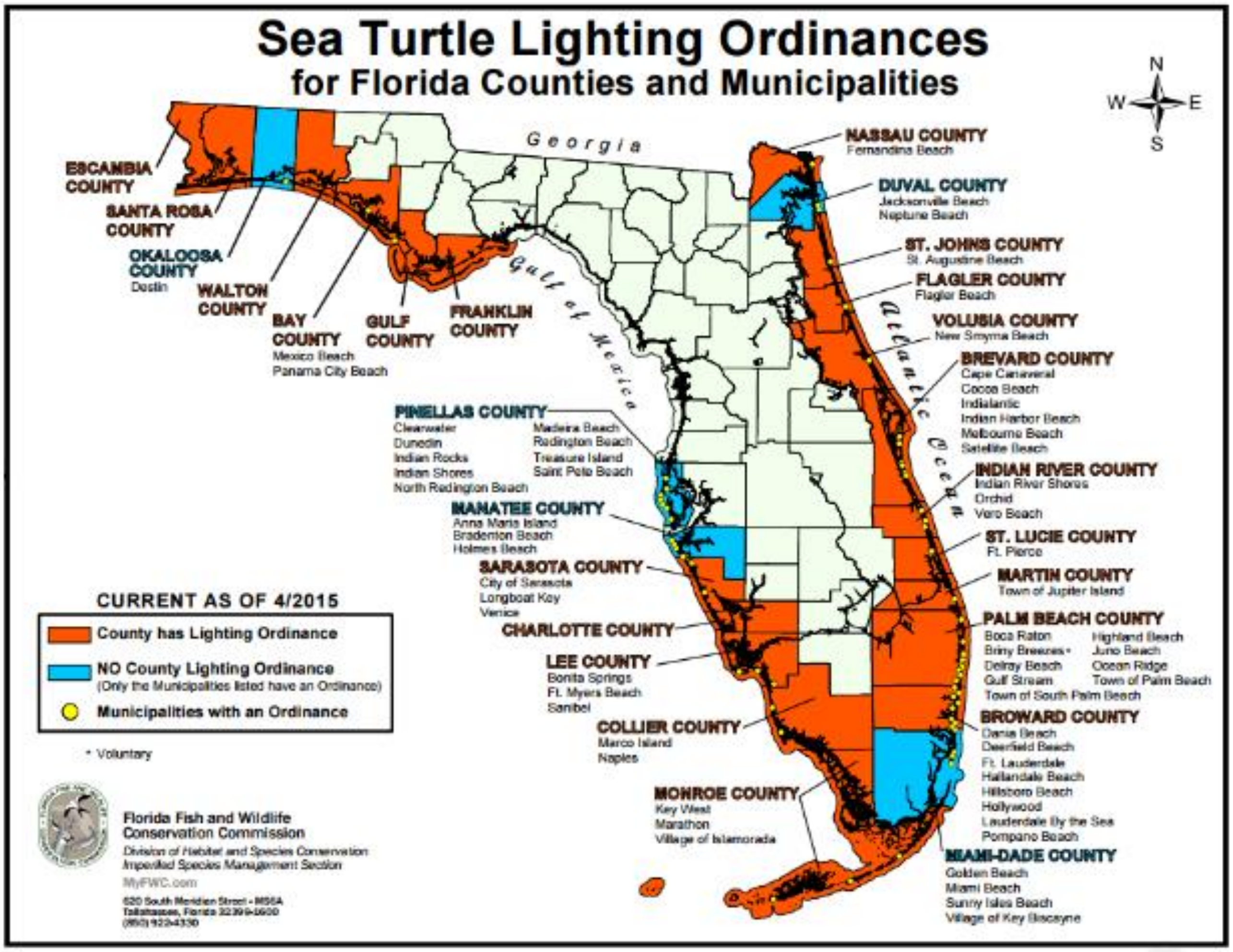
# Appendix

A.



Sea Turtle Lighting Ordinances
for Florida Counties and Municipalities

**B.** Important variables associated with sea turtle nesting. N/As indicate variable acknowledged, but data not yet collected or proving difficult to find. Some variables will be collected or calculated based on interpolations or management of data in ArcMap. Variable entity and calculations in green represent unsure processes

| Complete List of Variables for Analysis | | | |
|---|---|---|---|
| Variable | Code | Year data created/collected | Source |
| Land Use: | TOTALLANDU | 2012-2013 | North West Florida Water Management District - Land Use |
| Land Cover | LANDCOVERTr | 2012-2013 | North West Florida Water Management District - Land Use |
| Urban Land Use Types:<br>Urban Type<br>Urban Distance | URBANECLUD<br>URBANTYPE | 2012-2013 | North West Florida Water Management District - Land Use |
| Light- Street Lights | N/A | 2003 | http://www.dot.state.fl.us/research-center/Completed_Proj/Summary_EMO/FDOT_BB850_rpt.pdf<br>street light survey ( a-27) |
| Light – Total Pollution:<br>VIIRS DNB Cloud Free Composites: Version 1 Nighttime VIIRS Day/Night Band Composites | AvgLight | 2015-Monthly | NOAA/NGDC Earth Observation Group :<br>Visible Infrared Imaging Radiometer Suite (VIIRS) |
| Sand quality, grain size | GRAINSIZEI | 2012 | GeoChem |
| Sand Quality, sand color | N/A | N/A | N/A |
| Sediment type | N/A | N/A | N/A |
| Elevation<br>slope<br>aspect | Elevation<br>ELEVSLOPE<br>ELEVATIONA | 2013 | NED-USGS |
| Bathymetry<br>slope<br>aspect | SlopeBathM BathAspeM BathyM | 2000<br>*subject to find an updated version | NOAA-Coastal Services Center (CSC) |
| Seawall | SEAWALLPER | 2015 | FDEP |

| | | | |
|---|---|---|---|
| Nourishment Distance<br>Nourishment Source<br>Years since Nourishment | NOURISHMEN<br>NOURISHM_1<br>NOURISHM_3 | 2015 | Jorge Lagos, Florida Department of Environmental Protection, Beaches, Mining, ERP Support Program, Beaches, Mines, and ERP Support Program Manager |
| Tidal Distance | HighTideDi | 2015, 2010 | Google Maps, .S. Department of Commerce (DOC), National Oceanic and Atmospheric Administration (NOAA), National Ocean Service, (NOS), National Geodetic Survey (NGS), see land use variable and road source |
| Dunes | DUNEPERMIT | 2015 | FDEP |
| Roads | ROADRASTER<br>ROADTYPERA<br>ROADSDISTA | Oct. 2015 | Florida Department of Transportation http://www.dot.state.fl.us/research-center/Completed_Proj/Summary_EMO/FDOT_BB850_rpt.pdf : Road type described |
| Erosion presence | EROSIONDIS<br>EROSIONTYP | July 2014 report | Florida Department of Environmental Protection Critical Erosion Areas |
| Erosion Rate | N/A | N/A | N/A |
| Beach Length | MeanSurvLe | 2014 | Florida Fish and Wildlife Conservation Commissions Fish and Wildlife Research Institute |
| Beach Width (imagery, CUSP line) | Shape__1e_1 | E_12015, 2010 | Google Maps, .S. Department of Commerce (DOC), National Oceanic and Atmospheric Administration (NOAA), National Ocean Service, (NOS), National Geodetic Survey (NGS), see land use variable and road source |
| Population<br>House Abundance | POPULATION<br>HOUSERAST | 2010, 2010 | University of Florida GeoPlan Center/Florida Department of Transportation, Census Bureau |
| Urban Density | FINALURBAN | 2010, 2010 | University of Florida GeoPlan Center/Florida Department of Transportation, Census Bureau |
| Air temperature: GHCND (Global Historical Climatology Network)-Monthly Summaries Monthly Mean Temperature & Extreme | AirTAvg | 2015, monthly | NOAA National Climatic Data Center |

| | | | |
|---|---|---|---|
| maximum temperature | | | |
| Rainfall | PrecipAvg | 2015, monthly | NOAA National Climatic Data Center, National Weather Service: Advances Hydrologuic Prediction Service () [compare] |
| Park/Protection | CLASSIFY | 2015, 2011, Unknown | Office of Park Planning (Division of Recreation and Parks), Office of Coastal and Aquatic Managed Areas, unknown |
| Beach Access | N/A | 2010 | FDEP - Florida Coastal Office |
| Artificial Reef Type<br>Artificial Reef Distance | ARTIFICIAL<br>ARTIFICI_1 | 2008 | Florida Fish and Wildlife Conservation Commission-Fish and Wildlife Research Institute |
| Wetland<br>Wetland Distance | WETLANDRAS<br>WetlandDis | 2012-2013 | North West Florida Water Management District - Land Use |
| Hydrology Distance<br>Hydrology Type | HYDROLOGYE<br>HYDROLOGYR / HYDROLOGYT | 2015 | USGS |

## C. GRAIN SIZE scale and ranges

| *Scale* | *Size range (metric)* | *Size range (approx. inches)* | *Aggregate name (Wentworth class)* | *Other names* |
|---|---|---|---|---|
| ***<−8*** | >256 mm | >10.1 in | Boulder | |
| ***−6 to −8*** | 64–256 mm | 2.5–10.1 in | Cobble | |
| ***−5 to −6*** | 32–64 mm | 1.26–2.5 in | Very coarse gravel | Pebble |
| ***−4 to −5*** | 16–32 mm | 0.63–1.26 in | Coarse gravel | Pebble |
| ***−3 to −4*** | 8–16 mm | 0.31–0.63 in | Medium gravel | Pebble |
| ***−2 to −3*** | 4–8 mm | 0.157–0.31 in | Fine gravel | Pebble |
| ***−1 to −2*** | 2–4 mm | 0.079–0.157 in | Very fine gravel | Granule |
| ***0 to −1*** | 1–2 mm | 0.039–0.079 in | Very coarse sand | |
| ***1 to 0*** | 0.5–1 mm | 0.020–0.039 in | Coarse sand | |
| ***2 to 1*** | 0.25–0.5 mm | 0.010–0.020 in | Medium sand | |
| ***3 to 2*** | 125–250 µm | 0.0049–0.010 in | Fine sand | |
| ***4 to 3*** | 62.5–125 µm | 0.0025–0.0049 in | Very fine sand | |
| ***8 to 4*** | 3.9–62.5 µm | 0.00015–0.0025 in | Silt | Mud |
| ***10 to 8*** | 0.98–3.9 µm | $3.8\times10^{-5}$–0.00015 in | Clay | Mud |
| ***20 to 10*** | 0.95–977 nm | $3.8\times10^{-8}$–$3.8\times10^{-5}$ in | Colloid | Mud |

## Bibliography

Andrews, K. M., J. W. Gibbons, and D. M. Jochimsen. Ecological effects of roads on amphibians and reptiles: a literature review. In J. C. Mitchell and R. E. Jung (eds.). Urban Herpetology. Herpetological Conservation Vol. 3, Society for the Study of Amphibians and Reptiles, Salt Lake City, UT. In press. http://transwildalliance.org/resources/2009101416234.pdf

ArcGIS (2016) Calculate Density. From https://developers.arcgis.com/rest/analysis/api-reference/calculate-density.html

ArcGIS Desktop Help 9.3 - An overview of the Multivariate toolset. (n.d.).From http://webhelp.esri.com/arcgisdesktop/9.3/index.cfm?TopicName=An_overview_of_the_Multivariate_toolset

ArcGIS Pro. (n.d.). From http://pro.arcgis.com/en/pro-app/tool-reference/spatial-analyst/an-overview-of-the-multivariate-tools.htm

Barber U. (nd) Beach Nourishment Basics, [Online]. Available: http://www.brynmawr.edu/geology/geomorph/beachnourishmentinfo.html

Cairns, J., & Crawford, T. V. (1991). Integrated environmental management. Chelsea, MI: Lewis

Chahouki, M. A. (2011). Multivariate Analysis Techniques in Environmental Science. Earth and Environmental Sciences. From <http://cdn.intechopen.com/pdfs-wm/24570.pdf>

Christensen, N. L., A. Bartuska, J. H. Brown, S. Carpenter, C. D'Antonio, R. Francis, J. F. Franklin, J. A. MacMahon, R. F. Noss, D. J. Parsons, C. H. Peterson, M. G. Turner, and R. G. Moodmansee. 1996. The report of the Ecological Society of America Committee on the scientific basis for ecosystem management. Ecological Applications. 6:665-691.

Dawicki S. (2013). Loggerhead Sea Turtle Nesting Activity Driven by Recent Climate Conditions and Returning Nesting Females. NOAA Northest Fisherieis Science Center. From http://www.nefsc.noaa.gov/press_release/2013/SciSpot/SS1314/

Deconcini C. & Tompkins F., (2012). “Sea-Level Rise and its Impact on Florida”, World Resources Institute, [Online]. Available: http://www.wri.org/sites/default/files/pdf/sea_level_rise_in_florida.pdf

Environpaedia Rethinking Reality (2007). Integrated Environmental Management (IEM). Retrieved February 29, 2016, from http://www.enviropaedia.com/topic/default.php?topic_id=141

Fielding, A.H., and J.F. Bell. 1997. A review of methods for the assessment of prediction errors in conservation presence/absence models. Environ. Conservation 24:38-49.

Florida Fish and Wildlife Conservation Commission (November 2007) Marine Turtle Conservation Guidelines: Section 2 Nesting Beach Survey Activities. From http://myfwc.com/wildlifehabitats/managed/sea-turtles/conservation-guidelines/

Florida Fish and Wildlife Conservation Commission. 2015. Light Ordinance Map. From http://myfwc.com/media/418420/seaturtle_lightordmap.pdf

Florida Fish and Wildlife Conservation Commission (2015). Sea Turtle. From http://myfwc.com/wildlifehabitats/managed/sea-turtles/

Florida Fish and Wildlife Conservation Commission (2015) Sea Turtle Monitoring (the SNBS and INBS Programs) from http://myfwc.com/research/wildlife/sea-turtles/nesting/sea-turtle-monitoring/

Florida Fish and Wildlife Conservation Commission (2015) Sea Turtle Protection Ordinances Adopted by Counties and Municipalities From http://myfwc.com/conservation/you-conserve/lighting/ordinances/

Florida Fish and Wildlife Conservation Commission (nd), “Nesting Beach Surveys, Crawl Identification”, [Online]. Available: http://myfwc.com/media/3055670/crawlidentificationguidelines.pdf

Florida Ocean’s Coastal Council (2010), “Climate Change and Sea Level Rise in Florida: An Update of the Effects of climate change on Florida’s Ocean and Coastal Resources” [Online]. Available: http://www.dep.state.fl.us/oceanscouncil/reports/climate_change_and_sea_level_rise.pdf

Florida Statutes. 2010. CHAPTER 62B-55 MODEL LIGHTING ORDINANCE FOR MARINE TURTLE PROTECTION from http://myfwc.com/media/418521/Seaturtle_Rule62B_55.pdf

Frazer, N. B. (1992), Sea Turtle Conservation and Halfway Technology. Conservation Biology, 6: 179–184. doi: 10.1046/j.1523-1739.1992.620179.x From http://onlinelibrary.wiley.com/doi/10.1046/j.1523-1739.1992.620179.x/abstract;jsessionid=64B43524AF6157E4290B26117C8E8E14.f01t04 [Based on the keynote address for the Tenth Annual Workshop on Sea Turtle Conservation and Biology (February 1990), hosted by the Nongame and Heritage Trust Section of the South Carolina Wildlife and Marine Resources Department and Project Turtle Watch of the Museum of Hilton Head Island.]

Gallaher, A.A (2009), “The Effects of Beach Nourishment on Sea Turtle Nesting Densities in Florida”, [Online]. Available: http://ufdcimages.uflib.ufl.edu/UF/E0/04/10/87/00001/gallaher_a.pdf

Garmestani, A. S., Portier, K. M., & Rice, K. G. (2000). Nest-Site Selection by the Loggerhead Sea Turtle in Florida's Ten Thousand Islands. Journal of Herpetology, 34(4), 504. From http://www.jstor.org/stable/pdf/1565263.pdf?acceptTC=true

Hamann M, Godfrey MH, Seminoff JA, Arthur K, Barata PCR, et al. (2010) Global research priorities for sea turtles: informing management and conservation in the 21st century. Endangered Species Research 11: 245–269. http://dro.deakin.edu.au/view/DU:30058313

Hopley L and van Schalkwyk, J. 2011. The magnificent ROC. From http://www.anaesthetist.com/mnm/stats/roc/Findex.htm

Ilgaz, Ç, Özdemir, A., Kumlutaş, Y., & Durmuş, S. H. (2011). The effect of nest relocation on embryonic mortality and sex ratio of Loggerhead Turtles, Caretta caretta (Reptilia: Cheloniidae), at Dalyan Beach, Turkey. Italian Journal of Zoology, 78(3), 354-363.

Kamel, S.J., and N. Mrosovsky. 2004. Nest Site Selection in leatherbacks, dermochelys coriacea: individual patterns and their consequences. Animal Behaviour 68:357-366. From http://transwildalliance.org/resources/2009101416234.pdf

Kikukawa A., Kamezaki N. and Hidetoshi Ota H. (1999). Factors affecting nesting beach selection by loggerhead turtles (Caretta caretta): a multiple regression approach. Journal of Zoology, 249, pp 447-454.

Jaffé, R., Peñaloza, C., & Barreto, G. R. (2008). Monitoring an Endangered Freshwater Turtle Management Program: Effects of Nest Relocation on Growth and Locomotive Performance of the Giant South American Turtle (Podocnemis expansa, Podocnemididae). Chelonian Conservation and Biology, 7(2), 213-222. Retrieved from http://www.bioone.org/doi/abs/10.2744/CCB-0696.1

Margerum, R. D. (1999). PROFILE: Integrated Environmental Management: The Foundations for Successful Practice. Environmental Management,24(2), 151-166. From http://link.springer.com/article/10.1007%2Fs002679900223?LI=true#page-2

McLeod, K. L., J. Lubchenco, S. R. Palumbi, and A. A. Rosenberg. 2005. Scientific Consensus Statement on Marine Ecosystem-Based Management.

Miller JD, Limpus CJ, Godfrey MH (2003) Nest site selection, oviposition, eggs, development, hatching, and emergence of loggerhead turtles. In: Loggerhead Sea Turtles (eds BoltenAB, WitheringtonBE), pp. 125–143. Smithsonian Books, Washington.

Mortimer, J. A.. (1990). The Influence of Beach Sand Characteristics on the Nesting Behavior and Clutch Survival of Green Turtles (Chelonia mydas). Copeia,1990(3), 802–817. http://doi.org/10.2307/1446446

Mortimer, J. A. 1995. Factors influencing beach selection by nesting sea turtles. Pages 45–51 in K. A.Bjorndal, editor. Biology and conservation of sea turtles. Smithsonian Institution Press, Washington , D.C. Retreived from http://college.holycross.edu/faculty/kprestwi/chelonia/pubs/3_book_chapters/BeachSelection.pdf

Mosier, A.E. & Witherington B.E. (2000) “Documented Effects of Coastal Armoring Structures on Sea Turtle Nesting Behavior” [online]. Available: http://www.fws.gov/nc-es/ecoconf/mosier%20paper.pdf

National Oceanic and Atmospheric Administration (1975), The Coastline of the United States. http://shoreline.noaa.gov/_pdf/Coastline_of_the_US_1975.pdf

National Oceanic and Atmospheric Administration Fisheries. (2015, June 11). Sea Turtles. Retrieved from http://www.nmfs.noaa.gov/pr/species/turtles/

New South Wales (2011), Coastal Erosion and Inundation, [Online] Available: http://www.ses.nsw.gov.au/communitysafety/coastal-erosion

PBS (2015), “How Rising Seas Could Sink the Sea Turtle”, [Online], Available: http://www.pbs.org/newshour/updates/sea-turtles-rising-seas-sex-ratios/

Pfaller JB, Limpus CJ, Bjorndal KA. 2008. Nest-site selection in individual loggerhead turtles and consequences for doomed egg relocation. Conservation Biology 23:72–80

Pilkey O.H.(1989) “The engineering of sand.” Journal of Geological Education 37:308–311 from D.G. Rumbold, P.W. Davis, & C. Perretta (2001), “Estimating the Effect of Beach Nourishment on Caretta Caretta (Loggerhead Sea Turtle) Nesting. Restoration Ecology, 9(3):304 - 310. DOI: 10.1046/j.1526-100x.2001.009003304.x

Rich, C., & Longcore, T. (2006). Ecological consequences of artificial night lighting. Washington, DC: Island Press.

Rizkalla, C.E & Savage, A.(2011) “Impact of seawalls on loggerhead sea turtle (Caretta caretta) nesting and hatching success” Journal of Coastal Research, 27(1), 166–173. [Online]. Available: http://users.clas.ufl.edu/mbinford/GEOXXXX_Biogeography/Literature_reports_by_students/Report_4/Pritchard_Article4.pdf

Ruppert T.K. (2008), “Eroding Long-Term Prospects for Florida’s Beaches:

Florida’s Coastal Management Policy” [Online]. Available: http://biotech.law.lsu.edu/climate/docs/FINAL%20REPORT_8.19.08.pdf

Salmon, Michael. (2003). Artificial night lighting and sea turtles. Florida Atlantic University, USA. Biologist. 50;4. From http://www.science.fau.edu/biology/faculty/Artificial%20Lighting%20as%20a%20Threat.pdf

Sea Turtle Conservancy, 2015, Information About Sea Turtles: Why Care? http://cccturtle.org/seaturtleinformation.php?page=whycareaboutseaturtles

Sea Turtle Conservancy (2015). “Threats from Coastal Armoring” [Online]. Available: http://www.conserveturtles.org/seaturtleinformation.php?page=seawalls

Shanker, Kartik, BC Choudhury,Ashish Fernandes, Sanjiv Gopal, Areeba Hamid, Chandrasekhar Kar, Suresh Kumar, Janaki Lenin, Biswajit Mohanty, Bivash Pandav, Sudarshan Rodriguez, Aarthi Sridhar, Wesley Sunderraj, Basudev Tripathy, Romulus Whitaker, Sejal Worah & Belinda Wright (2009). A Little Learning… The Price of Ignoring Politics and History. Marine Turtle Newsletter, 124: 3-5. Retrieved from http://www.seaturtle.org/mtn/archives/mtn124/mtn124p3.shtml

Stephens, T. 2014. Titanic: Getting Started With R – Part 5 : Random Forest from http://trevorstephens.com/post/73770963794/titanic-getting-started-with-r-part-5-random

Stewart, C. & Leitao, R. (2015) “Sea Turtles Experiencing Higher Number of ‘False Crawls’”, [Online]. Available: http://www.wptv.com/news/region-n-palm-beach-county/tequesta/sea-turtles-experiencing-higher-number-of-false-crawls

Therneau, T, Atkinson B, Ripley, B., 2015. Packing ‘rpart’. From https://cran.r-project.org/web/packages/rpart/rpart.pdf

University of Florida (2014, July 17). Our History. Retrieved from http://accstr.ufl.edu/accstr-overview/our-history/

Urban, D.L. 2003. Habitat Classification Models: Classification and Regression Trees. Duke University, Lab.

Van Meter, V. B. 1990. Florida's Sea Turtles. Florida Power and Light Company; Miami, Florida. From http://www.bstp.net/PDFs/FL%20Sea%20Turtles%20(FPL).pdf

Witherington, B. E. (1992). Behavioral Responses of Nesting Sea Turtles to Artificial Lighting. Herpetologica, 48(1), 31–39. Retrieved from http://www.jstor.org/stable/3892916

Weishampel J.F., D.A. Bagley, L.M. Ehrhart, B.L. Rodenbeck (2003). Spatiotemporal patterns of annual sea turtle nesting behaviors along an East Central Florida beach. Biol. Conserv., 110, 295–303

Zambello, Erika (2015) Sea Turtles of Okaloosa County. From http://www.emeraldcoastfl.com/discover-the-coast/emerald-postings-blog/the-sea-turtles-of-okaloosa-county/