Examining The Density And Distribution Of Micro And Macroplastics As A Possible Contributor To Sea Turtle Nesting Sand Habitat Quality

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EXAMINING THE DENSITY AND DISTRIBUTION OF MICRO AND MACROPLASTICS AS A POSSIBLE CONTRIBUTOR TO SEA TURTLE NESTING SAND HABITAT QUALITY

By

CÉLINE MOLLET SAINT BENOÎT

Under the Direction of Christy Visaggi, Ph.D.

ABSTRACT

Since the 1950s, the mass production and use of plastics worldwide has increased exponentially. Their one-time use and durability has made them both accessible and affordable to global human populations. These more immediate benefits have come at a cost to the world's oceans. Plastics have since impaired, injured, and even killed countless marine species, such as sea turtles, often becoming entangled in or ingesting these plastics. New research has demonstrated the ability of microplastics to affect sea turtles before they hatch by altering the microenvironment within the nest. This research examines how both macro- and microplastics could contribute to the depreciation of the sand quality of a significant loggerhead (*Caretta caretta*) nesting beach on Jekyll Island, Georgia. The study utilizes historic data to identify existing long-term temporal and spatial trends in nesting activities, alongside census data on surface macroplastics, and microplastics extracted from the sediments of the sea turtle nest.

INDEX WORDS: Nesting beach, Plastics, Loggerheads, Anthropogenic effects, Sea turtles, Jekyll Island

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DEDICATION

I dedicate this thesis to my mom for always believing in me and constantly reminding me to sit on the head of the Tiger. This little saying is what has brought me to where I am today. You once gifted me a bracelet with the Tolkien quote, “Not all those who wander are lost.” This thesis breathes new meaning into this quote for me. To Hogan Smith, thank you for believing in me and reminding me to always give “Hogan Percent.” To my best friend, Jacky Baca, who knows me better than I know myself, and whom I know will always have my back, and cook me delicious tacos. I also dedicate this thesis to all my friends for their support over these past two years.

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SMI: Sediment Microplastic Isolation

MDT: Marine Debris Tracker

GSTC: Georgia Sea Turtle Center

1 INTRODUCTION

Human impacts on marine ecosystems have escalated in recent decades due to pollutant and nutrient runoff, overharvesting, habitat destruction and vast amounts of improperly disposed trash (Halpern et al., 2008). Based on 2010 U.S. Census data, coastal counties account for 39% of the nation's population and also include many of the largest cities and fastest growing counties (Wilson and Fischetti, 2010). Equally, the rate and quantity of the debris accumulated as a result of these activities has surged on beaches and ocean surfaces (Barnes, 2005; Claessens et al., 2011), largely attributed to the immense worldwide production of plastics. Since the beginning of their commercial and industrial production in the 1950s, plastic production has increased 200 fold within the United States alone (Li et al., 2016). Due to this increased use of plastics, resulting debris has quickly become a leading global environmental issue (Kershaw et al., 2011). Plastics are defined as synthetic or semi-synthetic organic polymers that are cheap to produce, durable, lightweight and corrosion resistant (Laist, 1987; Thompson et al., 2009; Li et al., 2016). Approximately 50% of all plastics produced are intended for one-time use (Hopewell et al., 2009). This attribute alone facilitates their ease of worldwide dispersal and accumulation (Barnes et al., 2009).

Plastics are resistant to corrosion, allowing them to infiltrate and persist in marine environments for upwards of hundreds to thousands of years (Barnes et al., 2009). Of the plastics produced, 49% are buoyant, promoting their transport across the world's oceans (EPA, 2008) and permitting them access to more remote areas of the globe. Once deposited in those ecosystems, plastics frequently break down into smaller fragments through corrosion, with further degradation occurring with exposure to UV radiation and the ocean's own salinity

(Moore, 2008). Although the rate is slower in the ocean than that on land (Hammer et al., 2012), this degradation allows them to persist for longer within the environment.

It is the longevity of plastics that poses the largest threat to wildlife, the integrity of the ecosystem, and the economic value of a location. Plastics are often a source of ensnarement or entanglement, limiting an organism's mobility and foraging abilities (Sheavly and Register, 2007). This ensnarement can then directly result in injuries or fatalities (Gall and Thompson, 2015), while active and accidental ingestion of plastics by marine organisms is also possible, with plastics frequently being mistaken for prey items. Hundreds of various marine species have been documented to have fragments of plastics lodged in their digestive tract disrupting ingestion (Gregory, 2009). They also can impact natural environments such as, contaminating soil and contributing to beach degradation (Oehlmann et al., 2009). Excessive plastic debris can decrease the aesthetic appeal of an area, negatively impacting tourism, which in turn can economically devastate an area (Barnes et al., 2009). Such economic effects can be substantial in coastal communities who rely upon tourism as a main source of economic income (Balance et al., 2000).

Jekyll Island in southeastern Georgia may be at risk to the detrimental effects of plastic use. The island is an established loggerhead sea turtle (*Caretta caretta*) nesting beach, which helps to drive a local economy that is predominantly funded on tourism (Ondich and Andrews, 2013). Previous research has highlighted zones of plastic as it has accumulated along the beach (Martin et al., 2019). These areas have the potential to lower the quality of sediment used by loggerheads to deposit their eggs. Within such sands, plastics have been documented elsewhere as altering the microenvironment of the nests, which, in excess, pose a variety of negative effects (Nelms et al., 2016). Along the beach surface, plastics can act as obstacles or traps for sea turtle hatchlings emerging from the sand (Triessnig et al., 2012). In an effort not only to maintain this critical sea turtle habitat, but to ensure the economic future of Jekyll Island, this research seeks to explore whether macro- and microplastics could potentially affect the nesting sand quality on the island. This research is divided into two parts: the first examines macroplastics present along the surface, and the second is to detect whether microplastics can be found within sea turtle nest cavities. With respect to sea turtles, extensive research has regarded macroplastics and microplastics separately, but there is a gap in the body of knowledge on how both of these plastics, together, could impact sea turtles. In prime sea turtle nesting habitats such as that of Jekyll Island, it is imperative to understand the separate and combined roles of macro- and microplastics in a prime sea turtle nesting habitat and how they may be affecting the future of this local loggerhead population.

1.1 Macroplastics

Previous research pertaining to plastics has an established classification based on size. Pieces, (produced to a specific size), or fragments, (broken off from a piece of plastic), larger than 20mm are designated as macroplastics and those smaller than 5mm are labeled microplastics (Thompson el al., 2009; Hammer et al., 2012; Romeo et al., 2015). A variety of other size classifications, such as mega- or mesoplastics, are also reported in the literature, however, macro- and microplastics are the most commonly referenced. Macroplastics alone comprise over half of all macro-sized marine debris including non-plastic forms (Derraik, 2002). They are most frequently documented in cases of wildlife ingestion, entanglement, strangulation, and methods of hitchhiking (Barnes, 2005). In addition, their plenitude, buoyancy, and resilience in long-distance travel make them potential vectors for the dispersion and distribution of numerous marine organisms (Gregory, 2009).

1.2 Microplastics

The robust densities of microplastics (smaller than 5mm) in both terrestrial and aquatic coastal environments are strongly correlated with areas of high human population densities (Oerlikon, 2009; Alomar et al., 2016). The abundance of these plastics on beaches is estimated to have tripled within the past two decades (Moore 2008), with beaches serving as sinks for microplastics (Barnes et al., 2009). Surface waters can also act as a vehicle for microplastics beach dispersal, with natural sediment erosion and accretion facilitating their integration into the sands (Barnes et al., 2019). Sources of microplastics are categorized as primary and secondary introductions (Li et al., 2016). Primary microplastics, known as "scrubbers," are distinguished by their microscopic size and are predominantly used for industrial and domestic products such as blasting media, facial cleansers and other related cosmetics (Zitko and Hanlon, 1991). These largely pose a threat to filter feeder organisms that can easily ingest plastics of this size (Fendall and Sewell, 2009). Secondary sources are fragments or shards of plastics originating from macroplastic pieces (Ryan et al., 2009; Hammer et al., 2012), or their degradation via UV-radiation and photo-oxidative processes (Ng and Obbard, 2006). The structural integrity of the larger pieces is often compromised as a result of natural weathering processes (Browne et al., 2007). Their size poses a challenge to researchers and presents difficulties in establishing a baseline standard of analysis (Imhof et al., 2012). As a result, microplastics are under researched as a form of marine debris (Doyle et al., 2011).

1.3 Plastics and Marine Environments

Almost 80% of marine debris is attributed to plastics originating from terrestrial sources, transferred to coastal and pelagic water systems (Andrady, 2011). Over the past 40 years, there has been a consistent increase in the accumulation of macro- and microplastics on beaches

(Thompson et al., 2004). Land-based sources of debris provide the largest input of plastics into marine ecosystems near densely populated areas (Hammer et al., 2012). A beach's topography, storm activity, and proximity to humans and their waste are contributing factors to the type and amount of plastics found on beaches (Storrier et al., 2007). Higher concentrations of plastic debris are often reported on more frequented beaches (Hammer et al., 2012) brought in by coastal tourism and recreational activities (Derraik, 2002). Shipping containers also act as a global contributor to marine plastics (Derraik, 2002), their contents making their way to shore via tides and winds. The most common forms detected on beaches are broken or abandoned fishing gear, pellets, scrubbers, microplastics films and flakes (Derraik, 2002). They can also accumulate indirectly via methods of fluvial transportation such as drainage systems, rivers, and wind (Corcoran et al., 2009).

Beaches provide optimal conditions for plastic fragmentation due to the natural chemical and weathering processes that occur within these systems (Corcoran et al., 2009; Li et al., 2016). Mechanical forces such as wind abrasion, wave action, and turbulence all contribute to the fragmentation of plastics (Barnes et al., 2009). However, most plastics do not mineralize, allowing them to persist as microplastics within the environment for an unknown length of time (Corcoran et al., 2009). The amount of time required for the complete degradation of plastics in marine systems is still unknown, but estimated in the hundreds to thousands of years (Andrady, 2005). This is largely due to the fact that plastics have only been in production for roughly 70 years (Li et al., 2016). In addition, beaches have a higher oxygen availability compared to aquatic environments as well as greater access to direct sunlight contributing to a faster breakdown in the physical structure of plastics (Browne et al., 2007). Photodegradation via sunlight causes oxidation within the polymer matrix resulting in the breaking of chemical bonds within the plastic (Barnes et al., 2009).

1.4 How Plastics Affect Sea Turtles

Global research has documented the ways in which marine organisms, and sea turtles, in particular, are affected by plastics within their habitats (Nelms et al., 2016; Barnes et al., 2009; Vegter et al., 2014). Concerns regarding sea turtles and plastics are often related to their ingestion and the potential they cause for entanglement (Carr, 1987; Nelms et al., 2016). Ingestion has been documented in 6 of the 7 global species of sea turtles (Ceccarelli, 2009), especially species known to be opportunistic foragers (Hardesty et al., 2012). In the ocean, plastics often occupy the same drift line habitats utilized by foraging juveniles, where they are mistaken for food sources, thus increasing their chances of consumption (Carr, 1987). Research shows that even very small pieces of plastics can be fatal to juvenile sea turtle due to their inability to be digested (Bugoni et al., 2001). At the very least, accumulation of plastics within the sea turtle's digestive tract can result in malnutrition, effecting both a turtle's buoyancy and swimming ability and making them more susceptible to predators (Nelms et al., 2016). Recent studies have also attributed plastic ingestion to the transfer of toxic chemicals through bioaccumulation (Teuten et al., 2009). As plastics progressively encroach upon spaces frequented by sea turtles, the associated negative impacts are likely to increase.

Sea turtles are long lived organisms with a complex life history and undergo ontogenic shifts in habitat use (Wyneken et al., 2013). Though they spend the vast majority of their life in the ocean, female sea turtles exhibit nesting site fidelity by return to the beach every few years to lay their eggs (Bowen and Karl, 2007). Their clutch is most often deposited on the berm of the beach above the high tide line (Hays and Speakman, 1991) into an excavated nest in depths of approximately 50cm (Grant and Beasley, 1996). Marine turtles, like other egg-laying organisms, select and rely on optimal nesting sand quality characteristics to increase the success of their offspring (Wood and Bjorndal, 2000). Yet, research on a local scale by Kelly et al. (2017) has demonstrated no statistical difference in nesting site selection by sea turtles in urbanized versus natural environments. However, with nesting occurring in both natural and urban environments, the quality of the sediment in urban areas, which tends to carry a larger human footprint, is of concern. Microplastics have been demonstrated in previous research to be in the highest densities on the top centimeters of beach sand, but capable of reaching depths of 60cm in sea turtles nests (Duncan et al., 2018). Concentrations of microplastics within beach sand sediment have been shown to alter porosity and permeability of the sand which could result in temperature fluctuations within the nest cavity (Nelms et al., 2016). This could directly impact sea turtles, whose offspring are temperature sex-dependent, and, with cooler temperatures in the nest, result in more male hatchlings (Godfrey and Mrosovsky, 1997). Thus, high aggregations of plastics changing the microenvironment, could be contributing to skewed sex ratios, prolonged incubation periods and even egg desiccation (Carson et al., 2001; Cooper and Corcoran 2010; Nelms et al., 2016).

1.5 Plastic Debris on Jekyll Island

Nesting beaches, an integral part of the sea turtle life cycle, are already under threat from development and erosion, and plastics may be contributing to this degradation as they accumulate on shorelines (Nelms et al., 2016). The amount of human traffic on Jekyll Island, a southeastern barrier island off of Georgia’s coast, may be a contributing source of plastic debris through improperly discarded trash from beachgoers to the flotsam of plastics washing upon the shore. Beach cleanups are facilitated by organizational groups on the island, as well as conducted by beachcombers and locals alike (Martin, 2013). As an outreach program, the Georgia Sea Turtle Center (GSTC) hosts monthly beach cleanups to reduce the amount of surface debris. Data recorded by citizen scientists using the Marine Debris Tracker App (MDT) created by the University of Georgia in collaboration with the National Oceanic and Atmospheric Administration's Marine Debris Program (Jambeck and Johnsen, 2015), from cleanup efforts over a one-year period indicate that plastics make up 89% of marine debris removed along Jekyll Island's coastline (Martin, 2013). These cleanups have a positive impact on the area in lowering the number of possible encounter of sea turtles with plastics (Martin et al., 2019).

1.6 Jekyll Island's Sea Turtles

Jekyll Island has numerous ecologically significant habitats including a sea turtle nesting beach (Norton, 2005). Several species of sea turtles nest on the island; loggerheads (*Caretta caretta*), green turtles (*Chelonia mydas*), and leatherbacks (*Dermochelys coriacea),* all of which are currently protected under the Endangered Species Act (Endangered Species Act, 1973). Returning every 2 to 3 years, loggerhead sea turtles *(Caretta caretta)*, nest the most frequently and in the highest densities on the island (Ondich and Andrews, 2013; Norton, 2005). The International Union for Conservation of Nature's Red List classifies loggerheads as *Vulnerable*; attributing to factors such as human development and marine debris (Tisdell and Wilson, 2005). Loggerhead nests on Jekyll Island are most threatened by inundation, predation, and coastal development, which also threaten hatchlings entering the ocean (Norton, 2005). Jekyll Island has been acknowledged as a loggerhead rookery since the 1930s, with consistent monitoring of the species beginning in the 1970s (Ondich and Andrews, 2013). The hatching success of nests was not continuously documented until 1997 when daily monitoring was implemented. In 2007, the Georgia Sea Turtle Center opened on the island, as a rehabilitation center for injured and sick turtles and the state of the art facility now oversees the sea turtle monitoring and research projects (Norton, 2005).

Sea turtle nesting on the island not only holds intrinsic value but also are an economic driver serving as a charismatic species that attracts over 1,000,000 annual tourists, benefiting the islands' economies and broadening their exposure to the public (Martin, 2013). The tourism-based economy of the island (Ondich and Andrews, 2013) has resulted in much of the coastline having been developed to cater to this industry. Included in this urbanization has been beach armoring, in the form of sea walls, which limits available nesting sites for sea turtles (Dodd and Mackinoon, 2008; Martin et al., 2019). Though nesting predominantly occurs at night with little human interactions, these man-made infrastructures are possible barriers to nesting female sea turtles (Witherington et al., 2011). To maintain and ensure the future integrity of its natural habitats however, Georgia law stipulates that 65% of Jekyll Island must remain undeveloped (O.C.G.A. §12-3-241). This research is intended to provide insight as to the quality of these beaches for nesting sea turtles and aid in the facilitation of the continued protection of this significant habitat.

1.7 Research Objectives

The majority of sea turtle research regarding plastic debris focuses upon on either macro- or microplastics, but few address both. To ensure the continued success of this nesting area, it is critical to examine the presence of macro- and microplastics in these settings and the role they may play as a potential influence on affecting sea turtle nesting habitats. The intent behind this research is to determine the presence of macro- and microplastics on Jekyll Island and how they may be contributing to the sediment quality and how, in turn, this can affect loggerheads utilizing the nesting habitat. The study will establish an approximate snapshot of surface macroplastics as well as microplastics within the sediment. Upon detecting the presence of macroplastics, the data will be examined in the context of how they relate in time and space to loggerhead nesting activity densities. Microplastics will be examined in regard to their quantity and distribution along the coastline. This approach could then allow for potentially at-risk regions to be identified, given new knowledge of areas with possibly depreciated nesting sediment quality that might negatively impact nesting microenvironments and hatchling development into the future. Areas of high plastic debris will be identified and compared to historic trends of nesting densities as well as the success of offspring development and emergence from the nest. Other possible influencing environmental factors that may contribute to nesting activities will be examined as well. Understanding these factors can help to construct how sea turtles utilize space along the island's coast and how that may be impacted in the future.

Research Question:

What, if any, are the relationships between patterns of distribution in macroplastics, microplastics, and loggerhead nesting success along the coast of Jekyll Island across time and space?

Objective 1: What is the abundance and type of surface macroplastics, along the coast of the island?

a. What are patterns of distribution in macroplastics during the 2018 loggerhead nesting season and along the beach?
b. Using GIS and spatial analyses, where, if any, are the hot spots for macroplastics along the beach?

Objective 2: Is there a presence of microplastics within the sediments of loggerhead egg chamber cavities?

a. If present, what are the quantity and types of microplastics detected within the nests?
b. Using GIS and spatial analysis, in what concentrations are they distributed along the coastline?

Objective 3: What, if any, are existing trends in nesting activity abundance, hatching, and emerging success for loggerheads on Jekyll Island?

a. By examining historical data for the last 11 years, what, if any, are the existing trends?
b. Through the use of GIS and spatial analysis, what is the spatial distribution of these variables along the beach?

Objective 4: What additional environmental factors may be contributing to patterns of distribution in nesting activity?

a. Using historic data and field observations, how do these factors vary over space and time?
b. How might these factors influence patterns of nesting activity over time?

2 STUDY REGION: JEKYLL ISLAND, GA

A part of Glynn County, Jekyll Island is one of 11 barrier islands located off the southeastern corner of the state of Georgia. Together, these islands protect the mainland against powerful storms, and their dynamic nature causing annual fluctuations in the state's shoreline.

These fluctuations result in sediment erosion and accretion (Schoettle, 1987), with sediments being transported from north to south by net longshore currents (Hails and Hoyt, 1969). Located near the head of the Georgia Bight, the island is 15.5km in length, the widest span of the island is approximately 3.5 km, with an area of 23.88km^2 (Yang et al., 2012). Previous research by Meyer (2016) details the topography on Jekyll Island ranging from a high of 45.2 ft msl centralized in the northern interior region of the island, with the coastline having a low of -2.3 ft msl (Figure 2.1). The elevation and frequency of tidal events facilitate a rich vegetative diversity along Jekyll's beaches and dunes (Jekyll Island Conservation Plan, 2011).

Jekyll Island's Atlantic coastline is a geographically significant sea turtle nesting beach with the coastline acting as a nesting habitat. To aid their sea turtle monitoring efforts, GSTC installed physical land makers at every kilometer along the vegetation line of the coast, with kilometer 0 being the northern-most point, to kilometer 14 at the curve of the southern edge of the island. Kilometers 1 through 2 comprise Driftwood Beach, an exposed boneyard of trees, which acts as a popular tourist spot. Following Hurricane Dora in 1964, a rock wall revetment was constructed in kilometers 3-5 in effort to reduce shoreline erosion (Jekyll Island Conservation Plan, 2011). The presence of this retaining wall, composed of granite boulders, negatively impacts the sea turtle nesting grounds, by reducing the available habitat on the island by 30% (Ondich and Andrews, 2013). Given their inability to absorb or disperse wave action, rock walls may exacerbate beach erosion, impacting interdunal swales utilized by sea turtles as nesting grounds (Jekyll Island Conservation Plan, 2011). The majority of coastal development spans from kilometers 3 through 9, to include private residences, beachside hotels and a shopping district. The southern end of the island in kilometers 12 and 13 are sports fields and a seasonal camp for children. The curved southern point facing back to the mainland in kilometer

14 is the site of the St. Andrews Picnic area that is another popular tourist site. These locations have direct access to the beach. This urbanization has resulted in various threats and stresses to Jekyll Island ranging from habitat fragmentation and edge effects, the alteration of sand movements, and the modification of wildlife diversity and movement across the island (Jekyll Island Conservation Plan, 2011).

Figure 2.1 Jekyll Island LiDAR Topography (Meyer 2016)

Following its acquisition by the state in 1947, the vegetation and dunes on Jekyll Island were rapidly leveled to allow for tourist attractions and lodgings (Caldwell, 1962), but after it was brought under the management of the Jekyll Island State Park Authority, it was mandated in 1971 that 65% of the island would be maintained as a natural environment (Ondich and Andrews, 2013). Yet, the tourism boom of the 1950s and 1960s had previously already developed a large portion of the island's coastline (Ondich and Andrews, 2013), restricting conservation efforts to the interior of the island. Balancing this growth in tourism while preserving the cultural and natural resources of the island is a prominent issue for Jekyll Island State Park officials, who oversee the island's resources (Yang et al., 2012). Land use on the island has been assessed in the Jekyll Island Conservation Plan (Figure 2.2), examining 5,847 acres of land, of which 1,099 acres is designated as urban and park lands (AECOM, 2011). This is approximately 27% of the total land on the island, a large portion of which is parallel to the Atlantic coastline (Jekyll Island Conservation Plan, 2011). The beach covers roughly 475 acres, the majority of which is accessible to the public. The decades of development and redevelopment on the island directly impact the island's wildlife through loss and fragmentation of habitat and indirectly from sources such as light and sound pollution (Jekyll Island Conservation Plan, 2011).

Jekyll Island is only one of four barrier islands in the state that is accessible to the public by vehicle (Martin et al., 2019) allowing for an influx of upwards of 1,000,000 tourists per year (Jekyll Island Authority Annual Report, 2015). The island is under state operation, but the economy is entirely founded on tourism without financial subsidies (Ondich and Andrews, 2013). With the growth of coastal tourism, so have its impacts on sea turtles (Norton, 2005). Citizen collected data from beach cleanups, conducted on Jekyll Island, indicate that debris was documented along the entire coast of the island (Martin et al., 2019). The majority of this debris was plastics, with the most prominent form being cigarette products, constituting nearly half of all plastics recorded (Martin, 2013; Martin et al., 2019). This extensive recovery of plastics and its overlap with areas of sea turtle nesting is of particular concern (Martin et al., 2019).

Figure 2.2 Land Use Assessment from the 2011 Jekyll Island Conservation Plan

3 METHODS

3.1 Macroplastic Sampling

Over the 2018 loggerhead nesting season on Jekyll Island, two beach transects occurred, one in June (12-13 June 2018) and a second in mid-August (12-13 August 2018). These sampling periods are to loosely reflect the loggerhead nesting season spanning June through the end of August. For precision, sampling efforts were conducted at the same time of day. These dates were chosen to establish an approximate amount of macroplastic debris that may be encountered by loggerheads on the beach sand surface. This allows for a census of macroplastic debris that comprised the beginning and end of the nesting season. It is worth noting that this period also overlaps with the height of the tourism season on the island, which would likely contribute a higher amount of improperly disposed trash, including plastics.

The 15 km coastline was pre-designated by the Georgia Sea Turtle Center with physical markers at every 1 km increment for use in tracking sea turtle nesting. To assess the density of macroplastics a beach transect was conducted along the shoreline at 0.5 km increments. The increment distances were designated at 0.5 km rather than 1.0 km to provide a more detailed assessment of macroplastic debris. Prior to the field data collection, the GPS locations for every 0.5 kilometers were delineated using Google Earth Pro. Each half kilometer point was derived by calculating the midpoint between the physical kilometer markers with GPS points provided by GSTC. This allowed for the beach transect quadrat analysis to be conducted at every 0.5 km along the beach (Figure 3.1). A quadrat (100cm x 100cm) was constructed of Polyvinyl Chloride (PVC) pipe with four 2-way connecting corner pieces, and nylon string creating the grid. At each sample site, the quadrat was manually placed at the wrack line along the shore. This area is consistent with the beginning of the berm on the beach, the primary area of beach where loggerhead nesting occurs. All inorganic debris within the quadrat was recorded to include quantity and type. To supplement transect data collected using the quadrat, any visually observed debris spanning from the dune vegetation to the shoreline (plastic and non-plastic alike) was personally cataloged using the Marine Debris Tracker as well. This app catalogues debris data and is used by researchers and citizen scientists alike (Jambeck and Johnsen, 2015). This additional survey approach was done in order to supplement the transect data collected by quadrat to provide a more encompassing view of debris along the coast of the island. The complete length of the beach was surveyed on foot to ensure continuous coverage of the beach during the census for both data collection efforts.

3.2 Beach Characteristics

At each 0.5 km of the transect data collection approach, additional data were collected regarding physical characteristics of the beach. The beach width from the morning's high tide line to the vegetation line was recorded to determine an approximate available area for sea turtle nesting. Anthropogenic data were collected regarding proximity to public crossovers, presence of beach armoring and whether or not trash and recycling receptacles were present at crossovers and public access points. Segments of the beach were under active construction at the time, predominantly in kilometer zone 3 and 4, restricting access to the public.

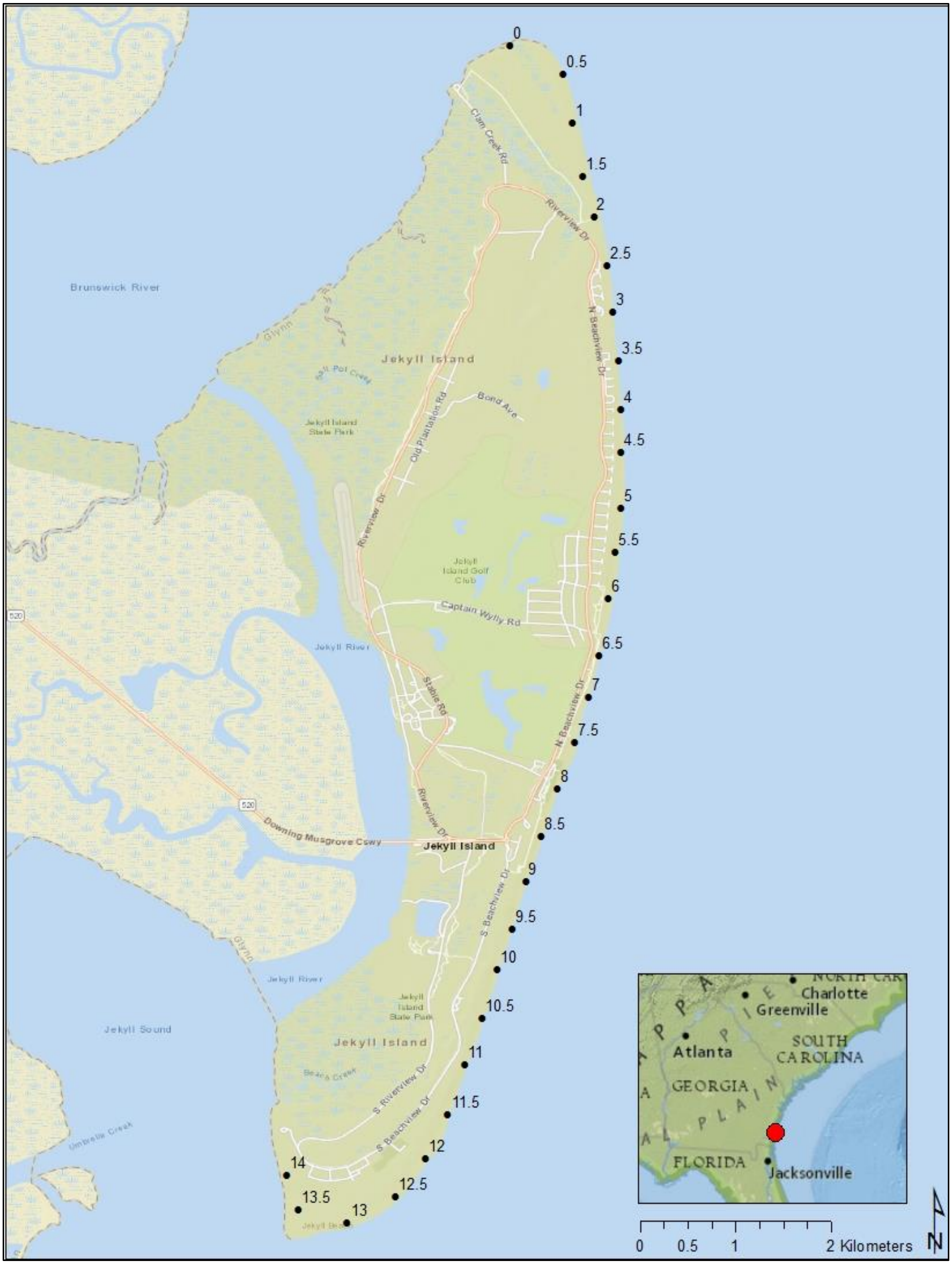


Figure 3.2 Half Kilometer Segment Markers on Jekyll Island

3.3 Sediment Sampling for Microplastics

The GSTC field research team retrieved sediment samples from within the nest cavity of loggerhead nests at the time of inventory. An inventory of nest contents is defined as an excavation of the nest either post-emergence of the hatchling or upon completion of the incubation period and involves the counting and assessing of all eggs within the nest cavity. Given permitting restrictions, only members of the GSTC research team were allowed to remove the sand samples. Due to the somewhat unpredictability of where nests are laid, a minimum of two nests were sampled per kilometer. This approach provided an encompassing view of the sediments from nest cavities across the 15 km study site. The amount of sand retrieved from the nest was ~500g of sediment, approximated using a sand bucket marking the estimated amount. Sand was retrieved post-inventory from the bottom and inside walls of the nest. It should be noted that under dry conditions, sand from the surface or upper walls may fall to the inside bottom of the nest. Samples were manually retrieved and placed within a 1-gallon Zip-lock™ bag and labeled with nest ID numbers. The ID numbers correspond to data collected by the GSTC when the loggerhead was first encountered at the time of nesting. A total of 56 sand sediments were collected by GSTC, with a minimum of two samples per 1 km zone of the beach. For the 2018 nesting year, several kilometers received no nesting events (km 3-6); no samples were retrieved in these zones. One sample was randomly selected for each kilometer stretch for further analysis to determine the presence and abundance of microplastics.

3.4 Laboratory Methods

Previous research has developed and tested methods of extracting microplastics from coastal sediments. The most commonly implemented method is via a separation density solution (Thompson et al., 2004; Reddy et al., 2006; Claessens et al., 2013). A saturated salt solution

(NaCl) is frequently utilized as a cost-effective extraction solution, as tested by Claessens et al. (2013) but results in a lower yield of microplastics. The same study recorded a higher yield from extractions utilizing a NaI solution; however, the solution requires multiple repeat extractions to obtain the higher overall yield (Claessens et al., 2013). $ZnCl_2$ is more costly but has been proven to yield a high quantity of plastics without the need for repeated extractions (Imhof et al., 2012; Coppock et al., 2017). This research follows the laboratory methods from Coppock et al. (2017), as their study tested the efficiency of several flotation media to determine the high recovery rate of using $ZnCl_2$ at 95.8% after just one extraction.

3.4.1 Sample Drying and Splitting

From the samples retrieved, the wet weight of each sample was recorded. All 56 collected samples were dried at 60°C for 48 hours in a VWR 1340 hot air dryer, after which the dry weight was recorded. For consistency across samples, each sample was weighted to an exact 500g of dry weight. Samples were then passed through a metal 5mm sieve to remove all large debris, plastic and non-plastic alike. Any debris recovered was identified, recorded, and bagged. To ensure standardization in comparing sediment samples from each nest, a splitting method was followed to split each replicate into batches, each weighing approximately 50g. Weight values were recorded, and samples assigned a letter ID of A, B, C, D or E; respectively.

Time and funding limitations prevented further processing of all samples, therefore one nest sample was randomly selected for analysis per kilometer zone where nesting occurred during the 2018 nesting season, for a total of 11 nests. Three of the 11 nests underwent microplastic extractions for 3 subsamples (subsamples A, B, and C). This initial step was to examine variability in the detection of microplastics within a nest. The remaining 8 (out of 11 total) nests only had one subsample (Subsample A) processed for microplastics. This single subsample per nest was randomly selected to be analyzed after determining similarities in the number and types of microplastics observed between subsamples after extractions done on the initial 3 nests. In addition, $ZnCl_2$ availability limited the number of subsamples that could be processed, thereby necessitating that only a single subsample be analyzed from sediments retrieved for the remaining 8 nests.

3.4.2 $ZnCl_2$ Solution Preparation

To prepare the $ZnCl_2$ solution, 972g of $ZnCl_2$ was added to 1L of Ultrapure water in a 3L glass beaker. The $ZnCl_2$ weight was determined by Coppock et al. (2017) as the recommended amount to extract microplastics from the sediment samples with a weight range of 30-50g. The mixture was gently stirred using a glass stirring rod until the salt had completely dissolved into solution.

3.4.3 Construction of the Sediment-Microplastic Isolation Column

Following the schematics of Coppock et al. (2017), a Sediment-Microplastic Isolation (SMI) unit was constructed using clear PVC piping and a ball valve that was fastened onto a PVC plate to provide support. This unit allowed for the sediment and $ZnCl_2$ solution to be contained while potential plastic debris floated to the meniscus of the solution. The valve then cut off the top layer of debris in solution from the sediment so that it could be easily poured off. A portion of the solution was then used to rinse the SMI unit, ensuring to open and close the valve several times.

3.4.4 Microplastic Extraction Procedure

For subsamples analyzed for microplastics, the following procedure was used: Per sediment subsample, 700mL of salt solution was poured into a beaker with a magnetic stir bar cleaned and rinsed in ultra-pure water. The 50g sediment subsample was then added and the mixture placed on a magnetic stirring plate for five minutes at 700 RPM. The rotation per minute speed was visually determined as the speed in which all sediment was actively being stirred within the beaker, an adjustment made based on the recommended speed of 600RPM as standardized by Besley et al. (2017). After the allocated time, three short bursts were performed to remove any potential air bubbles. The mixture was then completely poured into the SMI unit and set aside to settle for five minutes or until clear of sediment at which point the valve was manually closed. The supernatant was poured off into a 100mL beaker and then passed through a 45mm 2µm Whatman filter paper using vacuum filtration. The filter paper was then removed and transferred to a Petri Dish, sealed, and encased in Parafilm. The entire batch of the solution was itself filtered three times to remove any remaining sediments and possible sources of contamination. The solution can be used three times before considered exhausted (Coppock et al., 2017) and the waste then properly discarded.

3.4.5 Identifying Microplastics

The residue on the filter paper from each extraction was examined under a microscope (Fisher Stereomaster 12-562-2) to visually determine presence and quantity of plastics. To identify the various forms of plastics, the examination methodology used follows that of the Marine & Environmental Research Institute’s Guide to Microplastic Identification (2015). Quantitative data were collected in counting all microplastics detected on the filter paper. Qualitative data were collected to include the general type, shape, and color of each plastic detected. Types were categorized as filaments, round and angular fragments, and an additional category for miscellaneous shapes. To eliminate bias, no location information or any other attributes were looked at for each of the nest IDs during the entirety of the extraction and microplastic identification process.

3.5 Spatial Analysis

To better comprehend and assess loggerhead nesting, long-term data were provided by GSTC to detect any trends over the past decade from 2008 to 2018. The data analyzed are summarized in Table 1. ESRI ArcMap 10.6® was used to visually explore, analyze, and display the collected data. Implementing maps can easily identify trends along the island while also identifying potential at-risk areas for stretches of beach that are more inundated with plastics in comparison to other sections. The software allows for the overlapping of nesting activity data with debris data to identify possible at-risk areas. Both nesting activity and environmental factors underwent spatial analysis through the software to visually display hot spots of occurrence. Using ArcMap, Kernel Density, a form of spatial analysis, was performed on various attributes pertaining to loggerhead nesting. Under this analysis, the data were categorized using a quantile classification. This method identifies the hot spots based on the clustering of data points for such events such as nesting and false crawls. The resulting map visually identifies where the highest densities of points located along the coast of the island. Other nesting factors were examined that could factor into the nesting habitat quality of the loggerhead nests. These variables include relocated nests and the number of incubation days per laid nest. Relocated nests are nests that are deemed by GSTC to have a high probability of fatalities due to environmental factors such as constant seawater inundation, depredation, heavy foot traffic, and escarpment (Grand and Beissinger, 1997; Ware and Fuentes, 2018). Determining any spatial or temporal variations in relocation and incubation can help identify areas or times where any abnormalities may have occurred during the study period. Areas of consistent nest relocation could indicate a pre-existing at risk area for sea turtle nesting due to surrounding environmental factors. Distinguishing spans of beach or times where abnormally high or low incubation days occurred could result in affecting the hatching success of the nest, and indicate an existing area of reduced nesting habitat quality. It is important to identify these areas and how they may overlap or be further impacted by areas of high plastic concentrations.

Data collected from macro- and microplastic debris were also plotted within ArcMap. Macroplastic debris was plotted based on GPS coordinates at the observed on-site location to visually display quantity along the coastline. Microplastics were mapped using a graduated symbology. Using this symbology, the larger the quantity of microplastics observed, the larger the assigned symbol appears on the map.

Table 1: Data Utilized in Spatial Analyses

	Data Used	**Analysis Used**
Historic Data (2008-2018)	Nesting	Kernel Density Analysis
	False Crawls	Kernel Density Analysis
	Relocated Nests	Kernel Density Analysis
	Incubation Period	Kernel Density Analysis
2018 Data	Nesting	Kernel Density Analysis
	False Crawls	Kernel Density Analysis
	Beach Profile	Kernel Density Analysis
	Macroplastics	Point Location
	Microplastics	Graduated Symbology

3.6 Nest Success

Two success rates were calculated and examined to demonstrate possible variations across time and space. Hatching success is defined as the relative percentage of eggs in a nest that produced live hatchlings (Miller, 1999). The rate was calculated using the following:

$$\text{Hatching Success} = \frac{\text{Eggshells} >50\% \text{ [i.e. Hatched])}}{\text{(Unhatched eggs + Eggshells} >50\%)}$$

Emerging success was also included and is defined as the relative number of eggs in a clutch that produced live hatchlings that leave the nest chamber (Miller, 1999). The emergence success rate is calculated using the following:

$$\text{Emergence Success} = \frac{\text{Eggshells} >50\% - (\text{\# Dead hatchlings in nest + \# Live hatchlings in nest})}{\text{(Unhatched eggs + Eggshells} >50\%)}$$

Both of these rates were averaged across each year from 2008 to 2018. Average and median percentages for the success of nests for each year were calculated. To determine any difference in success along the coast of the island average and median percentages were also calculated for each of the 15 km zones.

4 RESULTS

Plastics, both macro and micro, were detected during the census walk and during microplastic extractions, respectively. During the beach transects, a total of 18 pieces of plastic macro-debris were recorded during the transect over the two sampling periods of June and August. Macroplastics were predominantly plastic fragments and cigarette butts. The fragments likely washed up on the shore or broke down over time on the beach, while the cigarette butts were most likely improperly discarded debris from beachgoers. Because sampling of macroplastics along the beach was only done using a quadrat at half kilometer increments, it was important to utilize data personally collected using the Marine Debris Tracker (MDT) app that spanned the complete length of the coastline. From the supplemental data catalogued in the app, cigarette butts were again recorded as the highest density detected during the sampling effort

(29.7%), and 225 debris items were documented overall. This is in line with citizen scientist sourced data for debris catalogued using the MDT app from 2012-2017, where cigarettes comprised approximately half of all plastic debris registered (Martin et al., 2019). The microplastic extractions performed on 11 nest sediment samples yielded 10 positive for microplastics. The range of detection spanned from 0 to 7 individual pieces of microplastics detected per sediment subsample.

To provide context for these results, a map was constructed of the island's prominent natural and man-made features along the beach to include crossovers and access points that are accessible to the public (Figure 4.1 Man-Made and Natural Features Along the Coast of Jekyll Island. The construction of this map provides a basis to explore trends of nesting and false crawl events over the 11 years of examined historic data along with the data collected during this research pertaining to macro- and microplastic debris collected in 2018. This summary map of natural and man-made features can aid in the interpretation of the four objectives of this research as well by providing an understanding for the environmental features of the island, and how they may possibly contribute to the presence and aggregation of plastics as well as trends in nesting activities over time. It is important to examine if there is a possible relationship between these features and how, into the future, if they may impact the sediments where loggerhead nesting is most abundant, as well as overall sea turtle nesting activities.

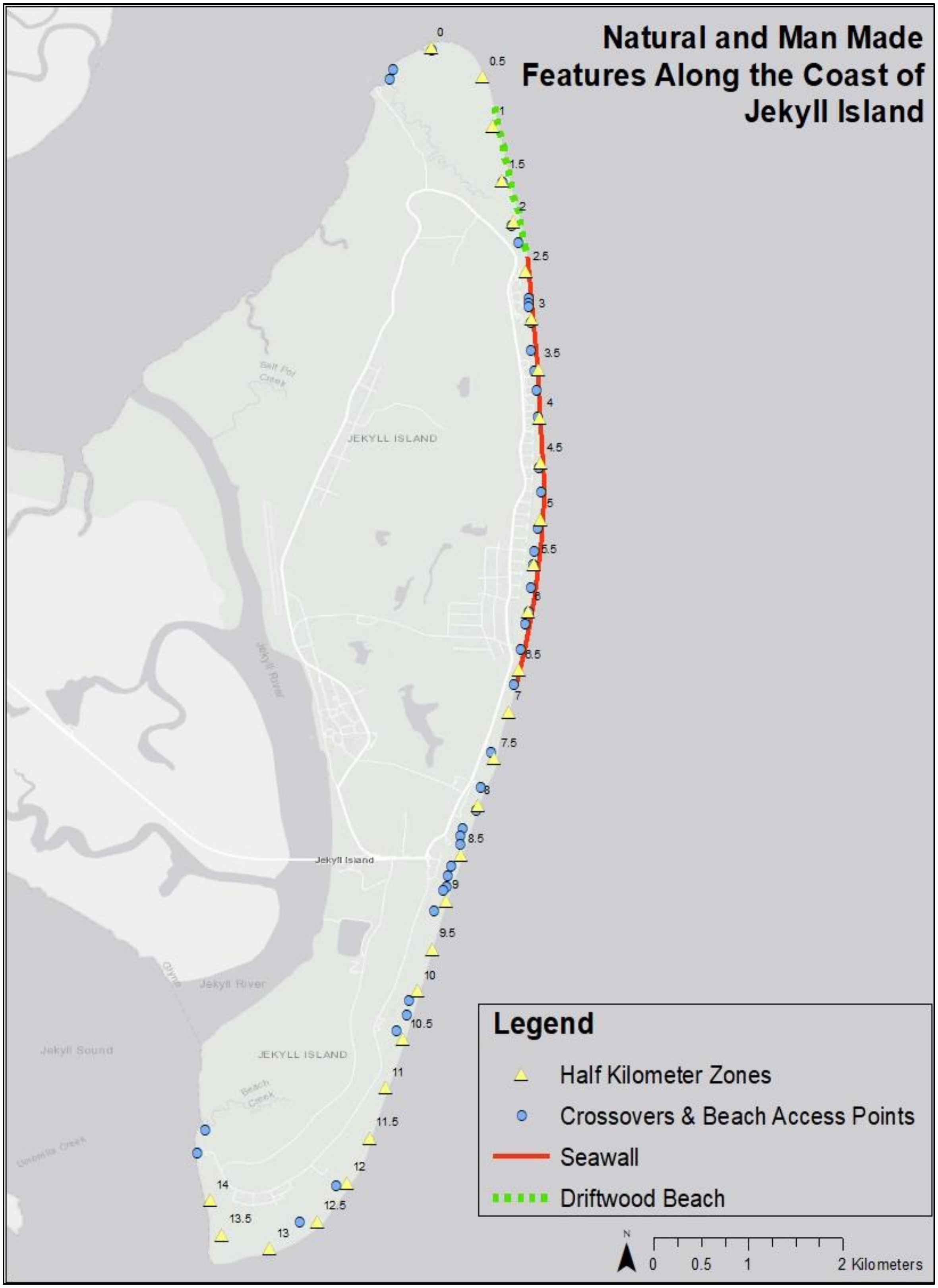


Figure 4.1 Man-Made and Natural Features Along the Coast of Jekyll Island

4.1 Macroplastics

The first objective of this research was to conduct transects along the beach surface to establish a census for the location and quantity of macroplastics on Jekyll Island. Over the two transect periods for June and August of 2018, a total of 18 pieces of macroplastics were detected on the sediment surface: 10 in June and 8 in August. In June, the most abundant form of plastic present within the quadrat was cigarette butts (Figure 4.2). During the second transect in August (Figure 4.3), plastic fragments were the highest observed. Cigarettes and plastic bottles were the second highest record in August. Given the low detections recorded during the half-kilometer transect data collection using a quadrat, data entered into the Marine Debris Tracker was used to provide a broader reflection of surface macroplastics during times of sampling. The personally collected data recorded during both sampling periods and entered into the MDT app yielded 110 pieces of plastics in June, and 115 pieces in August. Like the macroplastics noted during transect efforts, the MDT data were also categorized both quantitatively and qualitatively (Figure 4.4 & Figure 4.5). Over both sampling periods, cigarettes butts were the most prevalent comprising 27% and 32% respectively for June and August of all plastic debris catalogued. Plastic foam or fragments, food wrappers, and bags each comprised roughly 10-15% of plastics detected per sampling effort. Frequency of beach cleanup activity and events likely contribute to the low count of plastics observed during the census efforts.

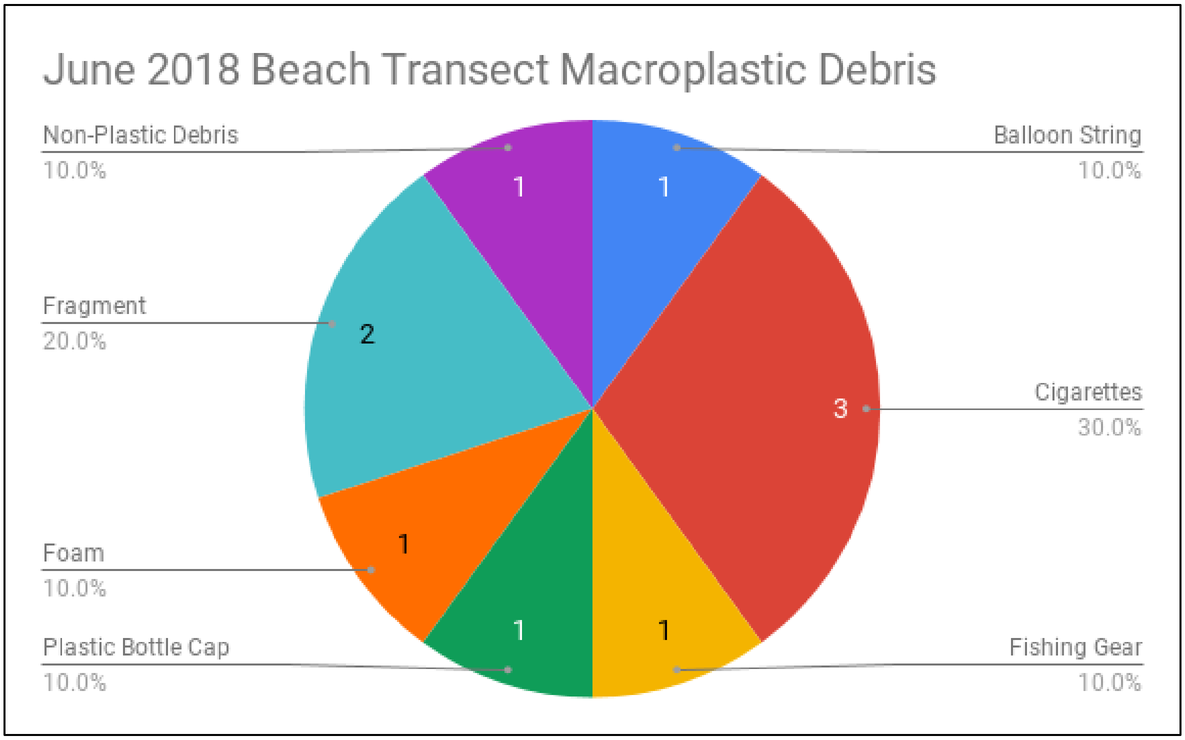


Figure 4.2 Macroplastics Detected from the Beach Transect in the June 2018 Sampling Period.

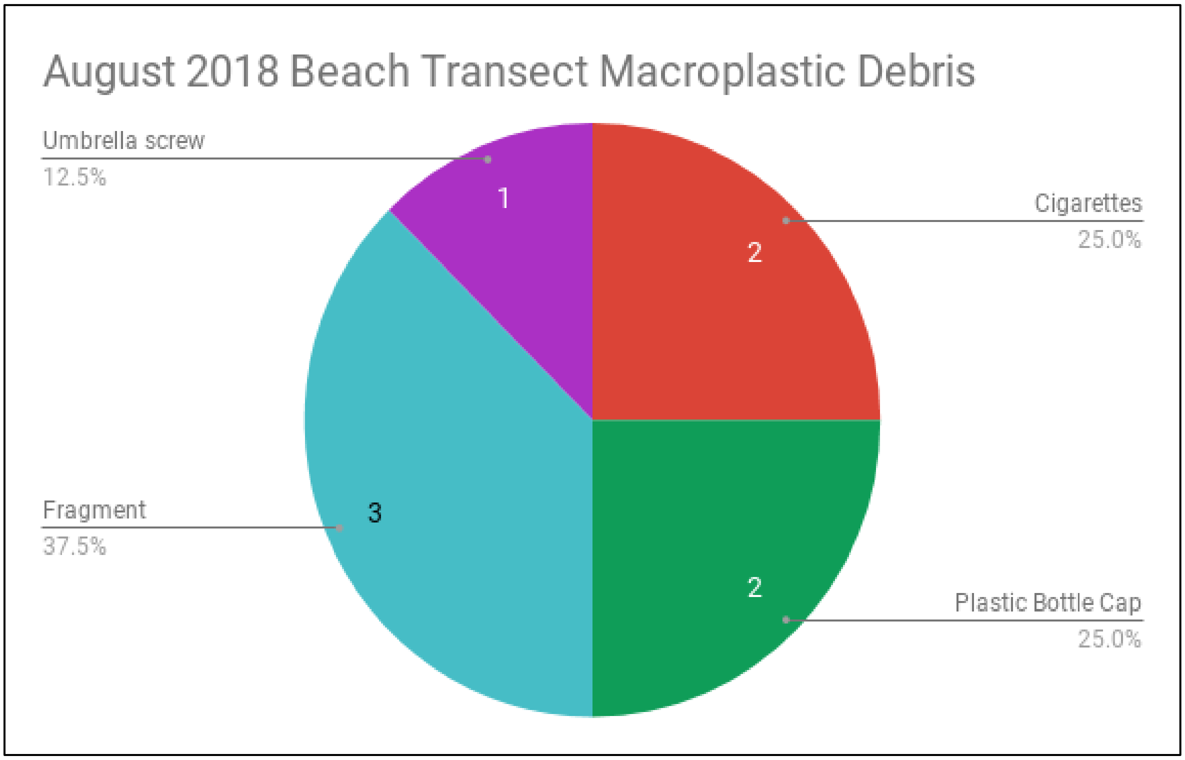


Figure 4.3 Macroplastics Detected from the Beach Transect in the August 2018 Sampling Period.

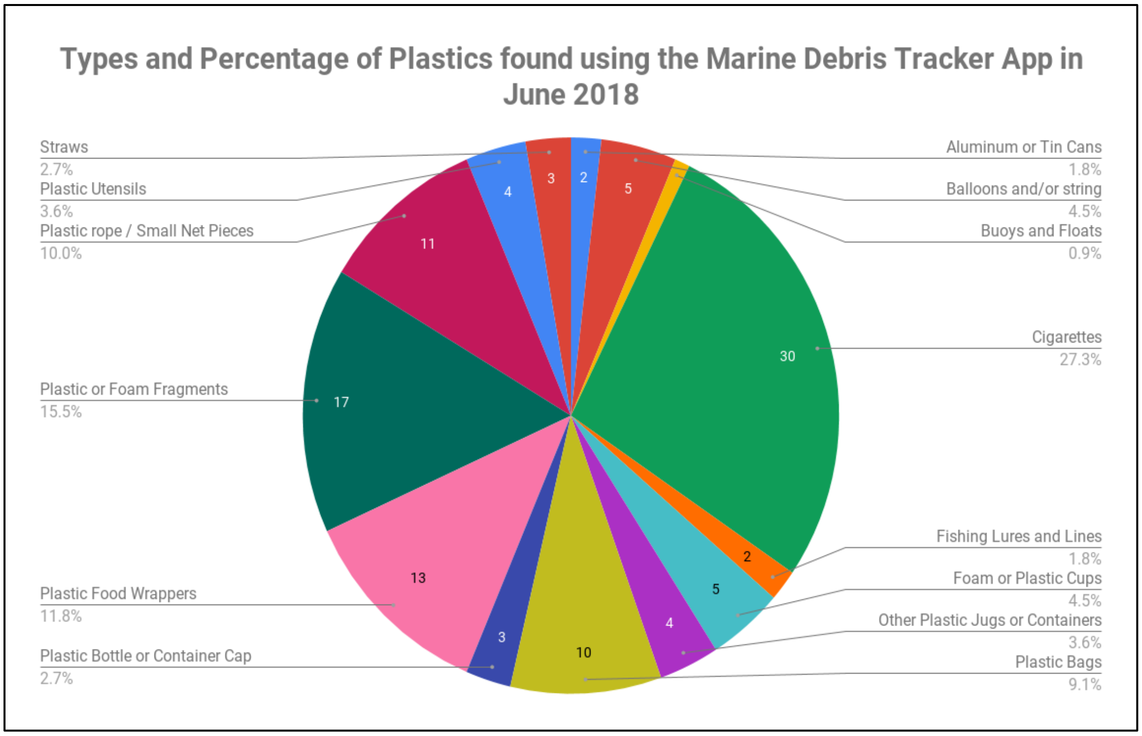


Figure 4.4 Macroplastics Catalogued Using the Marine Debris Tracker App in June 2018 Sampling Period.

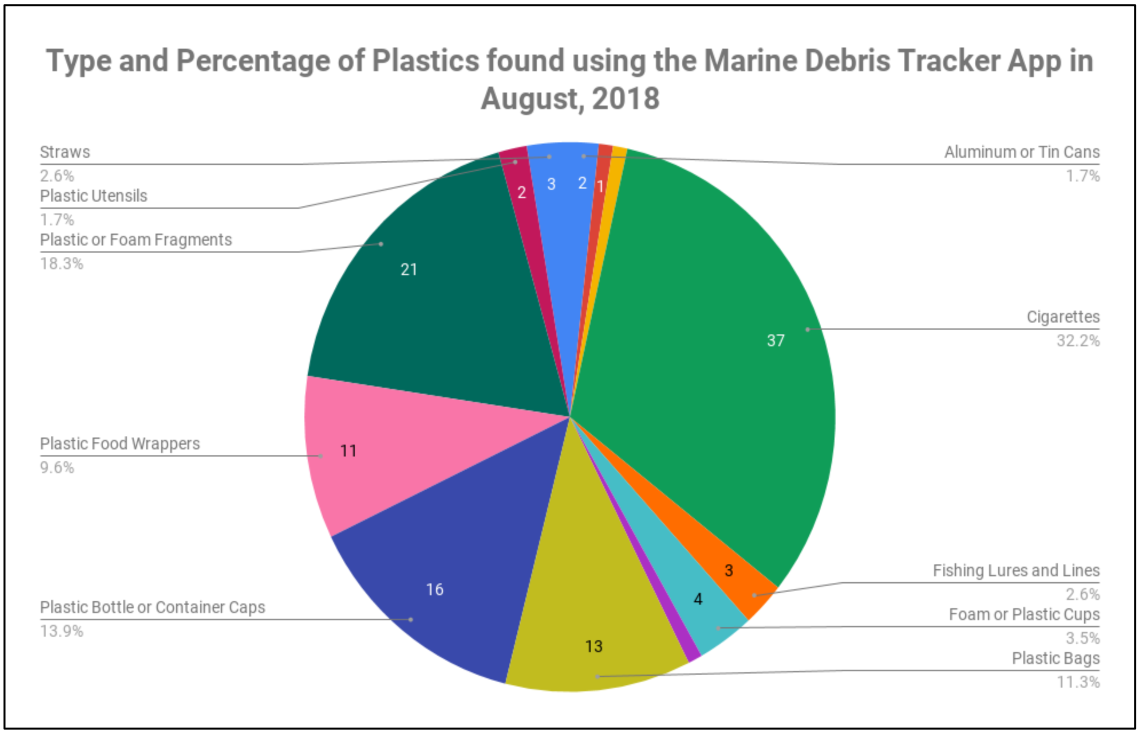


Figure 4.5 Macroplastics Catalogued Using the Marine Debris Tracker App in August 2018 Sampling Period.

For both June and August, the supplemented MDT data were overlaid with nesting activity (nests and false crawl events) from the 2018 sea turtle nesting season. This data set was selected for spatial analysis over the transect data as it was more robust and comprehensive with 110 and 115 pieces of plastic debris recorded respectively for June and August sampling periods. During 2018, nests and false crawls occurred across the span of Jekyll Island's coast with the exception of kilometers 3-6 for nesting and the stretch of beach where the rock wall is located (kilometers 3-5) for false crawls. A Kernel Density analysis conducted on the MDT data for each collection period determined the hot spot areas for plastic debris. In June, the peak zones of observed plastic debris were zones 2, 6, 9 and 14 (Figure 4.6). These peak debris zones overlapped with areas of both nesting and false crawl events during 2018 with the exception of the highest concentration of plastics on the far edge of kilometer 14, where the island faces the mainland and where little to no nesting activity was observed. This portion of the Jekyll Island, St. Andrews Picnic Area, is featured by a historic marker and is a frequently visited picnic area by locals and tourists alike (personal observation). In comparison to the 4 hot spots identified during the June collection period, 2 hot spots were identified in August, located in zones 8-10 and kilometer 2 (Figure 4.7). Minimal plastic debris was detected using the MDT app in the zonal span of the sea wall (2.5-7.0 km). At the time of the study in both June and August, the northern portion of the sea wall was an active construction site which restricted the feasibility of access to the public.

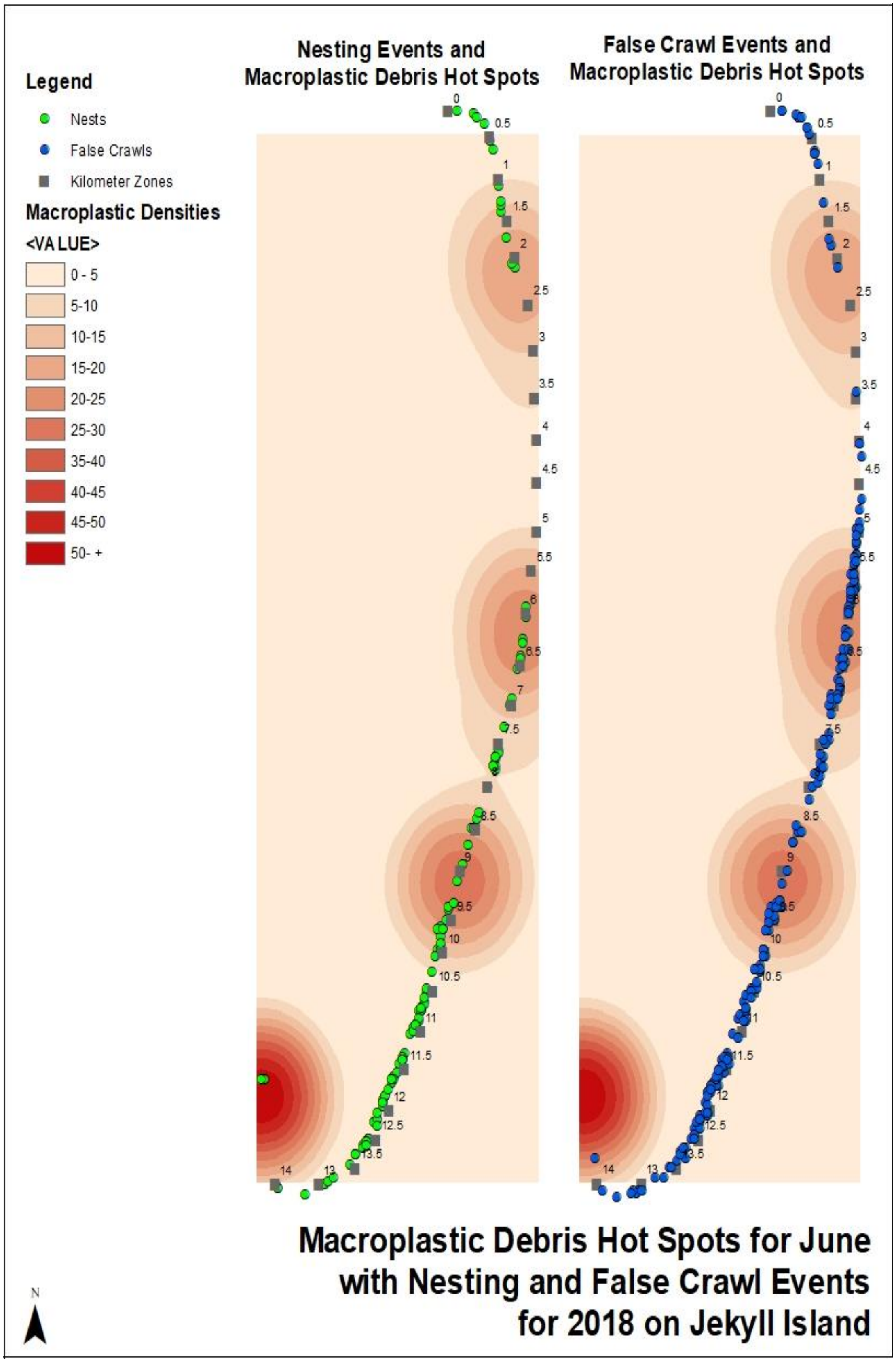


Figure 4.6 Macroplastic Debris in June for Marine Debris Tracker Data

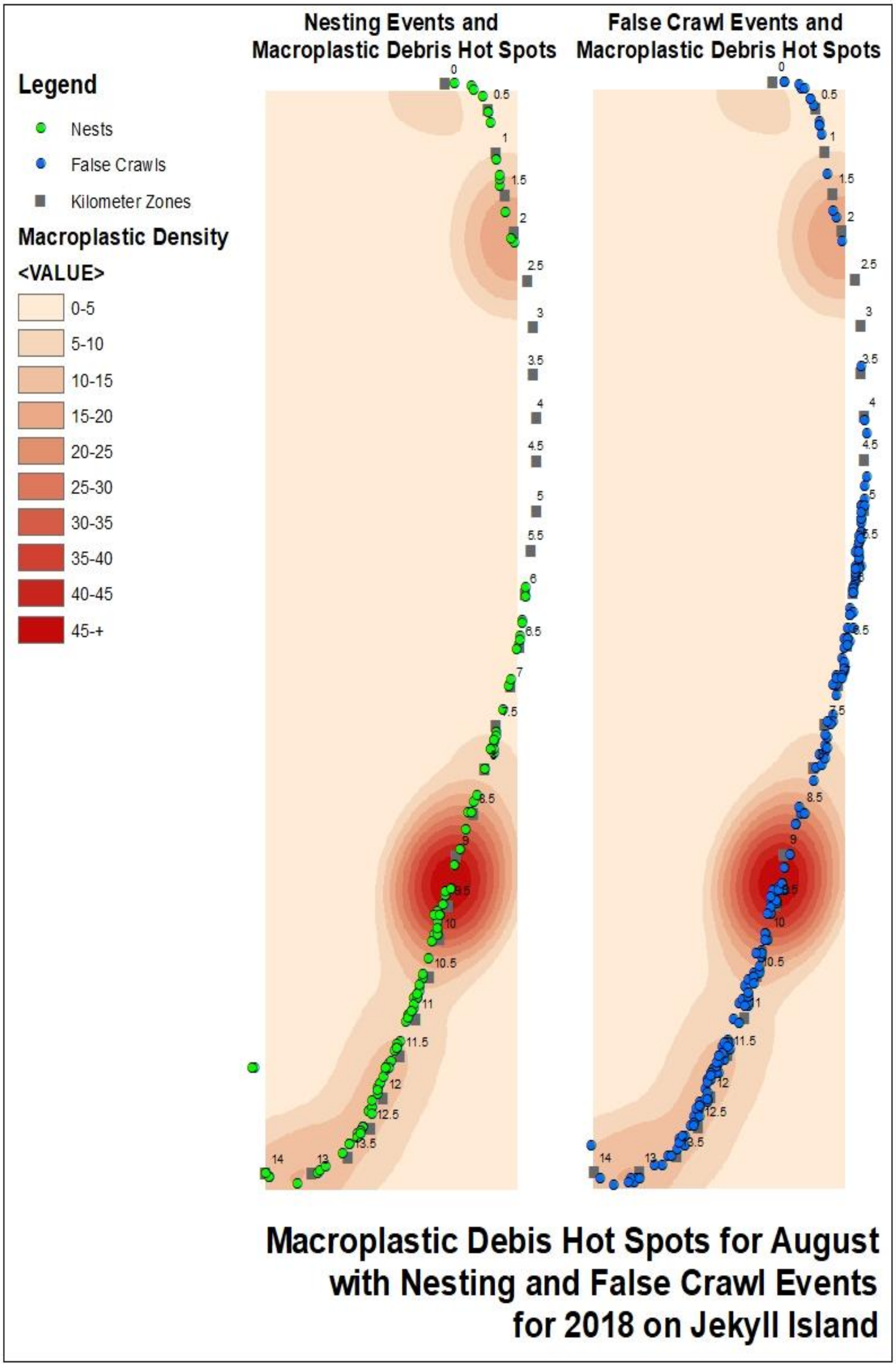
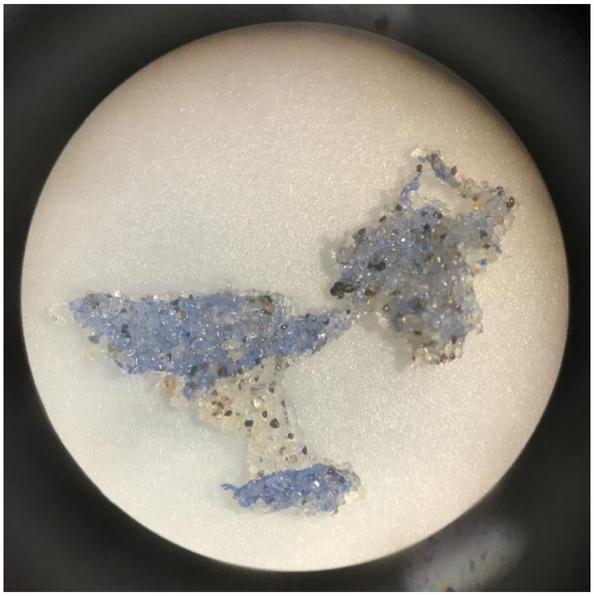


Figure 4.7 Macroplastic Debris in August for Marine Debris Tracker Data

4.2 Microplastics

The second objective of this research was to determine the quantity and types of microplastics present within loggerhead nesting cavities on Jekyll Island. Nests were sampled from all kilometer zones where nesting occurred during the 2018 season. These are kilometers 0 through 2 and 7 through 14, for a total of 11 nests tested (Figure 4.8). The rock wall limited nesting in kilometers 3-5 and no nesting events occurred in kilometer 6 during the 2018 season. After drying, all collected sediment samples were sieved using a 5mm metal sieve. Only one sample returned plastic during this process (Photo 1). This step removed all debris larger than 5mm from the sample.



Picture 1. A piece of macroplastic retrieved during sieving.

To examine potential variation within sediment collected from a nest, three unique nests (with 3 sediment subsamples per nest) were examined (Table 3.1). These nest subsamples were extracted and filtered for microplastics. Subsamples showed little variation in the types and number of microplastics detected within a nest. Thus, a decision was made to use only 1 subsample per nest as a representative of the nest sediment as a whole. This single subsample approach should serve as a sufficient baseline to capture a preliminary understanding of microplastics within a nest. Subsamples analyzed were A, B, and C for nest ID N008, whereas for nest IDs N061 and N118 B, C, and D were used instead. N061A and N118A were omitted as these samples were used to test the methods procedure initially. The results of the subsample level comparisons for the three nests had a detection rate of 0 to 6 pieces of microplastic per subsample.

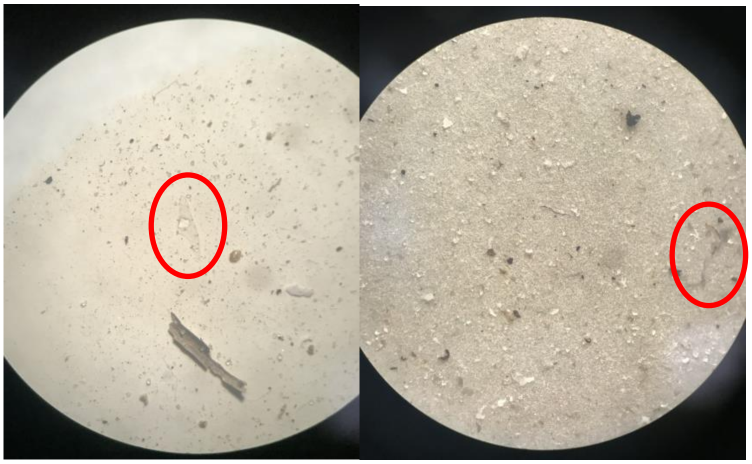
The type most frequently detected among subsamples for the 3 unique nests was blue filaments with a total of 15 for all subsamples, followed by white/transparent filaments with a total of 8 observed for all subsamples. Results indicate that minimal variation exists in the numbers and types of microplastics within a nest. Thus, due to the high cost of raw $ZnCl_2$ powder and to maximize its use efficiently, a decision was made to use only one subsample as a representative for the nest overall. Of 56 sediment samples available, only one nest per kilometer of nesting in 2018 was studied, each of which was analyzed by a single subsample per nest (50g of sediment). This reduced the potential sample size of n1 = 56; the total number of samples collected by GSTC, to n1 = 11 or one sample per stretch of kilometer where nesting occurred during the 2018 season.

Table 3.1 Quantity and Type of Microplastics Detected in Three Unique Nest Subsamples

Sample ID	**Filament: Blue**	**Filament: Red**	**Filament: White/Trans**	**Filament: Black**	**Angular: Blue**	**Total**
N061B	2		2			4
N061C	3					3
N061D	3	1	1	1		6
N008A	2			2		4
N008B	2		1	2	1	6
N008C			1			1
N118B						0
N118C	1		1		1	3
N118D	2		2			4
Total per Type	**15**	**1**	**8**	**5**	**2**	**31**
% Type	**48%**	**3%**	**26%**	**16%**	**6%**	

Figure 4.8 The Quantity of Microplastics Extracted and their Nesting Site Location

Plastics detected were sorted following the qualitative categorization of the Marine & Environmental Research Institute based upon the rules established by Hidalgo-Ruz et al. (2014). The type and quantity of all plastic detected in the samples is summarized in Table 3.2. The range of microplastics detected is 0 to 7 per nest. Three types of plastics were observed; filaments, angular, and a general category of other (Figure 4.9). It was determined that blue plastic filaments were the most frequently detected of all plastics documented in sediments of examined loggerhead nest cavities, with an average and median of 2 blue filaments per 50g of sediment. White/transparent filaments had a total of 15, and black filaments with a total of 7 for all nests. All other filaments or types of plastics detected were only represented by 1-2 pieces total for all nests examined. No plastics were detected in 1 of the 11 nests; sub sample N054A. The sample with the greatest quantity of blue filaments was N025A with four filaments. This nest was located in kilometer 11. The nests with the highest counts of white or clear filaments were located in kilometer 1 and 10 (and with 5 and 3 filaments detected, respectively). Blue filaments totaled 36% of all microplastics observed for all 11 nests, followed by white/transparent fibers at 16%. The percent type is calculated as the percent composition of all types of plastics detected. The highest numbers of black filaments observed were 3 for one nest (N020A), located in kilometer 13. N025A had the highest number of plastics detected in one sample; 7 pieces, that is 16% of all microplastics detected. This percentage is calculated by the number of plastics in N025A compared to all plastics detected for all nests extracted for microplastics. The average number of pieces of plastic per 50g of sediment was 3.45 and a median of 4. The results available from the initial subsample analysis as previously stated revealed similar patterns in the frequency and types of plastics documented with blue being the highest quantity observed, followed by white fibers and black fibers third. These results are congruent with the extractions from the total 11 nests analyzed, giving confidence to the overall patterns of microplastic distribution recorded using a single subsample per nest per kilometer zone.



Picture 2. (Left to right) A clear plastic piece of microplastic extracted from sand sample N089A and a clear filament extracted from sand sample N041A.

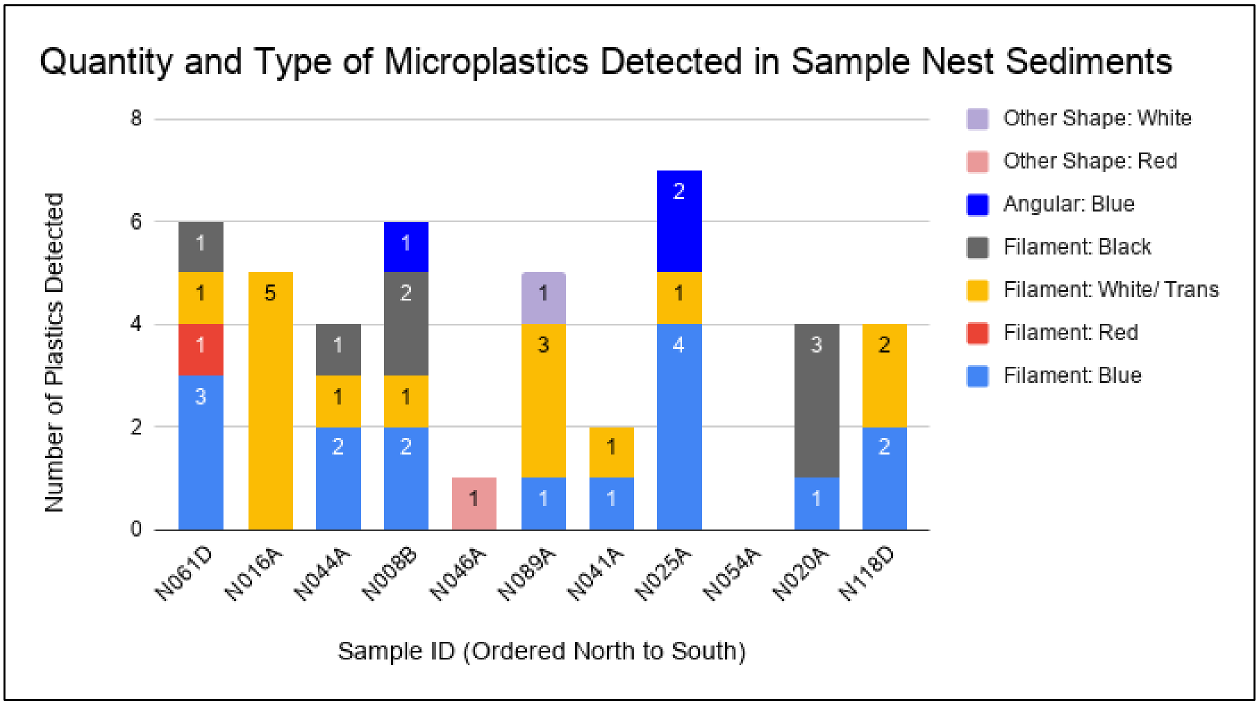


Figure 4.9 Types and Quantity of Microplastics Retrieved from Selected Nests.

Table 2.2: Table Overview of Types and Quantity of Microplastics Retrieved from Selected Nests

Sample ID	Kilometer Zone	Filament: Blue	Filament: Red	Filament: White/ Trans	Filament: Black	Angular: Blue	Other Shape: Red	Other Shape: White	Total per Sample	% Total
N061D	0	3	1	1	1				**6**	**14%**
N016A	1			5					**5**	**11%**
N044A	2	2		1	1				**4**	**9%**
N008B	7	2		1	2	1			**6**	**14%**
N046A	8						1		**1**	**2%**
N089A	9	1		3				1	**5**	**11%**
N041A	10	1		1					**2**	**5%**
N025A	11	4		1		2			**7**	**16%**
N054A	12								**0**	**0%**
N020A	13	1			3				**4**	**9%**
N118D	14	2		2					**4**	**9%**
Total per Type		**16**	**1**	**15**	**7**	**3**	**1**	**1**	**44**	
% Type		**36%**	**2%**	**34%**	**16%**	**7%**	**2%**	**2%**		

4.3 Nesting Characteristics from Historical Data

4.3.1 Nesting

The third objective was to determine pre-existing trends in nesting and related events using historical data. First, it was established where the high and low areas were in regards to nesting and false crawls on Jekyll Island to create a baseline of natural trends over time. This provides a framework to determine which areas were potentially most at risk of degrading nesting sediment due to the presence of plastic debris. The number of nests laid per year was graphed with an average of 145 nests per year and a median of 152 nests over the 11-year study period (Figure 4.10). Overall, nesting was fairly consistent on Jekyll Island with the exception of 2009, in which only 73 nests were deposited. Data over the 11-year sample period revealed that the majority of nests were laid within kilometer zones 10-12, followed by zone 8 and zone 1.

Little to no nests were laid within kilometer zones 3-5 annually (Figure 4.11). This 2 kilometer span likely has low nesting due to the presence of the sea wall within that area, kilometer 6 had no nest during the 2018 season (see Figure 4.1). This beach armoring serves to reduce beach loss and storm damage, but drastically reduces the availability of potential nesting grounds for sea turtles (Witherington, Shigetomo and Mosier, 2011). A study by Rizkalla and Savage (2010) shows that beaches in Florida with sea walls experience passive erosion, decreasing the number of nests laid in that area, and nesting that does occur has a greater chance of being washed away by storm activity. This trend can likely be attributed to the low nesting surrounding the sea wall on Jekyll Island. Finally, to detect nesting hot spots over time a Kernel Density Map was generated for each year during the 11-year span (Figure 4.112). The interpolations show that 60-100% of nesting is consistently occurring in kilometers 10-12, with high amounts also occurring in kilometers 7 and 1. This is consistent with the line graph (Figure 4.11) for overall nesting across the study period.

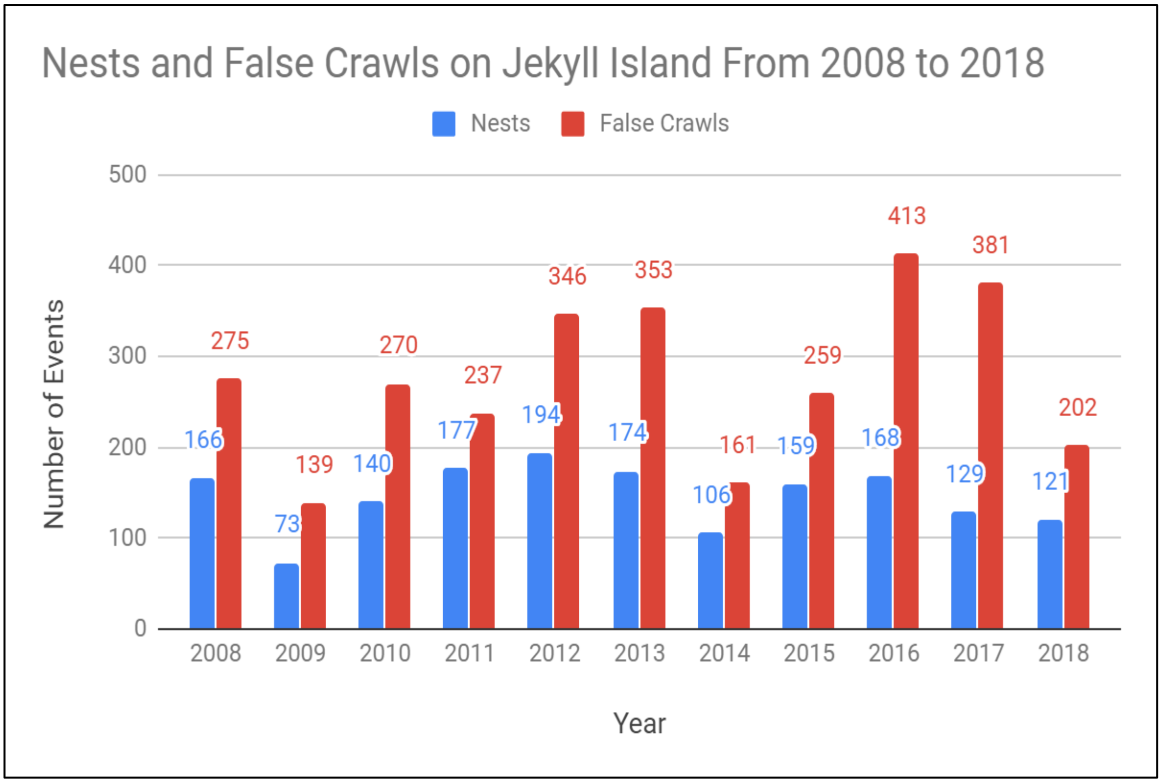


Figure 4.10 Bar Graphs Depicting Nesting and False Crawls from 2008 to 2018.

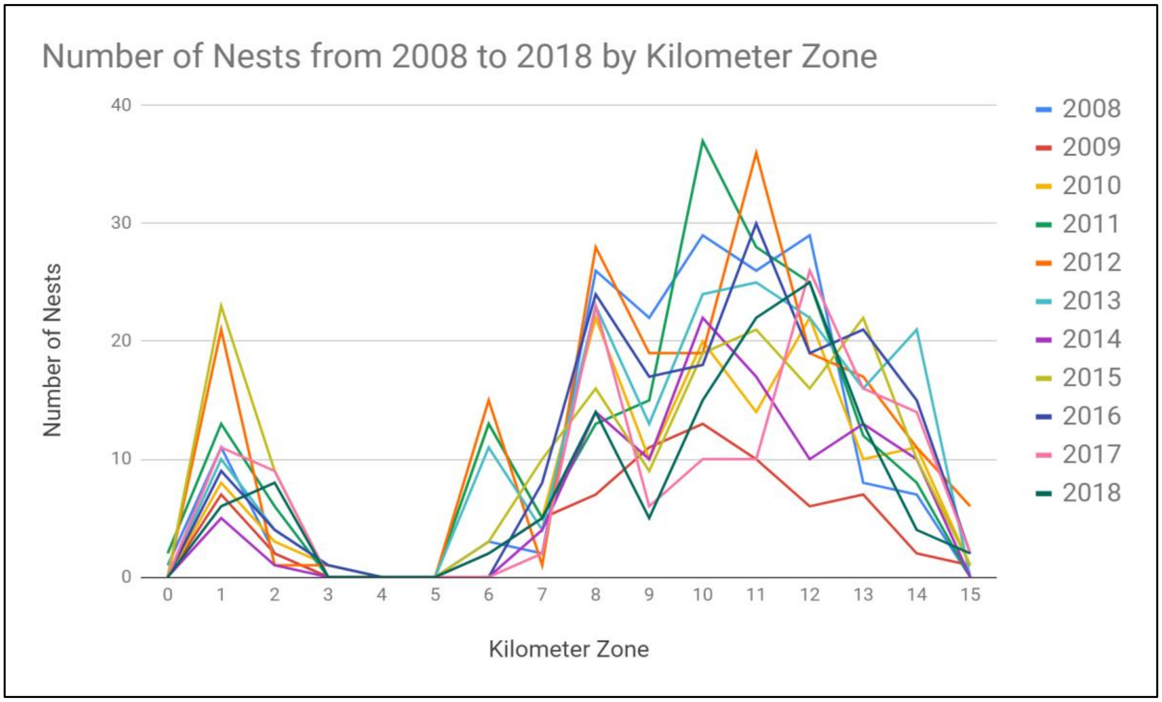


Figure 4.11 Line Graphs Depicting Nesting from 2008 to 2018 per Year per Kilometer Zones of the Study Site.

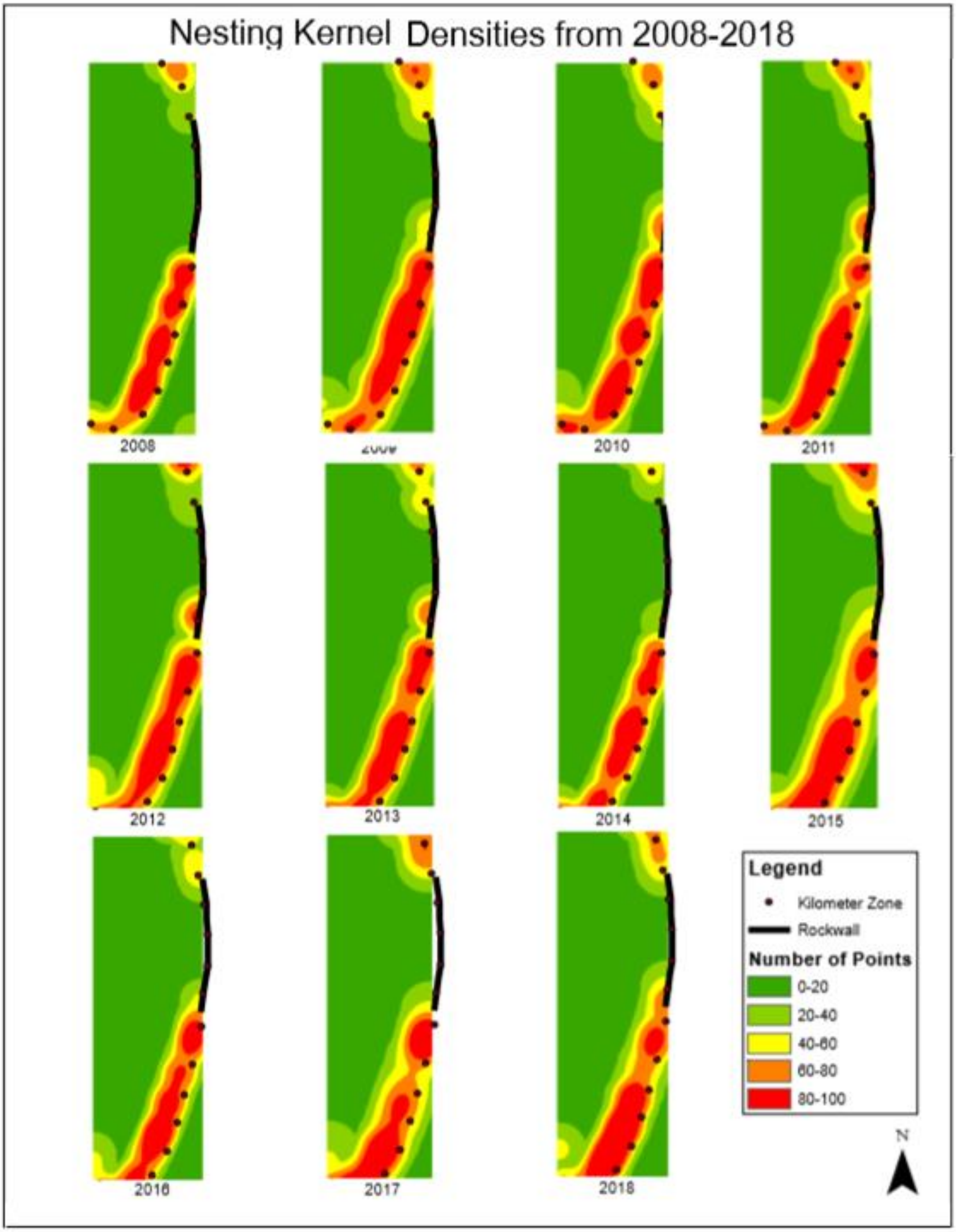


Figure 4.12 Kernel Density Maps of Percent of Nesting Along the Coast from 2008 to 2018.

4.3.2 False Crawls

False crawls were analyzed in the same manner as nesting. As previously mentioned, false crawls are occurrences in which the sea turtle attempts to nest on the beach or comes up onto the beach, but fails to deposit eggs. The average number of events was 276 false crawls with a median of 270 per year. For these events, three peak areas were evident. The first peak is in zone 1, the second spanning zone 5 through 8 and finally zones 10 through 12 (Figure 4.13). These zones are generally consistent with the more urbanized portions of the island. This is made evident by higher aggregations of public crossovers as compared to more stark areas of the island. Across the 11-year period, false crawls were continually more frequent in occurrence than nesting events. For the Kernel Density Maps (

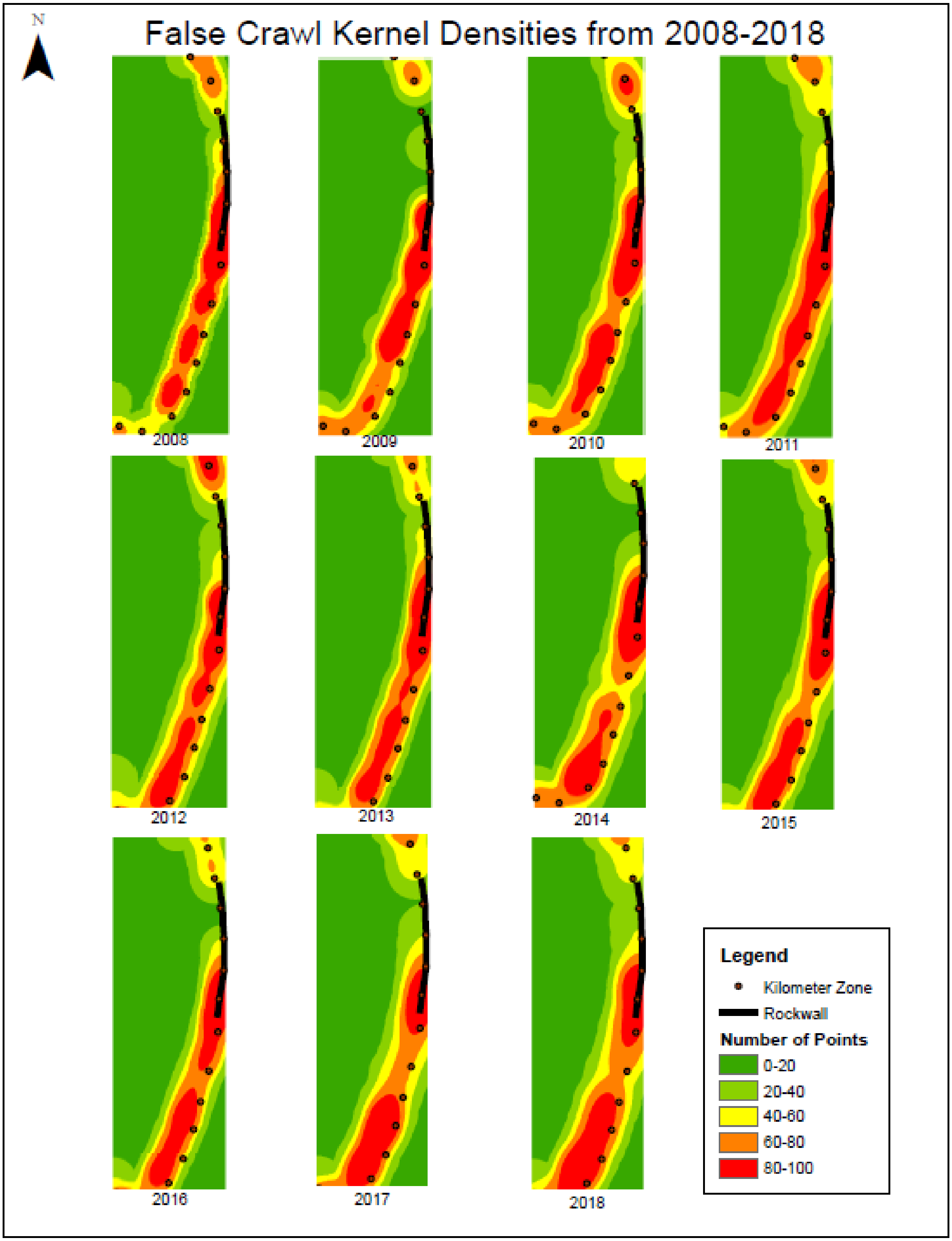


Figure 4.14), compared to the nesting maps, false crawls were more distributed in occurrence along the coast. The concentration of events was also more distributed along the coast in higher frequencies than that of nesting, where high frequencies were clustered towards the southern end of Jekyll Island.

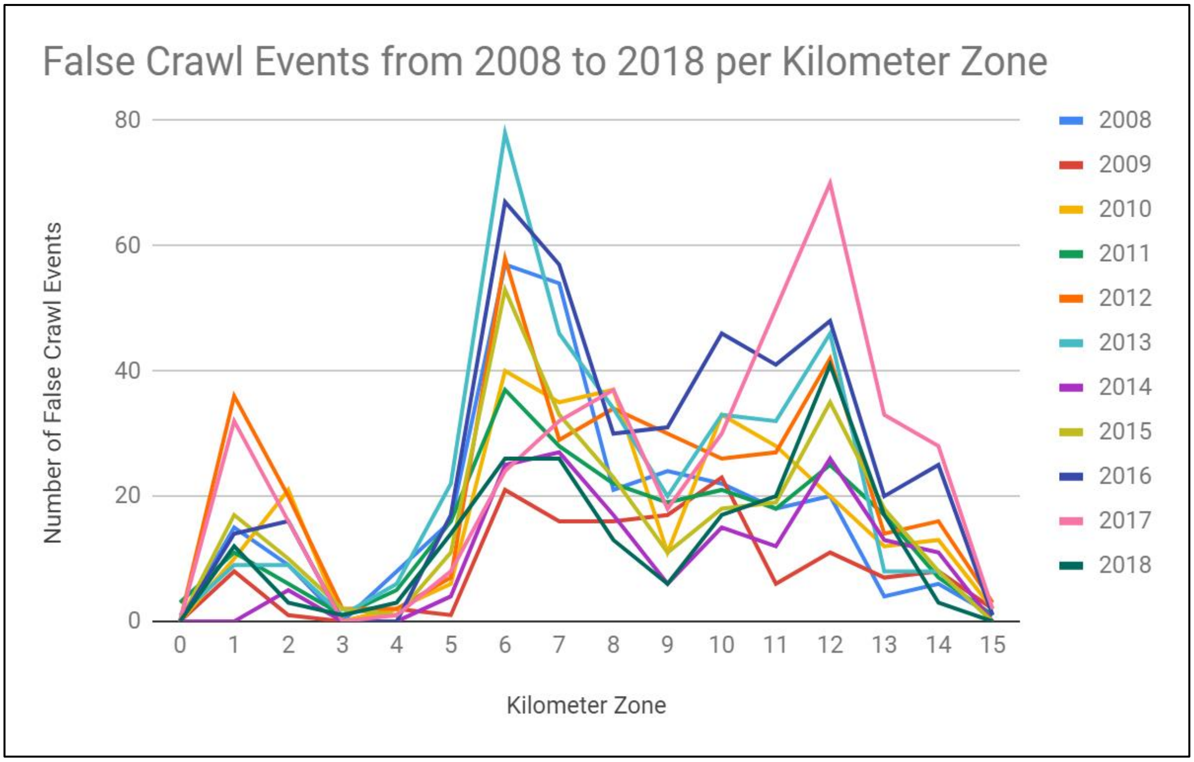


Figure 4.13 Line graphs depicting false crawls from 2008 to 2018 per year per kilometer zones of the study site.

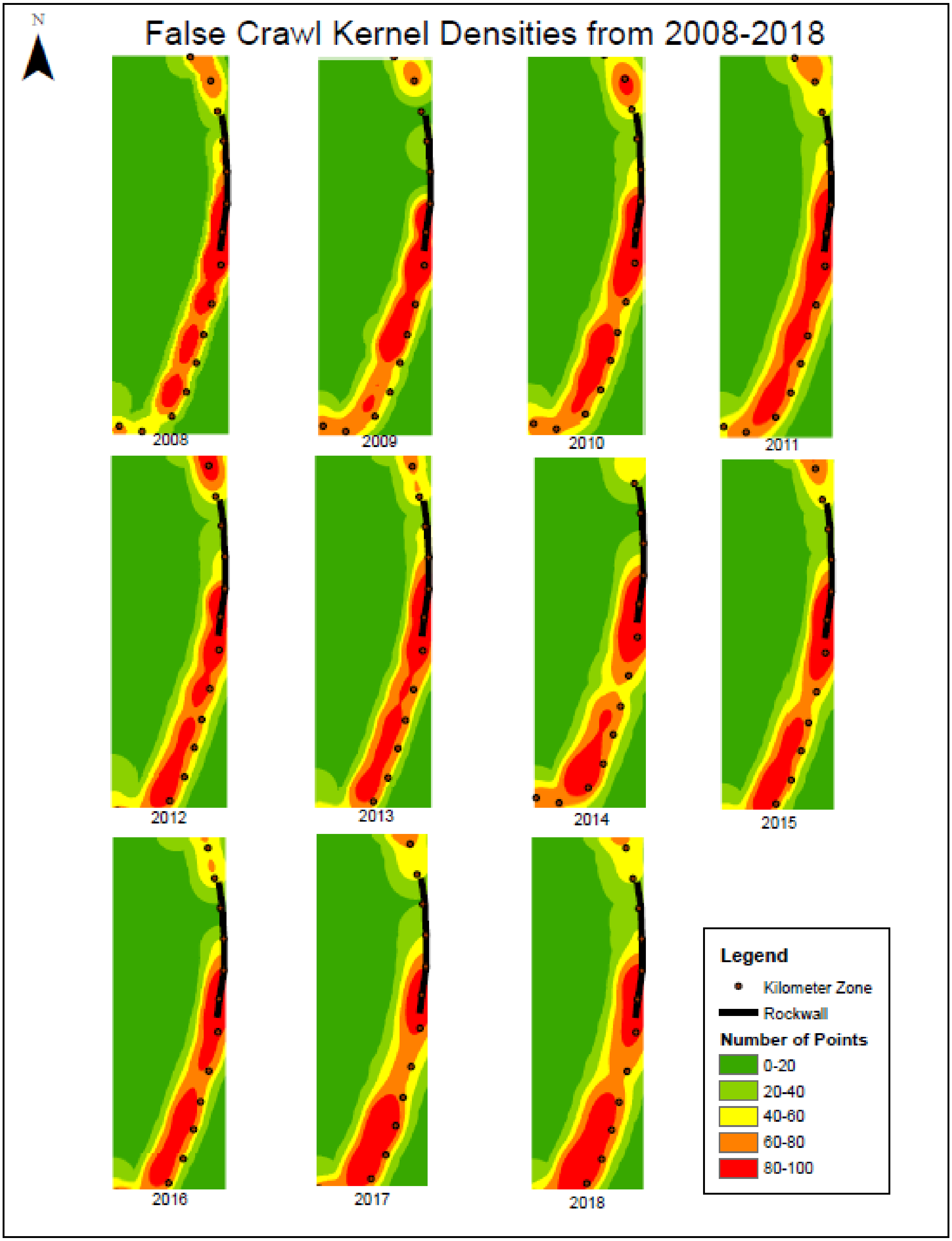


Figure 4.14 Kernel Density Maps of False Crawls Along the Island from 2008 to 2018.

4.4 Other Nesting Variables (Relocated nests, incubation, and beach profile)

4.4.1 Relocated Nests

To better comprehend the dynamics of the nesting beach, other nesting variables were examined to provide a framework for the quality of the nesting grounds on the island. Expanding upon the historical data from 2008 to 2018, hot spots for areas of relocated nests were delineated (

Figure 4.15). As previously mentioned, relocated nests are those physically excavated and relocated to another area of beach due to the high chance of endangerment by human and or environmental factors. Two major hot spots appear in kilometer zones 5-6 and 10-12. These had 20-30 relocated nests per area over the study period. A 1 kilometer span of beach (half kilometer marker 0.5 to 1.5) also had a high range of 15-25 relocated nests over the 11-year period. Little to no nests were relocated between kilometers 2 through 5. It should be noted that areas of high numbers of relocated nests are congruent with areas of high nesting activity. Knowing this, these areas of high nest relocation may not be abnormal hotspots given that they overlap with high nesting areas.

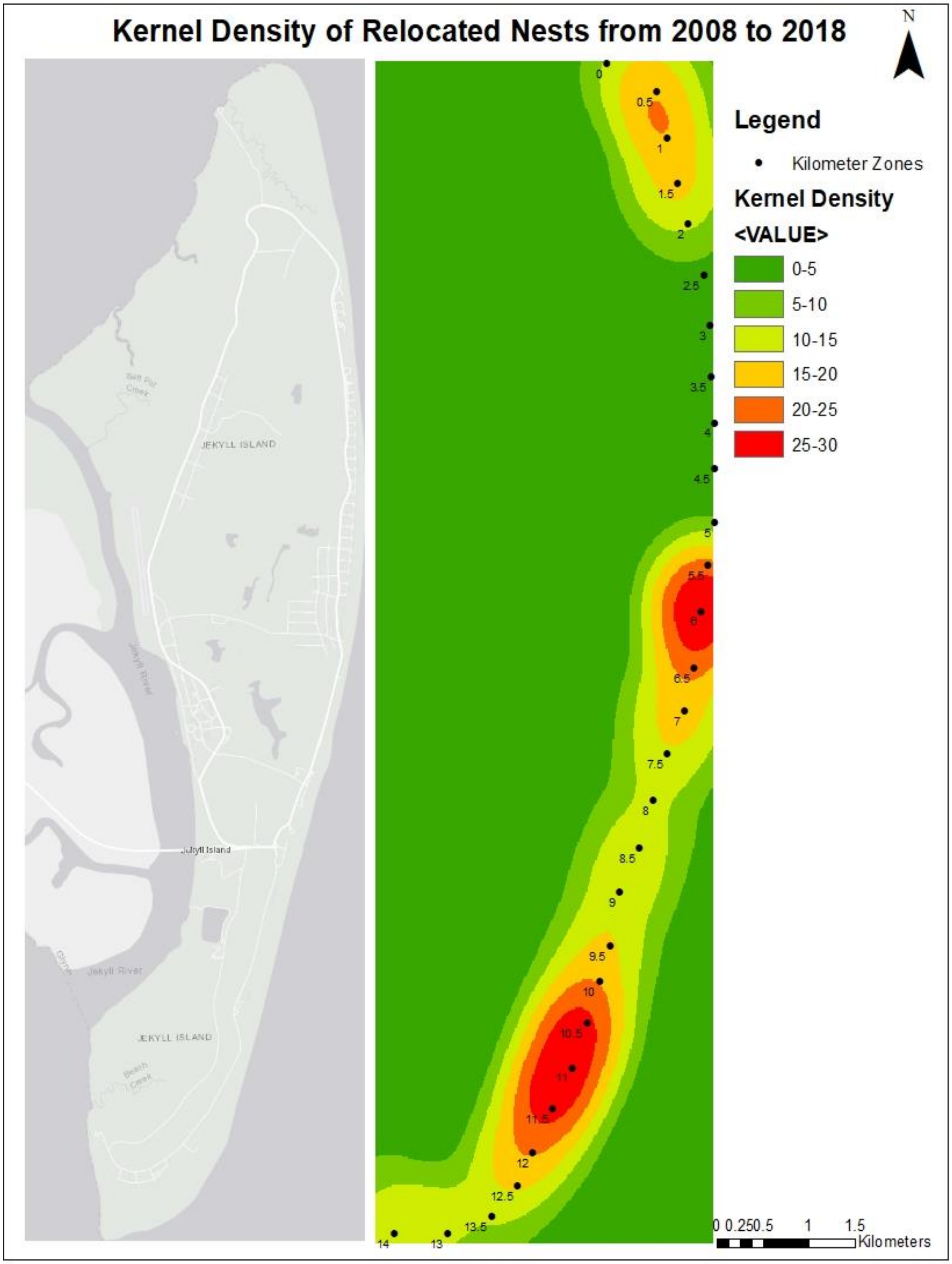


Figure 4.15 Kernel Density Map of Relocated Nests (2008-2018)

4.4.2 Incubation

Over the 11 years span of historical data, any possible changes in the duration of loggerhead incubation were examined. The overall mean number of incubation days from 2008 to2018 was 57 days with a mode of 55 days (

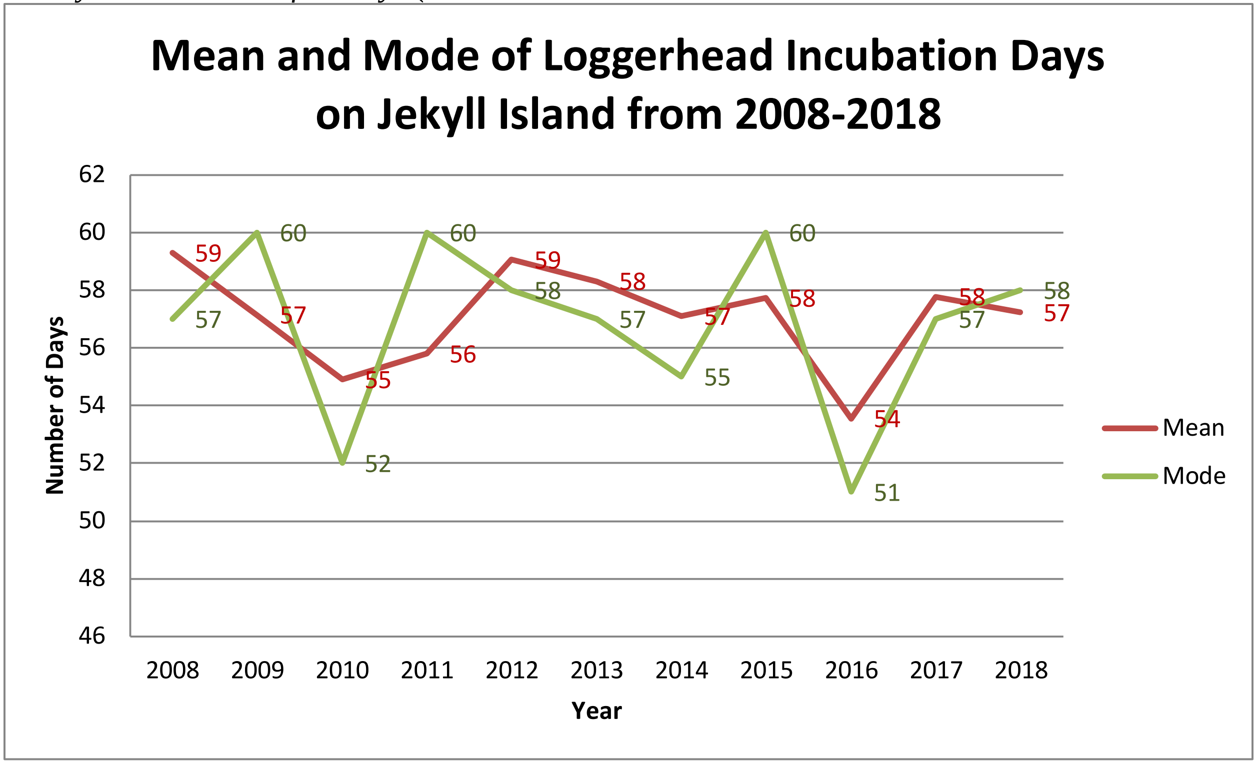


Figure 4.16). The lowest average durations occurred in 2010 with 55 days and 2016 with an average of 54 days. These years also have low modes for 2010 and 2016 of 52 and 51 days; respectively. The longest average duration occurred in 2008 and 2012 with 59 days. The highest mode was 60 days occurring in 2009, 2011 and 2015. The main driver for the duration of sea turtle incubation is temperature (Packard and Packard, 1988) with the period of incubation being inversely proportional to temperature (Limpus et al., 1983).

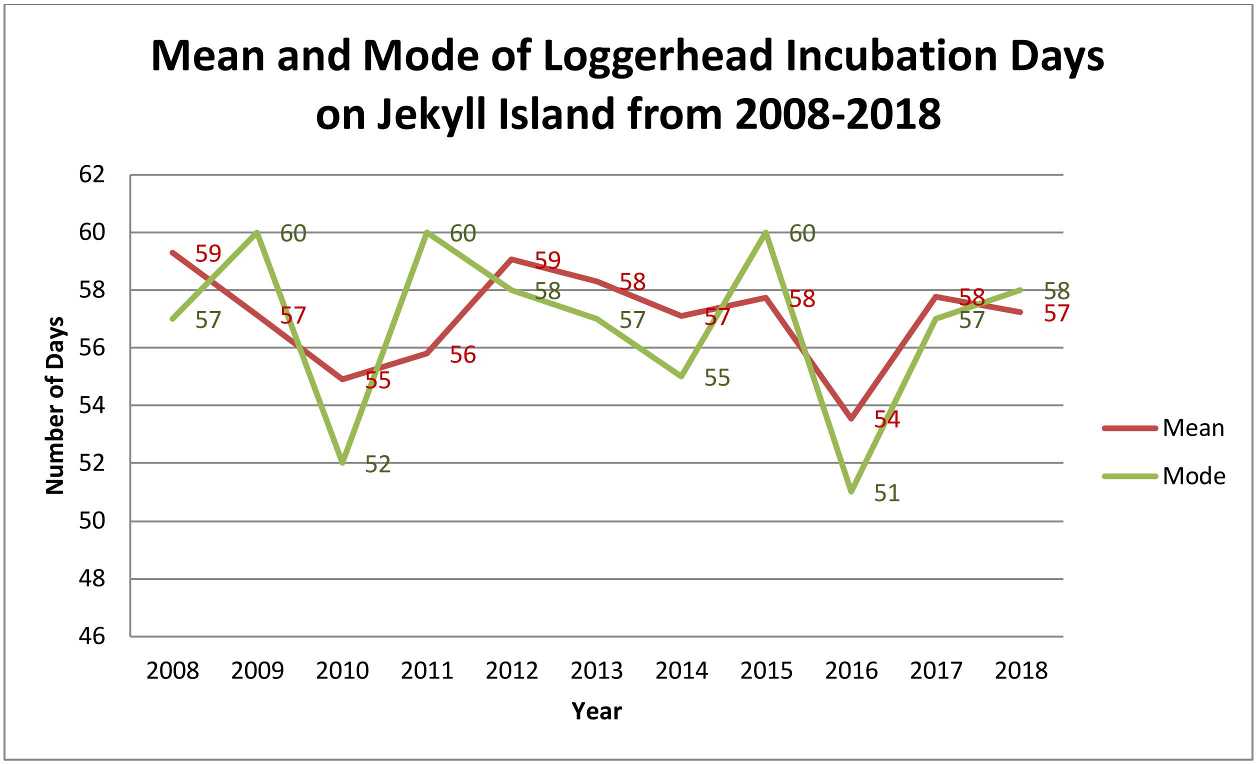


Figure 4.16 Mean and Mode for Loggerhead Incubation Period by Year.

4.4.3 Beach Profile

The width of the beach, spanning from the beginning of the berm to the vegetation line of the beach, was measured at every half kilometer during the census to determine the amount of available nesting area during the 2018 season (Figure 4.17). During both June and August, both transects show a much wider distribution of beach on the southern portion of Jekyll Island spanning from kilometers 8 through 14. This follows the natural process of erosion occurring on the northern portion of the island and deposition of sediments on the southern end brought on by net longshore currents (Hails and Hoyt 1969). There is a smaller spike between June and August from kilometers 2 through 3.5. These peaks are congruent with areas of high nesting activity, with higher concentrations of nesting in the southern kilometer zones. It is inferred that this occurs as the distance widens between the vegetation line and the berm, as more nesting grounds are physically available.

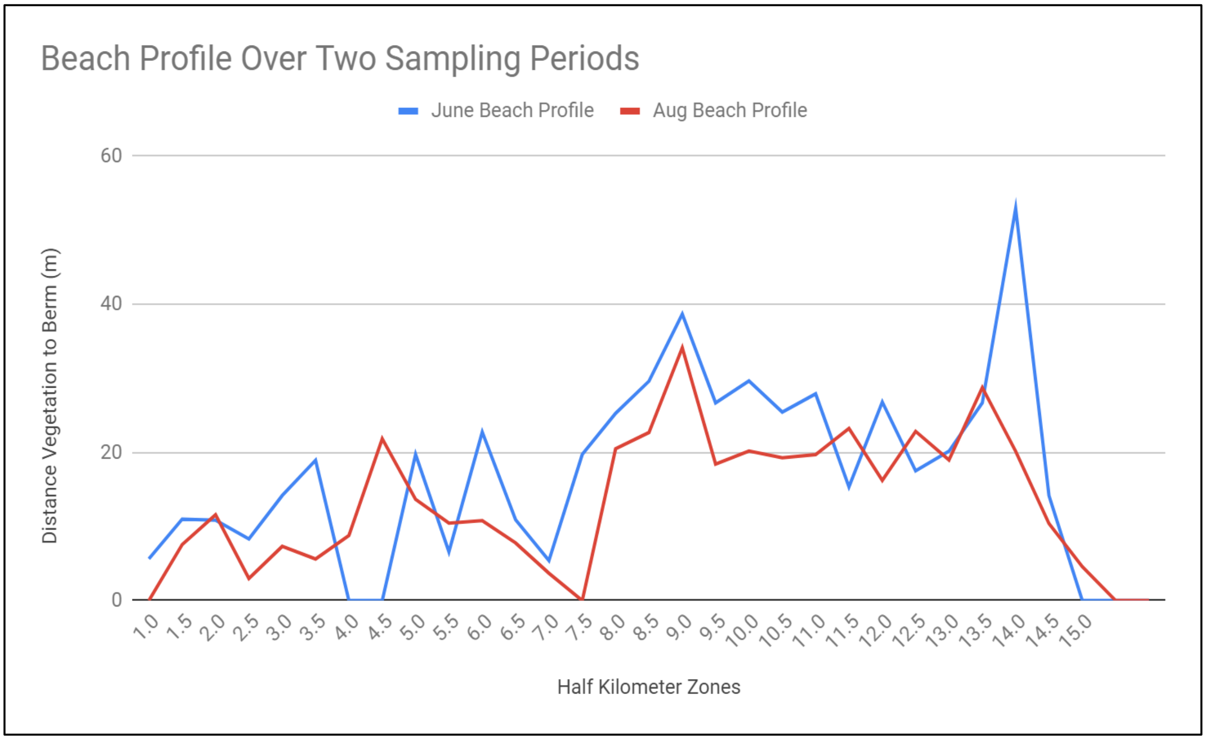


Figure 4.17 Map of the Beach Profile along the Coast of Jekyll Island

4.4.4 Historic Hatching and Emerging Success

The success of sea turtle nests can be measured by calculating the success of the hatching rate as well as the success of the number of offspring individuals that leave the nest, known as the emerging success. Both of these rates were calculated by overall year and by zone from 2008 to 2018. These rates highlight any potential areas with continuously low hatching and / or emerging success as they overlap with areas of clustered concentrations of plastic debris. The overall mean and median success for both variables increases over the 11-year period. In general, the average rate of hatching and emerging success over the examined period was approximately 60% with a gradual increase over time (

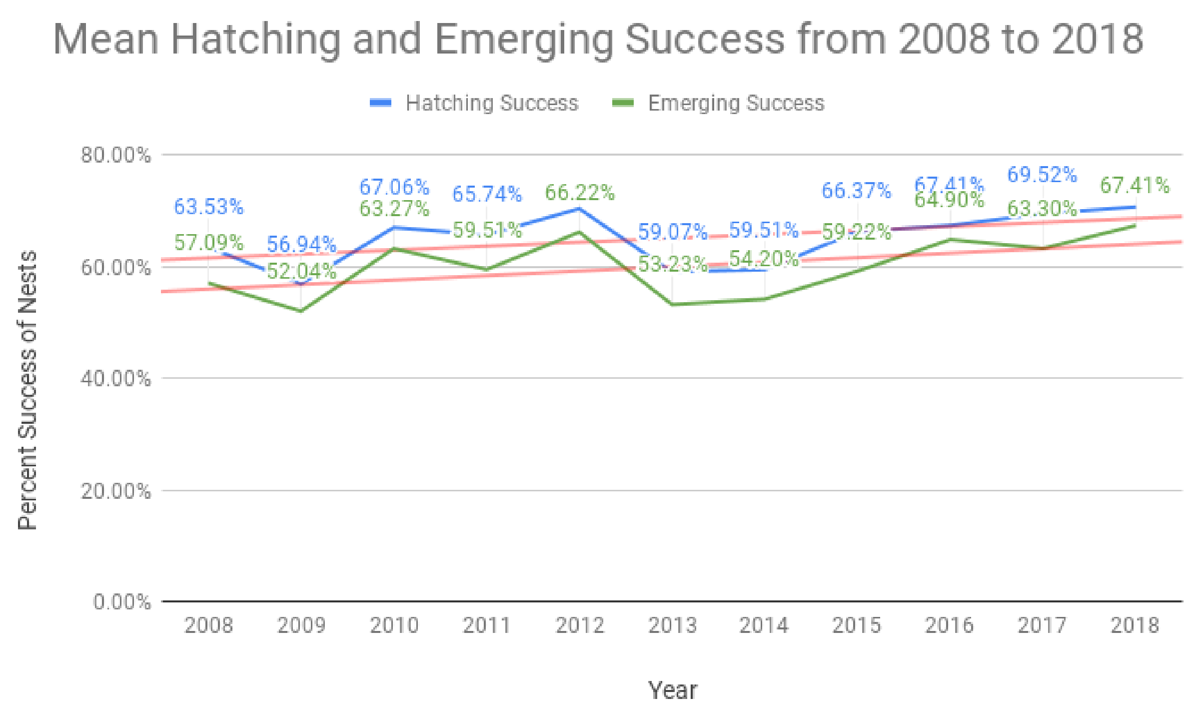


Figure *4.18*). The range of mean hatching success is a low of 59.07% and a high of 70.74%. Emerging success has a low average of 52.04% and a high of 67.41%. Both success rates were fairly in sync each year with peaks and valleys occurring at the same time. The median rates by year also increased over the 11-year period (Figure 4.19). Emerging success had a more sharply increasing trend, with a low of 57.75% success and a high of 86.21%. The increase in hatching success was more gradual, with a low of 71.57% and a high of 88.81%.

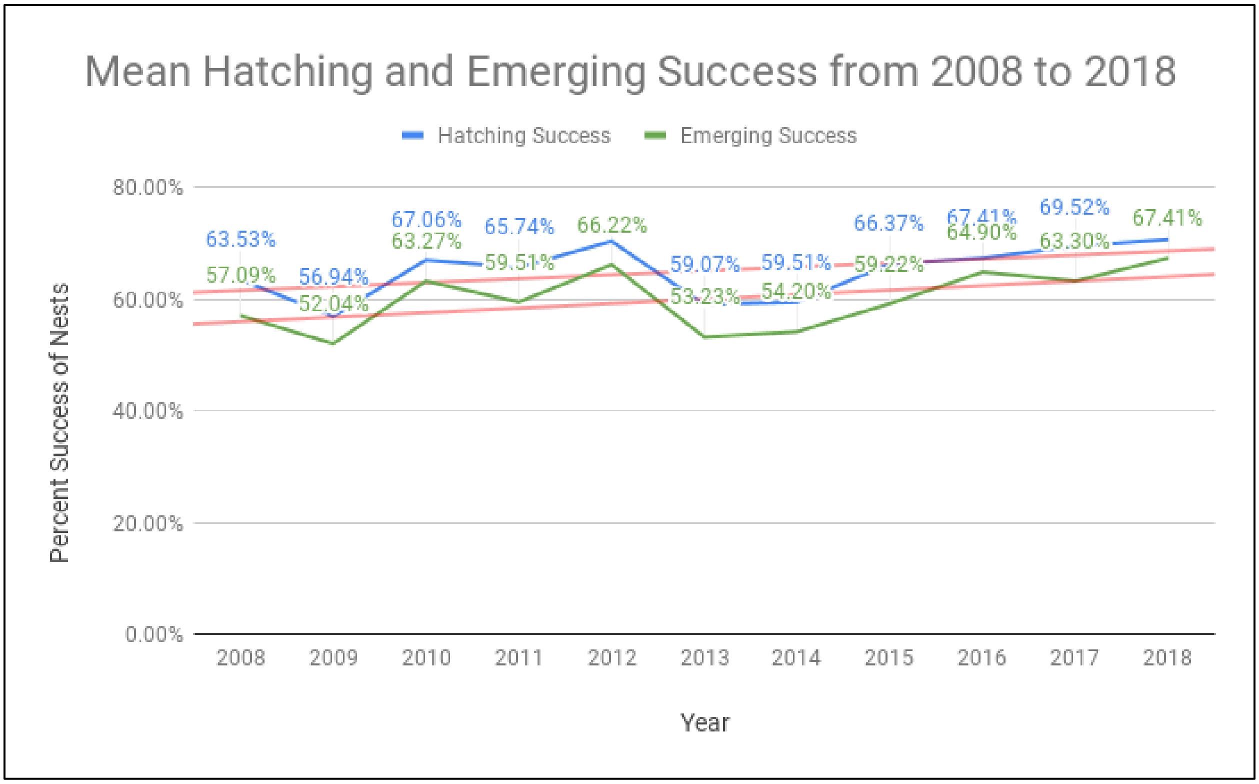


Figure 4.18 Percent Average Hatching and Emerging Success per Year

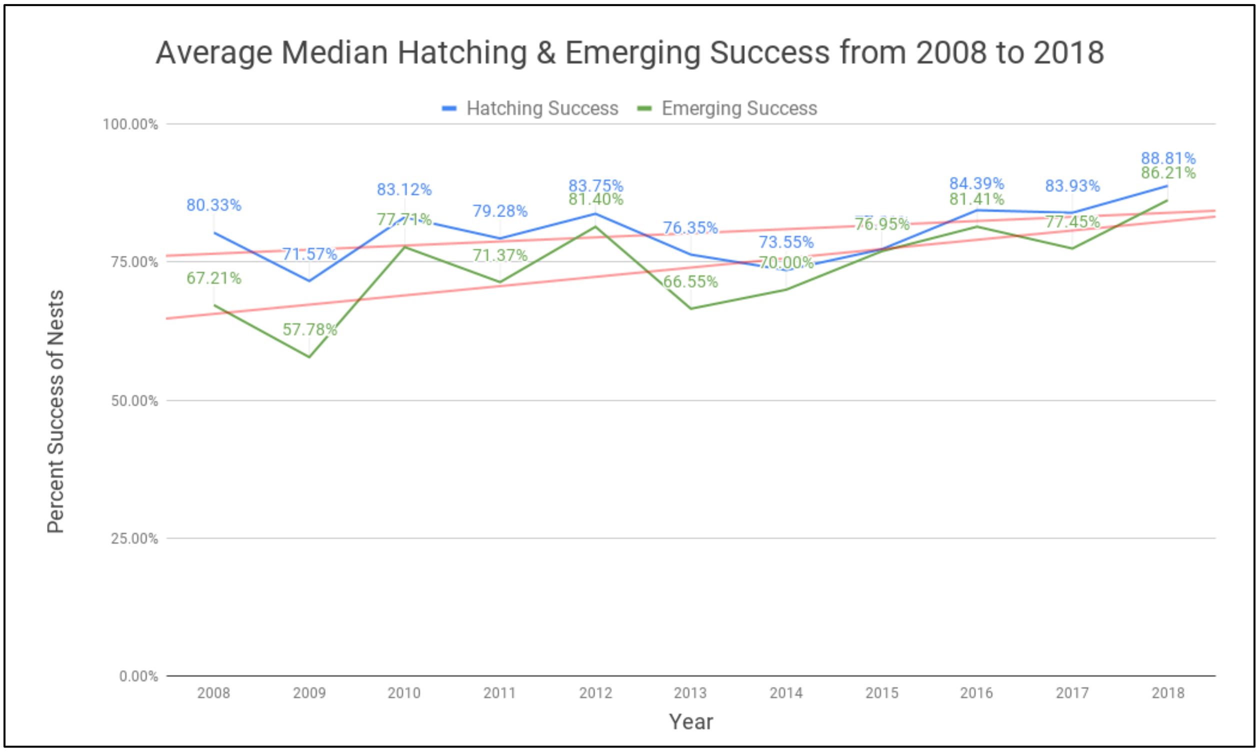
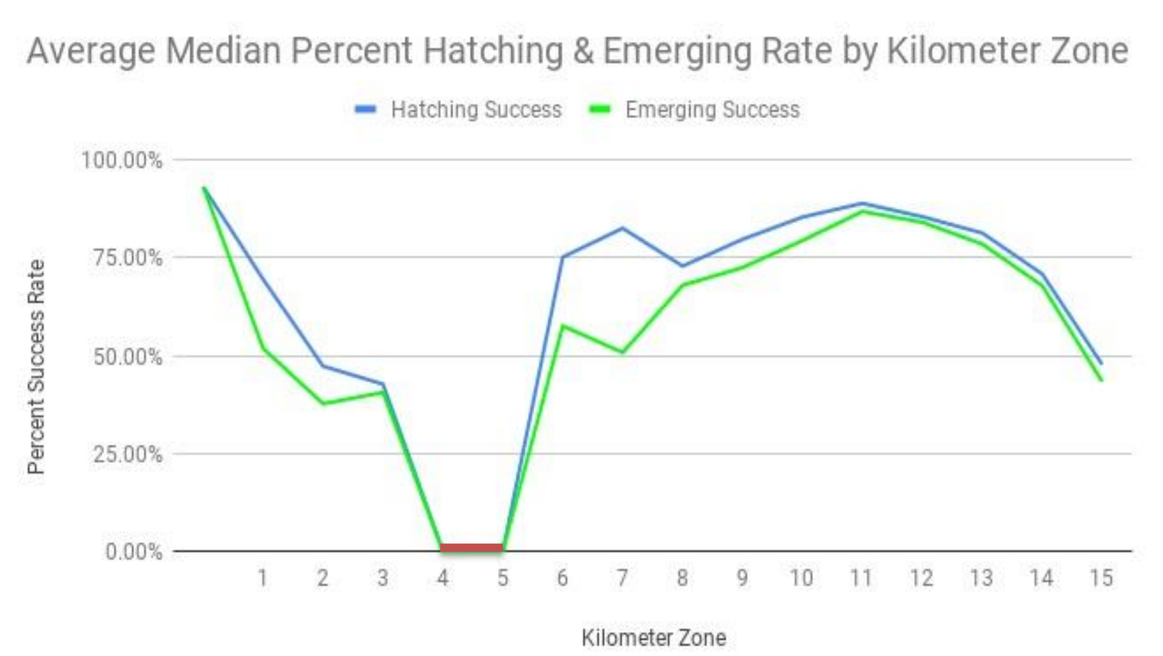


Figure 4.19 Percent Average Median Success Rates per Year

The average and median hatching and emerging success rates were also calculated by kilometer zone to see where successes are highest and lowest down the coast of the island. For the entire 11-year period, the mean for both hatching and emerging successes were highest in kilometer zone 0, with a 93% rate of success and then were lowest in kilometer 4 and 5 with a success rate of 0% (
Figure 4.20 and
Figure 4.21). The sea wall is located in zones 3 to 5, with little to no nesting occurring in this area, and correspondingly the rate drops in zone 3 and drops to 0 in zones 4 and 5 where there is no hatching or emerging events to calculate. In kilometer 11, both rates gradually increased to the second highest percentage peak before declining again. This zone lies within the high nesting stretch of beach from kilometers 10 to 12, and the median rates were slightly higher in comparison, especially in the southern kilometer zones 9-14, where the trend arced rather than a sole peak occurring in kilometer 11 as seen in the average success rates.

Red denotes the kilometer zone where no nesting events occurred, therefore success rates were unable to be calculated.

Figure 4.20 Average Mean Success Rates per Zone



Red denotes the kilometer zone where no nesting events occurred, therefore success rates were unable to be calculated.

Figure 4.21 Average Median Success Rates per Zone

5 DISCUSSION

This research provides a snapshot into the current quality of the sea turtle nesting habitat on Jekyll Island. Results show that plastics, macro and micro alike, are notably present along the Jekyll Island coastline, with certain areas of the beach having higher concentrations than others. With tourism being largely centralized on the beach, the majority of the urban development on the island is concentrated along the oceanic coastline. The increased human presence in this portion of the island could result in a higher amount of plastic debris on the beach, and in particular in certain zones along the beach that have greater human traffic. It is important to note that longshore currents may factor into the distribution of debris as well, as sediments are eroded to the north and deposited on the southern end of the island. Though significant efforts are undertaken by GSTC, volunteers, and beachgoers to clean up and minimize the debris, there are plastics amassing within the sands across nearly the entire coastline. Areas of nesting density hot spots in kilometers 10 through 12 are at a greater risk of potential impacts from plastic debris. These areas should be more closely surveyed during cleanups. Increasing targeted beach cleanup efforts and public education at these hot spots could help raise further public awareness and potentially change behavioral patterns of the public. It should be noted that current cleanup efforts are having a positive impact to aid in the reduction of debris on Jekyll Island (Miller, 2019). Beach cleanliness is not only economically desirable, given a tourism-based economy (Balance et al., 2000), but also these efforts will help to preserve the integrity of the nesting beach.

5.1 Plastic Debris

Plastics are an increasing problem of concern across the globe, especially with regards to coastal habitats (Barnes, 2009). Loggerhead sea turtles nesting on Jekyll Island, Georgia, are incubating their eggs on a beach that, based upon this research, has plastic debris both on the surface and within the sand sediments. Of all the habitats that sea turtles occupy throughout their life stages, nesting beaches have the greatest overlap with anthropogenic activities (Witherington et al., 2011), therefore impacts are inevitable. This being said some areas of the island's coast are less affected by debris than others. The MDT data totaled 110 and 115 pieces of macroplastics in June and August, respectively. During both of these sampling periods, cigarette butts composed approximately 30% of all plastic debris recorded. The Martin (2013) study examined all debris over a one year period on Jekyll Island using the MDT app where 88% of debris was plastics, and noted a similar observation of cigarette butts comprising 27.7% of all plastic debris recorded. For the 2018 loggerhead nesting season, areas of key concern such as Driftwood Beach (kilometer 2), the shopping and hotel district (kilometer 8-10) and the St. Andrews Picnic Area and beach access point (kilometer 14), all have a larger human footprint in comparison to natural areas as macroplastic debris hot spots were located in these areas. The Martin et al., (2019) study highlighted kilometers 8, 9, and 13 as being areas of high plastic debris, with kilometer 8 having the strongest overlap of nesting and plastic densities. This study attributes high plastic concentrations in kilometer 8 and 9 due to the available amenities and ease of access to the beach in this area. With the exception of kilometer 2, not listed as a hot spot in the Martin et al. (2019) findings, these kilometers are congruent to the areas identified by this research effort. Microplastics were detected in 10 out of the 11 nests sampled with an average of 4 pieces and a maximum of 7 detected per nest of the sediment subsamples analyzed (50g per nest). Given the small sample size of only 11 nests studied for microplastics (equating approximately to 1 per kilometer zone across the island), no spatial patterns were determined regarding variation in microplastic concentrations. Yet, microplastics are consistently distributed along the beach, data that had not yet been reported for Jekyll Island. Historic nesting from 2008 to 2018 indicated that nesting was concentrated in kilometer zones 10-12 (towards the southern end of the island), followed by zones 8 and zone 1 (towards the central and northern end). These zones had an average and median hatching and emerging success rate of over 50% over the past 11 years. Within context of the island’s historic hatching and emerging success rates as a whole, over 50% is a good outcome. These areas should be more closely monitored for plastics given higher nesting occurrences and especially for certain kilometer zones (e.g. km 8) in being identified as both a hot spot for plastic debris and nesting.

Peak tourist season on Jekyll Island spans from early May through the beginning of the school year in early August (Brunswick and The Golden Isles of Georgia Visitors Bureau, pers. comm. June 2018). This time frame coincides with that of loggerhead nesting season on the island (Norton, 2005). With this increase in human traffic, there is likely an increase in the amount of plastic debris left by beachgoers, especially in more highly trafficked areas. There are garbage and recycling receptacles present at almost all public crossovers and beach access points, promoting the proper disposal of trash. Despite these receptacles, the majority of macroplastics from both the quadrat census and the personally collected MDT data, were cigarette butts comprising up to 30% of the macroplastic detected on the beach. The three categories of plastic bags, bottle and, food containers were the second largest contributors ranging from 10-20% of the total. Similar results were obtained in the 6 year Martin et al., (2019) study for Jekyll Island, with 48% cigarettes and 18% plastic of foam fragments comprising all debris, both plastic and non-plastic alike recorded by citizen scientists with the app. In addition, their study specifies kilometer zone 8 as a target area given both high nesting and quantities of plastics detected, which is consistent with the kernel density mapping from the MDT data analyzed in this research. Their findings conclude that ease of access and nearby amenities are possible reasons for the increased debris in kilometers 8 and 9. These undisposed plastics degrade slowly allowing them to persist in the environment (Driedger et al., 2015), and accumulate in the sands on the island. All of these items are indicative of short-term daily beach related activities. The majority of the debris was not weathered or discolored from extensive sun exposure, further indicating recent abandonment by beachgoers. With macroplastics exhibiting little to no weathering clustered around areas of high human traffic, they are likely sourced from beach visitors and not from other sources such as waterways, where they would have been impacted more by weathering processes. Overall, this research is in agreement with the conclusions from the Miller et al. (2019) study, in that there is repeated overlap of plastic debris along the beach surface in areas of significant sea turtle nesting activity.

Of the microplastics detected in samples across the available loggerhead nesting habitat along the coast, the most abundant colors observed were blue, white, and black. Recent hurricane activity along Georgia's coast and any potential damage could be related to the high count in blue filaments. Blue tarps are frequently used to contain damaged areas in commercial and residential buildings in the aftermath of hurricanes. The island underwent two recent hurricanes; Hurricane Matthew in 2016 and Hurricane Irma in 2017. It is possible that fibers from the use of these tarps, fragmented and accumulated within the sands. White and clear fibers were likely from fishing lines or nets used by fisherman both recreationally and within the commercial industry. A more in-depth analysis of these filaments could provide more precise insight into their nature of origin, such as the use of FTIR spectroscopy to identify the plastic polymers present within recovered plastic debris (Mecozzi et al., 2016). This research is the first to examine microplastics on Jekyll Island and contributes to a growing body of knowledge regarding factors that are important to consider in determining how best to manage and conserve the island's regionally significant sea turtle nesting habitat.

5.2 Nesting and False Crawls

Kernel Density analysis identified density hot spots along the coast of the island for nesting and non-nesting events. Nesting was demonstrated to occur along the entire coast with the exception of in and around the stretch of beach parallel to the rock wall in kilometers 3-5. These structures serve to benefit the integrity of the land by preventing erosion, however, they inadvertently act as physical barriers for sea turtles (Witherington et al., 2011). This hindrance is evident in the minimal to zero loggerhead nests laid in the section of beach occupied by the sea wall. False crawls, on the other hand, were clustered in the southern portion of the sea wall, indicating that loggerheads are actively attempting to nest in this area, but are also abandoning these efforts at a high rate. This behavior has been documented to occur in sections with beach armoring in comparison to sections with a natural beach (Mosier, 1998). False crawls occurred largely between kilometers 8 and 12. The northern kilometers of this range (8-9 km) parallel the beachside retail and hotels, which carry a larger human presence than in kilometers 10 to 12. The northern portion of these false crawls could potentially be attributed to a higher possibility of human interactions. The southern portion of this concentration likely cannot be attributed to the same reasoning, as there is no extensive development or beach access points in that area.

5.3 Nesting Factors

Nest relocation, length of incubation, and available nesting beach are all factors contributing to the success of the sea turtle nest. Over the 11 years of historical data, there were two kilometer zones on the beach that were more likely to have nest relocation. These two spans are from kilometers 5 to 6 and from 10 to 11. Nest relocations occur when the GSTC determines that the clutch is at risk due to various factors such as tidal inundation, escarpment, or predation. Given the likelihood of relocation, these two sections of beach likely have environmental factors at play that require the nests to be physically relocated In kilometers 4 and 5, success rates were unable to be calculated due to a lack of data from no nests being laid in this area during the 2018 season. This range is also where false crawls begin to aggregate. In comparison, the average mean and median hatching and emerging success rates in kilometers 10 through 11 are approximately 75% success, which is a substantial increase in comparison to kilometer 5.

5.4 Hatching and Emerging Success

Since 2008, the hatching and emerging success rates for loggerheads on Jekyll Island are slowly increasing. This affirms the significance of the island as an established sea turtle rookery in the southeastern United States. The location of the nest is a predominant factor in these success rates. Nests laid in kilometer zone 0 have an average of 93% hatching and emerging success. As no nests were laid in kilometer 4-5 during 2018, no success rates could be calculated. Rates decrease going south as they approach the rock wall and increase to approximately 60% at kilometer 6. The rates peak and begin to decline again around kilometer 12, where they steadily decline to under 50%. This decline to the southern portion of the island is likely due to the large presence of driftwood and frequent tidal inundation. Nesting occurs less frequently in this span of the island, where the available beach rapidly tapers off as it enters into a marsh habitat.

5.5 Maintaining the Integrity of the Nesting Habitat

Data on macro- and microplastics indicate that indeed there is a presence of both on the subsurface and within the sediments across the whole coastline of Jekyll Island. This study and others (e.g., Martin et al., 2019) indicate that more macro debris may be found in areas with higher human impacts. Given the small sample size no specific patterns of variation in the concentrations of microplastics are presented at this time. Nesting occurs along the coast of Jekyll Island with exception to the roughly 2 kilometers occupied by the retaining wall. The occurrence of macroplastics down the coastline of the island appears to overlap with areas with high human activity. With tourism season occurring at the same time as sea turtle nesting season, the probability of frequent overlap between plastic debris and sea turtles is high. Barrier islands, such as Jekyll Island, have unique and fragile ecosystems and already actively face challenges balancing ecosystem conservation and tourism (Ortiz et al., 2018). Peak human traffic would equate to higher chances and occurrences of improperly discarded or abandoned trash, likely equating to higher amounts of plastics on the beach. Improperly discarded plastics crack and fragment under the high temperatures of the sun (Barnes, 2005), making them harder to clean up and facilitate their amassing within the sands. Facilitated and recreational, beach clean ups are frequently conducted on the island; however manual debris removal is often unable to successfully remove smaller plastic debris (Driedger et al., 2015). Given the small sample size of sediment samples extracted for microplastics, no conclusions were drawn between concentrations of macro- and microplastics along the beach. A more robust number of extracted sediments, along with longterm macroplastic data could further highlight areas of high plastic concentrations both on the surface as well as within the sands. This research concludes that despite the limited sample size, plastics are indeed accumulating within the sands. Without consistent cleanup efforts, areas of higher plastic debris upon the surface could in turn fragment and contribute to a greater presence of microplastics in the sands. . The rate of incorporation with the sediment would be dependent upon the chemical makeup and the type of plastic. Areas of higher concentrations of plastic debris would expect to have higher amounts within the sediment; however, environmental factors such as wave and wind action might contribute to displacement. Current literature shows that no negative impacts are presently observed on Jekyll Island between plastics and sea turtles. However, this study does highlight that certain areas of the beach are likely more at risk than others. Proactive measures in conservation efforts would best serve to ensure the continued success of loggerheads on Jekyll Island. These areas would be zones with historic low hatching and emerging success where extensive plastics could influence the microclimates of the nests. The southern portion of the island, with greater concentrations of nests, would also be more at risk compared to kilometers 3-5, for example, where little to no nesting occurs due to the sea wall. It is important to note that this habitat is fluid and that kilometer zones are human constructs and arbitrary to sea turtles during their nesting site selection. Providing the results of this research in terms of kilometer zones serves to provide spatial context to identify target spans of beach and to collect and analyze data on trends through time.

5.6 Research Limitations & Future Research

The intent of this research was to establish a snapshot census for macro- and microplastic debris to consider how it could impact areas of sea turtle nesting habitat on Jekyll Island. Transects of macroplastic debris were conducted over two different two-day periods at the start and end of the sea turtle nesting season. The results are limited in their representation of the overall status of the beach habitat given the narrow timeframe of the study period. Yet, they provide insight into plastic debris on the beach surface at specific meaningful points in time. Plastics are not stationary and their presence and clustering may change over time. Recognizing this phenomenon is important in considering how to study and address target areas of potentially higher plastic concentrations. Obtaining data from daily accounts of macroplastic detection during the entirety of the nesting season as well as throughout the year would provide a more encompassing view of plastic distribution along the beach. Previous research conducted by Martin et al. (2019) supports the need to examine longterm citizen-collected data on shoreline debris. Though the time scale of this research was narrower in comparison to the Martin (2019) et al. study with regard to debris data, in general, patterns of plastic distribution recorded during this research coincided with their findings. To note, there were variables that influenced the data collection for macroplastic debris in this research. Based on personal observation, the time of day in which the transect census was conducted could impact the results. Individuals, residents and tourists alike, would walk the shoreline in the early mornings removing trash. On at least one noted instance, a local had removed visible trash from the beach prior to Marine Debris Tracker data collection. The recorded macroplastic debris would have been different had this not occurred.

Further research is needed to establish a more robust baseline of plastics on and within the coastline of Jekyll Island. Given the significant and long-term sea turtle nesting on the island, data on the abundance of macro- and microplastics must be collected continually. The research conducted during this study was limited to two windows of sampling for macroplastics during the census. The Martin et al. (2019) study provides an assessment for the densities and distributions of macroplastic debris over a more encompassing time scale across their 6 year study period. Future research on macroplastics should be conducted throughout the year to determine possible temporal trends to aid in conservation practices and more refined beach cleanup efforts. Documenting certain patterns of variability in the concentration of microplastics along the coastline would require future research. This work demonstrates that there are microplastics within the sands with blue and white/transparent fibers noted in the greatest concentrations along the beach, and that microplastics were recovered from nests representative of nearly the entire coastline

A more robust assessment of the beach sand sediments on Jekyll Island could further elucidate the quantity and type of microplastics present and their distribution along the beach. Funding limitations and time restricted the ability to process and analyze additional nest cavity sediment samples. The initial patterns documented in this work were observed both the level of variations across the nest and overall patterns of nests across Jekyll Island. Yet, additional analysis at the level of more samples per zone could strengthen the results documented here. Performing extractions on more nests across the island and over a multitude of years could offer even more in-depth insight into the density, distribution, and composition of microplastics in sea turtle nests. Given that nesting consistently occurs in the greatest densities in the southern regions of Jekyll Island, initial future efforts could be focused on this portion of the island. Like macroplastics, microplastics are not unchanging in time and space. Rates of observations are subject to variations across time but are important to quantify nonetheless. The body of knowledge surrounding the effects of microplastics on sea turtles is a relatively new area of research and is largely still developing. To add, little research has been conducted regarding the sedimentology of sea turtle rookeries (Fuentes et al., 2010). Considering the global inundation of plastics on a vast number of coastal habitats, it is extremely valuable to further understand their impact on loggerhead nesting beaches, and the individuals themselves. This research provides some insight as to the global need of understanding how microplastics might affect sea turtle rookeries worldwide. Though active cleanups occur on Jekyll Island, microplastics are less easily detected, which also makes them much harder to remove from the sands. With these increased aggregations of plastics, there exists also a greater possibility of changes within the sea turtle nest micro-environment (Nelms et al., 2016). With Jekyll Island's economy being mainly founded on tourism and sea turtles, it is critical to continue to monitor the presence of macro- and microplastics to preserve the island's ecological integrity.

6 CONCLUSION

The intent of this research is to establish a census of both macro- and microplastics and begin to examine how this debris could factor into the success of loggerhead nests on Jekyll Island in southern Georgia. Along the beach, both macro- and microplastics were observed, with several kilometer zones identified as hot spots for macro-debris. Macroplastics, sampled in June and August of 2018, yielded 110 and 155 pieces, respectively. These results were regarded alongside nesting and false crawls from the 2018 loggerhead nesting season. Areas of overlap where both macroplastics and nesting activities were in high concentrations were identified at kilometers 2, 8-10 and 14 as hot spots for macroplastics at time of sampling. Of all macroplastics detected, cigarettes were the highest recorded accounting for 30% of all observed debris. An increased human footprint in the kilometer zones would increase the chance for improperly discarded debris. Without the island's active beach cleanups there likely would be an increased possibility of degradation to the quality of the nesting site. Microplastics were extracted and observed in 10 of the 11 nest cavity sediment samples distributed along the coastline, of which various colors and shapes were identified. Blue and white filaments dominated the microplastics detected within a nest as well as across all nests sampled. To ascertain kilometers of potentially at-risk zones for depreciated nesting sediment, 11 years of historical data from 2008 to 2018 regarding various nesting activities were examined to establish possible trends. Historically, nesting is aggregated toward the southern kilometers 10 through 12 of the island, where there is the largest stretch of berm from the vegetation line to the wrack line due to sediment deposition from net longshore currents. False crawls have several peaks along the coastline in kilometers 6 and 10 through 12. Little to no nesting activity, nesting or false crawls, occurred in kilometers 3-5 due to the presence of the rock wall. Nests were continuously relocated in kilometers 5 and 10 as the original nesting site was deemed at risk by the Georgia Sea Turtle Center. The duration of incubation across the 11 years was relatively consistent fluctuating within a 10 day range. Overall hatching and emerging success rates are showing a gradually increasing trend over time, indicating an overall good reproductive outcome for the nesting population of loggerhead sea turtles on the island.

The abundance of improperly discarded plastics is a rapidly rising global issue, and with it is the increase in the public's awareness of the ecological harm they are capable of causing. The predominant issue related to plastics is their longterm persistence, with fragmentation adding to the challenges of removing them from the system. Realizing effective conservation methods for species with complex life histories, such as sea turtles can prove to be an intricate task (Martin et al., 2007). Loggerhead sea turtles, with a vulnerable conservation status, are already under threat from anthropogenic activities, most of which impact sub-adult and adult individuals. Yet a more nuanced threat to embryonic sea turtles is the presence of microplastics within the sand, disrupting the fragile developmental micro-environment of the nest. There is clear documentation of a presence across the island that microplastics are accumulating in the sediments. Further work would need to investigate any variability in the concentrations that might lead to more concerns on nesting habitat degradation. With the numerous existing anthropogenic threats to sea turtles; stunted growth due to plastics only further decreases an individual's survivorship. It is crucial to continue to monitor the presence of both surface and subterranean plastics on Jekyll Island to further understand how this debris could detrimentally impact sea turtle offspring in the future. Female sea turtles demonstrate nesting site fidelity indicating that hatchlings on Jekyll Island will likely return to the island to nest. Depreciated nesting sediment would decrease the survivorship and fitness of these individuals, with the effects of extensive plastic accumulation potentially having a multi-generational impact. This research attempts to address how current quantities of macro-and microplastics could threaten sea turtle nesting site quality into the future, under current conservation efforts. Jekyll Island's economy is strongly tied to their sea turtle ecotourism industry, and ensuring its integrity into the future is to the benefit of not only the local economy, but to the intrinsic value of this important sea turtle nesting habitat and the survivorship of the species as a whole.

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