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Nest Success and Nest Predators of Seaside Sparrows  
(*Ammodramus maritimus*) following the *Deepwater Horizon* Oil  
Spill

Megan Hart

Nest Success and Nest Predators of Seaside Sparrows (*Ammodramus maritimus*) following the

*Deepwater Horizon* Oil Spill

A Thesis

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The College of Graduate Studies

Austin Peay State University

In Partial Fulfillment

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Master of Science in Biology

Megan Hart

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To the College of Graduate Studies:

We are submitting a thesis written by Megan Hart entitled “Nest Success and Nest Predators of Seaside Sparrows (*Ammodramus maritimus*) following the *Deepwater Horizon* Oil Spill”. We have examined the final copy of this thesis for form and content. We recommend that it be accept in partial fulfillment of the requirements for the degree of Master of Science in Biology.

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Megan Hart

08/09/2017



I dedicate this work to my wonderful family, who are always by my side. Without their support, none of this work would have been possible. This work is also dedicated to my two loving grandfathers that always believed I could do anything I put my mind to and encouraged me to make my dreams a reality. Thank you for making me the person I am today.

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## ABSTRACT

MEGAN E. HART. Nest Success and Nest Predators of Seaside Sparrows (*Ammodramus maritimus*) following the *Deepwater Horizon* Oil Spill. (Under the direction of DR. STEFAN WOLTMANN).

In 2010, the *Deepwater Horizon* oil platform released 4.9 million barrels of oil into the Gulf of Mexico. Out of the 1700 kilometers oiled, the heaviest oiling occurred on the Louisiana shoreline and salt marshes, which are the habitat for many organisms including year-round residents like the Seaside Sparrow (*Ammodramus maritimus*) (Michel et al. 2013). We monitored nests from mid-March to June of 2012 to 2017 on oiled and unoiled areas in Plaquemines Parish located in southeastern Louisiana. Nests were monitored every two to three days until nest fate was determined and categorized as successful, failed, or unknown. After fate was determined, vegetation structure and composition was recorded for nests and a corresponding random point (typified the overall plot vegetation). The main fate of Seaside Sparrow nests was failure and 83% of all nests failures were due to predation. When nest and plot vegetation were examined, there appears to be some difference between oiled and unoiled plots with some overlap between the two treatments. Nests placed in oiled areas had lower daily nest survival rates than nests in unoiled areas across all the years with variation between years. When we examined what variables were driving nest success, day of nest initiation within the breeding season and vegetation appeared to be important to predicting nest success. We were also able to identify three nest predators: Marsh Rice Rat (*Oryzomys palustris*), American Mink (*Neovison vison*), and Squareback Marsh Crab (*Armases cinereum*). It appears that Seaside Sparrow nest success may not be driven by oil presence but by differences in vegetation and nest initiation, which has the potential to affect predation probability.

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## Chapter I

### Introduction

The coastal ecosystems of the northern Gulf of Mexico provide a myriad of ecological and economic services like the protecting inland areas from storms and floodwater and providing habitat for food and game species, but these areas are also susceptible to anthropogenic disturbances. One such disturbance occurred on April 20, 2010, when the *Deepwater Horizon* platform exploded and sank in the Gulf of Mexico, which resulted in the deaths of 11 men aboard the platform and the uncontrolled release of oil. Over the next 87 days, the well continued to discharge oil while efforts were made to cap and contain the flow from the broken wellhead, spilling an estimated 4.9 million barrels of oil into the surrounding waters, making it one of the largest marine oil spills in United States' history (Camilli et al. 2010). By the time the cap was placed, oil had been widely distributed by currents to the northern Gulf coast, and much oil coated the ocean floor (Valentine et al. 2014). In all, 1,700 kilometers of shoreline were affected along the northern Gulf of Mexico, with the heaviest oiling occurring in Louisiana, which was the closest land area to the *Deepwater Horizon* platform (Mendelssohn et al. 2012, Michel et al. 2013). Because there had been few previous oil spills of this magnitude in the warm coastal waters of the Gulf of Mexico, the persistence of oil residue and the long-term effects of oil on these coastal and marine ecosystems are unknown.

The persistence of oil residue depends on the particular hydrocarbon composition of the oil, which may increase or decrease longevity of oil in the environment. Regardless of origin, all crude oil is made up of the same four main hydrocarbon compounds known as resins, asphaltenes, saturates, and aromatics (Leahy and Colwell 1990). These four components vary in



their concentration based on where the oil originates, but saturates and aromatics are usually the most abundant compounds found in crude oil (Mendelssohn et al. 2012). Saturates are usually straight-chained, branched, or cyclic structures and typically make up the greatest percentage of hydrocarbons found in crude oil, with some of the cyclic saturates being resistant to biodegradation (Mendelssohn et al. 2012). Aromatic hydrocarbons can range from simple single-ring structures to the more complex cyclic aromatic structures with multiple condensed rings, which are known as polycyclic aromatic hydrocarbons (PAHs; Mendelssohn et al. 2012). PAHs are the most toxic of the compounds in oil due to their unique structure and bonding capabilities, which increases their solubility and ability to influence various enzyme-mediated reactions that occur in organisms (Akcha et al. 2003). Because of the toxic and mutagenic effects of PAHs, they are the most environmentally significant compounds found in crude oil. In addition to their toxicity, PAHs are typically the last compounds to degrade in the environment and can persist years after a spill, which is the case in the 1989 *Exxon Valdez* spill (Short et al 2007, Esler et al. 2010). The long-term effects of toxic oil compounds are largely unknown and are of great concern for organisms and ecosystem functions in the affected areas (Mendelssohn et al. 2012). In contrast with the almost immediate impact to the shoreline following the *Exxon Valdez* spill, *Deepwater Horizon* oil (also known as Macondo oil, as it originated from the Macondo well) did not reach mainland Louisiana until May, which allowed for degradation via ultraviolet radiation and microbial processes before it washed ashore (Leahy and Colwell 1990, Turner et al. 2014). However, the extent of degradation of PAHs and the potential effects of oil in coastal ecosystems is still not fully understood.

When organisms come in contact with oil, effects from the exposure are varied in their severity and symptoms. Direct effects of oil often involve the physical coating of organisms, and

symptoms appear soon after contact (Ball and Truskewycz 2013). Oil reduces the water-repellant and thermoregulatory capabilities of fur and feathers, causing hypothermia and potentially death from inadequate thermoregulation (Jenssen 1994). Oil coating can also affect flight performance in birds, and can cause suffocation if oil is ingested or inhaled by organisms like aquatic mammals or seabirds that utilize the water and air interface for feeding or breathing (Ball and Truskewycz 2013). In addition, oil in hypoxic areas like the Dead Zone in the northern Gulf of Mexico can also cause a further oxygen deprivation from microbes breaking down the oil compounds, which can cause suffocation and result in large die offs of aquatic organisms (Whitehead 2013). These direct effects can cause increased mortality in many species exposed to oil, and this is what typically comes to mind when first considering the dangers of oil to organisms.

Exposure to oil can also have effects that are not as readily apparent compared to the external coating of an organism. These effects may not be immediately lethal but have the potential to persist for many years (Bergeon Burns et al. 2014). For example, the longevity and toxicity of PAHs can cause damage to organisms and their surrounding environment; damage by toxic substances can often be identified through the upregulation of detoxification genes. PAHs can be detected relatively soon through the upregulation of the detoxification gene hepatic cytochrome P450 oxygenase (CYP1A) (Oris and Roberts 2013). Prolonged exposure to PAHs can cause the formation of PAH metabolites that bind to and damage an organism's DNA, which causes the formation of DNA adducts that are genotoxic (Neff 1979, Bergeon Burns et al. 2014). If these adducts are not repaired by the body, normal cells can malfunction that, in turn, can lead to mutations and cancer, especially in longer lived organisms like humans (Akcha et al. 2003). Other effects of PAHs include reproductive dysfunction, immunosuppression, hepatic and renal

damage, and edema in vertebrates (Malcom and Shore 2003, Alonso-Alvarez et al. 2007). PAHs can have developmental effects on the offspring of organisms in affected areas and exposure primarily occurs through maternal transfer or topical exposure, which can cause damage to cells, developmental abnormalities, reduction in body measurements, and reduced survival of young (Albers 2006). Some of these developmental abnormalities were observed on developing Mahi Mahi (*Coryphaena hippurus*) larvae when exposed to different concentrations of *Deepwater Horizon* oil. The larvae exhibited developmental abnormalities in their cardiovascular system and were symptoms of cardiogenic syndrome like contractility, looping, and circulatory defects (Edmunds et al. 2015). This relative sensitivity to oiling was seen in the early developmental stages of the organisms, which underlines the potential adverse effects on organisms that were oiled during the larval or juvenile stage during the *Deepwater Horizon* oil spill (Edmunds et al. 2015).

Secondary poisoning is another main pathway by which organisms are directly affected by oil; this typically occurs through ingestion of contaminated prey items (Bergeon Burns et al. 2014). Both original source oiling and secondary oiling (both are types direct oiling) was seen in Common Loons (*Gavia immer*) after the *Deepwater Horizon* oil spill. Common Loons had oil on their feet, abdomen and tail, which is attributed to original source oiling. Common Loons also had PAH accumulations in their tissues from ingestion of contaminated prey items and the preening of feathers exposed to oil, which constitute secondary and original source oiling (Paruk et al. 2014).

Of the many areas that were impacted by the *Deepwater Horizon* spill, coastal wetlands and salt marshes were among the most heavily affected, accounting for 45% of the overall oil impacted areas (Mendelssohn et al. 2012, Michel et al. 2013). The southern Atlantic and Gulf



coasts of North America hold the greatest concentration of the salt marshes in the world, which cover around 15,000 square kilometers (Greenberg et al. 2006). Due to the proximity of the *Deepwater Horizon* oil rig to the Louisiana coast, 95% of all salt marsh oiling occurred in Louisiana. Salt marshes are wetlands that form near relatively sheltered coastlines of major continents in areas that also have both freshwater and saltwater influence, which allows for the build-up of sediment overtime (Greenberg et al. 2006). These areas of sediment are subsequently colonized by salt tolerant grasses like *Juncus roemerianus* (Black Needlerush) and *Spartina alterniflora* (Smooth Cordgrass), which are typically the dominant plant species in these areas and help stabilize sediment (Greenberg and Maldonado 2006).

North America has experienced an estimated overall loss of 30-40% of coastal wetlands from anthropogenic activities like diking, development, and agriculture. The southeastern United States lost an estimated 13,000 hectares of salt marsh from 1985-1995 (Greenberg et al. 2006). Additionally, sea level rise has resulted in reduction of coastal wetlands and is projected to continue to lose 0.5% to 1.5% of marsh per year through 2025 (Titus 1988). Sea level rise will continue to put more pressure on these systems and any additional stressors like the *Deepwater Horizon* oil spill, for example, may speed up the rate of marsh loss and affect the ecological function of the marsh.

Salt marshes are an important ecotone between terrestrial, freshwater, and marine ecosystems. For example, they provide refuge to a variety of year-round and seasonal marine and terrestrial life because of the important and close-linked interface between land and water (Greenberg and Maldonado 2006, Paruk et al. 2014). These areas are also known host fisheries for economically important marine species and provides habitat for a diverse variety of invertebrate and vertebrate species (Greenberg and Maldonado 2006). Even though salt marshes

are diverse with vertebrate and invertebrate species that live around or utilize the marsh for part of the year, there are relatively few terrestrial vertebrates that live year round and breed in salt marshes. Even fewer terrestrial vertebrates are salt marsh specialists, which may be due to their patchy distribution, high salinity, frequent flooding, and overall low structural heterogeneity (Greenberg and Maldonado 2006). The few year-round residents and specialists that are reliant on the salt marsh ecosystem affected by the *Deepwater Horizon* oil spill are the most susceptible to detrimental effects from oil contamination (Bergeon Burns et al. 2014).

The Louisiana salt marshes were some of the most heavily impacted areas of the oiled coastline. One way that the marsh was affected was through changes of vegetation health and structure. Gulf coast salt marshes are composed predominately of *Juncus roemerianus* and *Spartina alterniflora* with each of these residing in different proportions throughout the marsh (Greenberg and Maldondo 2006). When *Juncus* and *Spartina* were heavily oiled, both suffered mortality, which could be due to reduced cellular respiration and photosynthesis (Pezeshki et al. 2000, Lin and Mendelssohn 2012, Silliman et al. 2012). When both species were exposed to moderate amounts of oil, *Spartina* did not suffer as much mortality when compared to *Juncus*, which still suffered heavy mortality (Lin and Mendelssohn 2012). *Spartina* also displayed no significant effect of oil on the aboveground biomass and stem density (Lin and Mendelssohn 2012). *Juncus*, on the other hand, had reduced aboveground biomass and stem density at oiled sites (Lin and Mendelssohn 2012). *Spartina* was much less susceptible to shoot oil coverage than *Juncus* (Lin and Mendelssohn 2012). In addition, *Spartina* took up to seven months to recover from total shoot coverage oiling while *Juncus* was not able to recover as well (Lin and Mendelssohn 2012). These responses of marsh vegetation to heavy and moderate oiling

increased shoreline erosion in the affected areas, which are already under pressure from sea level rise and marsh subsidence (Lin and Mendelssohn 2012, Silliman et al. 2012).

One of the most abundant vertebrate species found in the salt marsh is the Seaside Sparrow (*Ammodramus maritimus*). Seaside Sparrows are one of the few endemic and year-round resident vertebrates in the salt marshes along the Atlantic and Gulf coasts of North America. The salt marshes of the two coasts differ in their abiotic and biotic influences, including, higher tides on the Atlantic coast, and different vegetation composition, both of which appear to have resulted in differences in nesting strategies of marsh-dwelling sparrows (Greenberg and Maldonado 2006). Most research on Seaside Sparrows has focused on the Atlantic coast populations, which has left the Gulf coast populations fairly understudied.

In all five of the Gulf coast states, the Seaside Sparrow is listed as a species of conservation concern mainly due to pressures of sea level rise on the salt marsh ecosystem (Bergeon Burns et al. 2014). Seaside Sparrows live and build their nests in the salt marsh grasses and feed primarily on invertebrates and seeds found within the marsh vegetation and on the sediment, which may put them at higher risk of contamination from oiled sediments and vegetation (Post and Greenlaw 2009). In the first two years after the oil spill, there was a decrease in Seaside Sparrow abundance on oiled sites (Stouffer et al. 2013). These findings, along with preliminary analyses that have shown lower fledging probability at oiled sites, indicate that Seaside Sparrows were affected to some degree by the *Deepwater Horizon* oil spill (Bergeon Burns et al. 2014). Seaside Sparrows could mainly be affected through vegetation structure change due to their reliance on vegetation for the concealment of nests and areas in which to forage (Post and Greenlaw 2009). With decreased stem density, nests may be more exposed and, therefore, more at risk for nest predation, which is the leading cause of avian nest



failure (Ricklefs 1969, Martin 1995). Because these birds are year-round residents, closely tied to the marsh ecosystem, nest within the salt marsh grasses, and have been shown to have been affected by oil, they are a good indicators marsh health after the *Deepwater Horizon* oil spill.

One way to assess changes in fitness and survival in avian species like the Seaside Sparrow is through studying nest success. Nest success is the probability that a nest survives to produce at least one fledgling (Rotella et al. 2004). Estimates of nest success may help explain changes seen at the population level (Rotella et al. 2004). For example, if nest success for a species is lower in one breeding season than others, one would expect to see a decrease in the population size or perhaps a shift in age structure for the population over time. A change in fitness could also be seen through a decrease in genes that were not passed on to the subsequent generation because of the lower nest success. Nest success studies have been widely used to study anthropogenic changes to the landscape, effects of nest parasites and predators, edge effects, and microhabitat differences (Keyser et al. 1998, Benson et al. 2010, Johnson et al. 2012, Vasseur and Leberg 2015).

There are many factors that can positively or negatively affect nest success for Seaside Sparrows. For example, on the Atlantic coast, Seaside Sparrow nest success was found to be influenced by the height of the nest site chosen by the female (Hunter et al. 2016). Seaside Sparrows used threat predictability to decrease the chances of failure by lowering nest height, which reduces the chances of detection by predators (Hunter et al. 2016). If a pair's previous nest was flooded, nest height of the subsequent nest was raised, presumably to reduce the chances of flooding occurring again (Hunter et al. 2016). However, nests placed in higher vegetation may be located near areas inhabited by Marsh Rice Rats (*Oryzomys palustris*; a potential Seaside Sparrow nest predator), which tend to live in taller *Juncus* and *Spartina* patches (Post 1980;

Gjerdrum et al. 2005). This predation risk could drive Seaside Sparrows to seek out lower vegetation to avoid detection by Marsh Rice Rats, which could lead to higher chances of flooding (Post 1980). Along the Gulf coast, nest concealment from predators may be the main driving force behind Seaside Sparrow nest success because tidal flooding risk is lower and less predictable than on the Atlantic coast. If oiled areas have altered vegetation characteristics from oiling (e.g., decreased *Juncus*), it may result in reduced nest concealment, which, in turn, could decrease nest success.

To identify effects of oil on Seaside Sparrow nest success, we conducted a study from 2012-2017 in the southern Louisiana salt marshes affected by the *Deepwater Horizon* oil spill. We monitored Seaside Sparrow nests on oiled and unoiled plots, conducted vegetation surveys on each nest, and used video surveillance to assess causes of failure. Nest survival data were used to build models to describe factors that influence nest success, which included variables for year, plot, vegetation, and precipitation. We hypothesized that there would be a difference in nest success between oiled and unoiled plots. It was predicted that (1) oiled plots would have lower nest success than unoiled plots, (2) vegetation characteristics at nests would be different from the overall vegetation of the plot, (3) Seaside Sparrows would place their nests non-randomly on the plot to increase nest concealment, and (4) predation by Marsh Rice Rats would be the main cause of failure. This chapter represents an overall introduction to the various studies conducted in this thesis.

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## CHAPTER II

# Nest success of Seaside Sparrows (*Ammodramus maritimus*) after the *Deepwater Horizon* oil spill

### Introduction

The coastal ecosystem of the northern Gulf of Mexico provides a myriad of ecologic and economic services, but these areas are also susceptible to anthropogenic disturbances. One such disturbance occurred on April 20, 2010, when the *Deepwater Horizon* platform exploded and sank in the Gulf of Mexico, which resulted in the deaths of 11 men aboard the platform and the uncontrolled release of oil. Over the next 87 days, the well continued to discharge oil while efforts were made to cap and contain the flow from the broken wellhead, which led to the spill of an estimated 4.9 million barrels of oil into the surrounding waters and made it one of the largest marine oil spills in United States' history (Camilli et al. 2010). By the time the cap was placed, oil had been widely distributed by currents to the northern Gulf coast, and much oil coated the ocean floor (Valentine et al. 2014). By the end of the oiling event, 1,700 kilometers of shoreline were coated along the northern Gulf of Mexico, with the heaviest oiling occurring in Louisiana, which was the closest land area to the *Deepwater Horizon* platform (Mendelssohn et al. 2012, Michel et al. 2013). Because there have been few oil spills of this magnitude in the warm coastal waters of the Gulf of Mexico, the persistence of oil residue and the potential long-term effects of oil on coastal and marine ecosystems is poorly understood.

Of the many areas that were impacted by the *Deepwater Horizon* spill, coastal wetlands and salt marshes were among the most heavily affected, accounting for 45% of the overall oil impacted areas (Mendelssohn et al. 2012, Michel et al. 2013). Of these affected areas, 95% of all salt marsh oiling occurred in Louisiana (Michel et al. 2013). Heavily oiled salt marshes

experienced die-offs of Black Needlerush (*Juncus roemerianus*) and Smooth Cordgrass (*Spartina alterniflora*), which are the dominant vegetation species in this system (Pezeshki et al. 2000, Lin and Mendelssohn 2012, Silliman et al. 2012). When both species were in areas that were moderately oiled, *Spartina* suffered less mortality compared to *Juncus* (Lin and Mendelssohn 2012). In addition, areas where *Spartina* was heavily oiled took up to seven months to recover completely; *Juncus* took a year or longer to recover (Lin and Mendelssohn 2012). These responses of marsh vegetation to heavy and moderate oiling increased shoreline erosion by almost double in some of the affected areas, which are already under pressure from sea level rise and marsh subsidence (Lin and Mendelssohn 2012, Silliman et al. 2012).

The effects of oiling can vary in their severity and symptoms. Direct effects of oil (original source oiling) often involve the physical coating of organisms and symptoms appear soon after contact occurs (Ball and Truskewycz 2013). Oil reduces the water-repellant and thermoregulatory capabilities of fur and feathers, causing hypothermia and potentially death from inadequate thermoregulation (Jenssen 1994). Oil coating can also affect flight performance in birds, and can cause suffocation if oil is ingested or inhaled by organisms like aquatic mammals or seabirds that utilize the water and air interface for feeding or breathing (Ball and Truskewycz 2013). Secondary poisoning is also thought to be one of the main pathways by which avian species are affected by oil; this typically occurs through ingestion of contaminated prey items (Bergeon Burns et al. 2014). Both original source oiling and secondary oiling was exhibited by Common Loons (*Gavia immer*) after the *Deepwater Horizon* oil spill. Individuals had visible oil on their feet, abdomens, and tails, which is attributed to original source oiling. Common Loons also had polycyclic aromatic hydrocarbon (PAH) accumulation in their tissues

that resulted from ingestion of contaminated prey items and the preening of feathers exposed to oil, which constitute secondary and original source oiling (Paruk et al. 2014).

One of the most abundant vertebrate species found in the salt marshes of eastern North America is the Seaside Sparrow (*Ammodramus maritimus*). The Seaside Sparrow is one of the few endemic and year-round resident vertebrates in the salt marshes along the Atlantic and Gulf coasts. Seaside Sparrows live and build their nests in the salt marsh grasses, and feed primarily on invertebrates and seeds found within the marsh vegetation and on the sediment, which may put them at higher risk of contamination from oiled sediments and vegetation (Post and Greenlaw 2009). In the first two years after the oil spill, there was a decrease in Seaside Sparrow abundance in oiled areas (Stouffer et al. 2013). These findings, along with preliminary analyses that suggested lower fledging probability at oiled sites, show that Seaside Sparrows were affected to some degree by the *Deepwater Horizon* oil spill (Bergeon Burns et al. 2014). Due to the fact that these birds are year-round residents, closely tied to the marsh ecosystem, and have been shown to have been affected by oil, Seaside Sparrows are a good indicators of marsh health after the *Deepwater Horizon* oil spill.

One way to assess changes in fitness and survival in avian species like the Seaside Sparrow is by studying nest success. Nest success is the probability that a nest produces at least one fledgling (Rotella et al. 2004). Estimates of nest success may help explain changes seen at the population level (Rotella et al. 2004). Nest success studies have been widely used to study anthropogenic changes to the landscape, effects of nest parasites and predators, edge effects, and microhabitat differences (Keyser et al. 1998, Almario et al. 2009, Benson et al. 2010, Johnson et al. 2012, Pretelli et al. 2015, Vasseur and Leberg 2015). The results of these studies can inform management decisions to increase avian productivity of at risk species (e.g., by promoting



vegetation structure that increases nest success, or implementing predator control measures) and understand the effects of anthropogenic disturbances on avian nest survival.

To identify possible impacts of oil on Seaside Sparrow nest success, we conducted a study from 2012-2017 in the salt marshes in the affected areas of southern Louisiana. We hypothesize that there would be a difference in nest success between oiled and unoiled plots. We tested our predictions that (1) nest success would be lower on oiled plots, (2) vegetation characteristics at nests would be different from overall plot vegetation, and (3) predation would be the main cause of nest failure.

## Methods

Our study sites were in Plaquemines Parish, in southeastern Louisiana (Figure 1). These salt marshes were among the most heavily oiled by the *Deepwater Horizon* oil spill (Michel et al. 2013). Plots were 50 m deep (inshore) and 500 meters long, as oil generally did not penetrate farther than 50 m into the marsh (Khanna et al. 2013). Three plots were designated as unoiled (little to no oil) and four plots were designated as oiled (moderately to heavily oiled) based on Shoreline Cleanup and Assessment Technique (SCAT) surveys maps (<http://gomex.erma.noaa.gov/erma.html#/x=-89.37870&y=29.14486&z=7&layers=16+6770+15879+19872+19897>) (Santner et al. 2011). All saltmarsh in the study area is dominated by Smooth Cordgrass (*Spartina alterniflora*), Black Needlerush (*Juncus roemerianus*), and, to a lesser extent, Saltgrass (*Distichlis spicata*).

Seaside Sparrow nests were monitored from mid-March to June of 2012 – 2017. Nests were located using behavioral cues and systematic searches. Search effort was measured as person-hours and effort was made to equalize person-hours between treatments. Nests were monitored every two to three days throughout the 25 to 26 day nesting cycle (time in which a

nest is active) until fate was determined. A nest was classified as successful if the nest fledged at least one nestling, which was determined by either sighting of fledglings near the nest, adults carrying food to the area post-fledging (nestling age day 9), begging sounds of fledglings, or fledgling fecal matter in or on the rim of the nest or on the surrounding vegetation (Martin et al. 1997). Nests were classified as failed if eggs or nestlings disappeared from the nest before fledge day with no evidence of early fledging, the presence of egg shells or nestling remains, or if the nest was torn, tilted, or destroyed before fledge date. An unknown fate was assigned to nests that were empty near fledge day, but no parents or fledglings were seen and no other signs of predation of fledging were found.

After nest fate was determined, we measured vegetation characteristics around each nest. Nest vegetation data were collected following the protocol of Lehmiche (2014). A one meter square made of four 1 meter PVC segments was centered on the nest. A Wiens pole was placed in the ground next to the nest with 20 centimeter increments (Wiens and Rotenberry 1981). The Wiens pole was then placed in each of the four corners of the one meter square and the number of live stems, dead stems, woody material, and other vegetation materials like vines that were touching the pole were counted within each 20 cm increment (Wiens and Rotenberry 1981). From these values, the total number of stems and variance were calculated for each 20 cm increment. Percentages of cover were estimated for the main vegetation species for the one meter square and five meter square. For each nest, a random point was chosen within 8- 25 m of each nest, and the same vegetation survey was done for the random points except for the nest height measurement and predominate vegetation species for the nest. The random point was chosen at a maximum distance of 25 meters to increase the likelihood that it was within the territory of the male, and was representative of a potential nest site not chosen by the female (Jones 2001).

We used a principal components analysis (PCA) using package R stats in R version 3.3.1 (R Core Team 2016) to evaluate whether nest placement on plots was non-random through the descriptive evidence provided by the PCA. Vegetation data were first Box Cox transformed using *preprocess* in package Caret (Table 1) (Kuhn et al. 2016). Variables with zero or near zero variance were removed using *nearZeroVar* using package Caret (Kuhn et al. 2016). Pairwise correlations between variables were examined and any pair with Pearson's correlations of  $r^2 \geq 0.50$  had one of the two variables removed. The command *prcomp* from the R stats package was used to perform a principal components analysis (R Core Team 2016). The *fviz\_pca* package was used to visualize PCA output (Wickham and Chang 2016, Kassambara and Mundt 2017). We used *fviz\_contrib* to characterize the variables contributing most to each axis (Wickham and Chang 2016, Kassambara and Mundt 2017).

MARK v 6.2 (White 2016) was used to build models to describe what drives nest success and to estimate daily survival rates (White and Burnham 1999, White 2016). We formatted our nest survival data by placing failure date at the midpoint between nest checks. For nests that were found and failed during the incubation period, we placed their nest initiation date at the midpoint of the incubation period (day 6) in order to maximize the number of nests that could be used for our analyses (Pretelli et al. 2015). Several variables were investigated that were thought to affect nest success like precipitation, day of nest initiation within the breeding season, year, treatment, and vegetation variables. All models used the logit link function, which allows for daily survival rates to vary among groups of nests, among individual nests, and among days (Rotella et al. 2004). We used an information theoretic approach to evaluate support for models with models having a  $\Delta AIC$  of less than 2 considered as having substantial support.

## Results



A total of 286 active nests was found and monitored across oiled and unoiled sites from 2012-2017. Of these nests, 65 succeeded, 201 failed, and 20 had unknown fates (Figure 2). The main fate for Seaside Sparrow nests in all years was failure (Figure 2). We categorized failure as due to: flooding, predation, or unknown. Of the 201 nests that failed, 167 failed due to predation, 8 to flooding and 26 to unknown causes (Figure 3).

Nest and random point vegetation characteristics (Table 1) were selected to conduct our principal components analysis (PCA) to examine differences in nest and plot characteristics between treatments and if nest placement was non-random. Principal components 1 and 2 accounted for 36.7% of the variation in the data (Table 2). The PCA revealed that nests on oiled plots typically had less *Juncus* and shorter vegetation, with a tendency for more *Distichlis* and other types of ground cover near the nest than nests on unoiled plots (Table 2, Figure 4, Figure 5). Vegetation structure and composition characteristics for nest sites among treatments reflect plot level characteristics, with PC2 providing most of the separation between treatments (Figure 4). However, there is still much overlap in vegetation characteristics between the two treatments; similar vegetation characteristics can be found to varying degrees on both unoiled and oiled plots. Using the same PCA, we found that nest placement is random: nest points and random points overlapped broadly within treatments (Figure 5). However, there may be a small amount of nest site selection due to some atypical nest site choices that lie outside of the vegetative characteristics found on the overall plot.

We examined various daily survival rate (DSR) scenarios to see if treatment was having an effect on survival. Overall DSR ( $0.905 \pm 0.007$  SE) was estimated by combining all years and treatments. When treatment was examined, oiled plots had lower daily survival rates than

unoiled plots (Oiled:  $0.897 \pm 0.0092$  vs. Unoiled:  $0.919 \pm 0.010$ ) and this trend was seen in all years of the study (Figure 5).

We explored models of DSR using combinations of variables we suspected may affect nest success (e.g., vegetation, precipitation, year, treatment, and day of nest initiation). The top eight models and the global model are shown in Table 3. No single model best described what is driving nest success. The model with highest support contains PC2 and day of initiation, but it is within 2 AIC units of the six subsequent models. Day of initiation and PC2 consistently appeared in most of the top models (Table 3). As initiation day occurs later in the season, daily survival rate estimates tend to decrease (Figure 6). Daily survival rate decreases as PC2 increases in the top model, which describes less *Juncus* and shorter vegetation (Figure 7).

## Discussion

Seaside Sparrows and their habitat were exposed to oil from the *Deepwater Horizon* oil spill in the salt marshes of southeastern Louisiana. We found that failure was the main nest fate for Seaside Sparrows, and that the primary cause of nest failure was predation. This finding contrasts with studies along the Atlantic coast, where flooding from high tides are the main cause of nest failure (Gjerdrum et al. 2005, Hunter et al. 2016). Gulf coast tides are mainly driven by wind direction and speed whereas Atlantic tides are more strongly driven by lunar cycles, and thus are more predictable threats to nests (Greenberg and Maldondo 2006).

Vegetation structure and composition can affect nest success of birds (Flaspohler et al. 2000, Weidinger 2002, Gjerdrum et al. 2005). Nest vegetation on oiled and unoiled plots appear to differ to some extent on our study sites. Oiled plots tended to have less *Juncus* and shorter vegetation, while unoiled plots typically had taller vegetation and more *Juncus*. Despite some differences between the two plots, there is still a substantial amount of overlap between the

vegetation characteristics on the two treatments. Seaside Sparrows also appear to place most of their nests randomly on the plots, which can be seen by the nearly complete overlap in vegetation characteristics. We conclude that Seaside Sparrows do not seem to select specific vegetation characteristics for nests based on the microhabitat variables we measured for each nest site. However, we cannot rule out some level of nest site selection due to characteristics that were unable to be measured like differences in vegetation between the edge and inland areas of the marsh because of the study limitations (i.e. plot dimensions and placement along edges of marsh).

Nest initiation date appeared in most of our top models of DSR. DSR appears to decline between March and June. These differences in nest success during the nesting season could be due to a lower density of nests at the beginning of the season. Daily survival rate estimates could also be driven by increased predator density and movement at the end of the nesting season, which has been suggested for higher DSRs in early nesting seasons compared to late nesting season in Clay-colored Sparrows and Vesper Sparrows (Grant et al. 2005). As the season progresses, there are more nests and increased parental activity, which could inform predators where nests are located on the plot (Weidinger 2002).

Our nest success models support the assumption that vegetation composition and structure influences nest success for Seaside Sparrows. One variable that consistently appeared in our top models was vegetation PC2. PC2 describes the amount of *Juncus* and vegetation height. Nest success decreased as vegetation around it was shorter and contained less *Juncus*, which are characteristics more commonly found on oiled plots. These differences in vegetation may have contributed to daily nest survival rates being consistently lower on oiled plots than unoiled plots. One explanation for lower nest success in areas with these vegetation



characteristics is easier detection by predators. Higher predation rates were seen on plots that had shorter vegetation and less *Juncus*. Shorter vegetation could decrease nest concealment, which could increase predator detection (Weidinger 2002, Johnson et al. 2012). The available nesting areas in oiled plots may also be the preferred habitat for both Seaside Sparrows and their main nest predators. Seaside Sparrows and Marsh Rice Rats share many ecological requirements, such as similar habitat, food sources, and nesting sites, and Marsh Rice Rats are thought to be a main predator of Seaside Sparrow nests (Post 1981). Additional work is needed to better understand bird nest predator communities.

Differences of vegetation composition and structure on oiled and unoled plots may not be due to oil presence. Although vegetation was affected by the oil spill, salt marsh vegetation on oiled plots recovered within six months to a year after being oiled and much of the original shoreline that was affected may have eroded away (Lin and Mendelsohn 2012, Silliman et al. 2012, Khanna et al. 2013). The vegetation differences we detected may be due to fundamental differences in the plots like shoreline aspect, which influences water levels, flooding, and whether oil reached the shoreline in the first place (Michel et al. 2013). Oiled plots tended to have south-facing shorelines, were generally drier, and more frequently dominated by shorter vegetation. In contrast, unoled plots were not south-facing, were more frequently inundated by water, and more frequently had taller vegetation structure. Therefore, the observed differences in Seaside Sparrow nest survival may be more closely tied to natural differences in vegetation structure or nest predator community than to differences due to oiling history.

Unfortunately, due to lack of pre-spill data regarding nest success and vegetation structure, it is difficult to assess how much of these differences in DSR are due to oil or fundamental plot characteristics. This study provides useful baseline data on Seaside Sparrow

nest success and vegetation structure and composition of nests and plots in the Louisiana Gulf coast salt marshes. These data can be used to compare changes in nest success and plot characteristics due to sea-level rise, future oil spills, and other disturbances. There is still much we do not know about Seaside Sparrow life history, especially on the Gulf coast. It is thus imperative that we continue research on this species so we can predict how future changes in habitat will affect this salt marsh endemic.

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### Tables and Figures

TABLE 1. Vegetation variables used in principal components analysis.

Variable	Description
Green Stems	Total number of live stems touching the Wiens pole from 0-140 cm
Dead Stems	Total number of dead stems touching the Wiens pole from 0-140 cm
Total Stems	Total stem number touching the Wiens pole from 0-140 cm
Variance	Measures heterogeneity from 0-140 cm
Percent Cover (1 and 5 meter <sup>2</sup> )	Percent cover of <i>Juncus</i> , <i>Spartina</i> , <i>Distichlis</i> , Water, Bare, Detritus, and Other

TABLE 2. Highest contributing variables and directions of their effects on principal component 1 and principal component 2.

	Variables	PC Loadings
PC 1	Amount of <i>Distichlis</i> within 1 meter <sup>2</sup> (+)	0.472
	Amount of live and dead stems from 20-40 cm (+)	0.400
	Heterogeneity of stems from 40-60 cm (+)	0.363
	Live stems from 0-20 cm (+)	0.345
	Amount of cover of other materials within the 5 meter <sup>2</sup> (+)	0.284
PC 2	Amount of dead stems from 100-120 cm (-)	-0.513
	Heterogeneity of stems from 80-100 (-)	-0.507
	Amount of <i>Juncus</i> cover within 1 meter <sup>2</sup> (-)	-0.500

TABLE 3. The top models that explain nest success of Seaside Sparrows.

Model	AICc	Delta AICc	AICc Weight
PC2 + Initiation Day	882.4861	0	0.21775
DSR varies across season	883.2375	0.7514	0.14955
Initiation Day	883.497	1.0109	0.13135
Treatment + Initiation Day	883.7853	1.2992	0.11372
Treatment + PC2 + Initiation Day	883.8511	1.365	0.11004
DSR varies across season + Initiation Day + PC2	884.0796	1.5935	0.09816
PCA1+PC2 + Initiation Day	884.1215	1.6354	0.09816
Precip+PC2 + Initiation Day	884.487	2.0009	0.09816
Global Model	890.8979	8.4118	0.00325

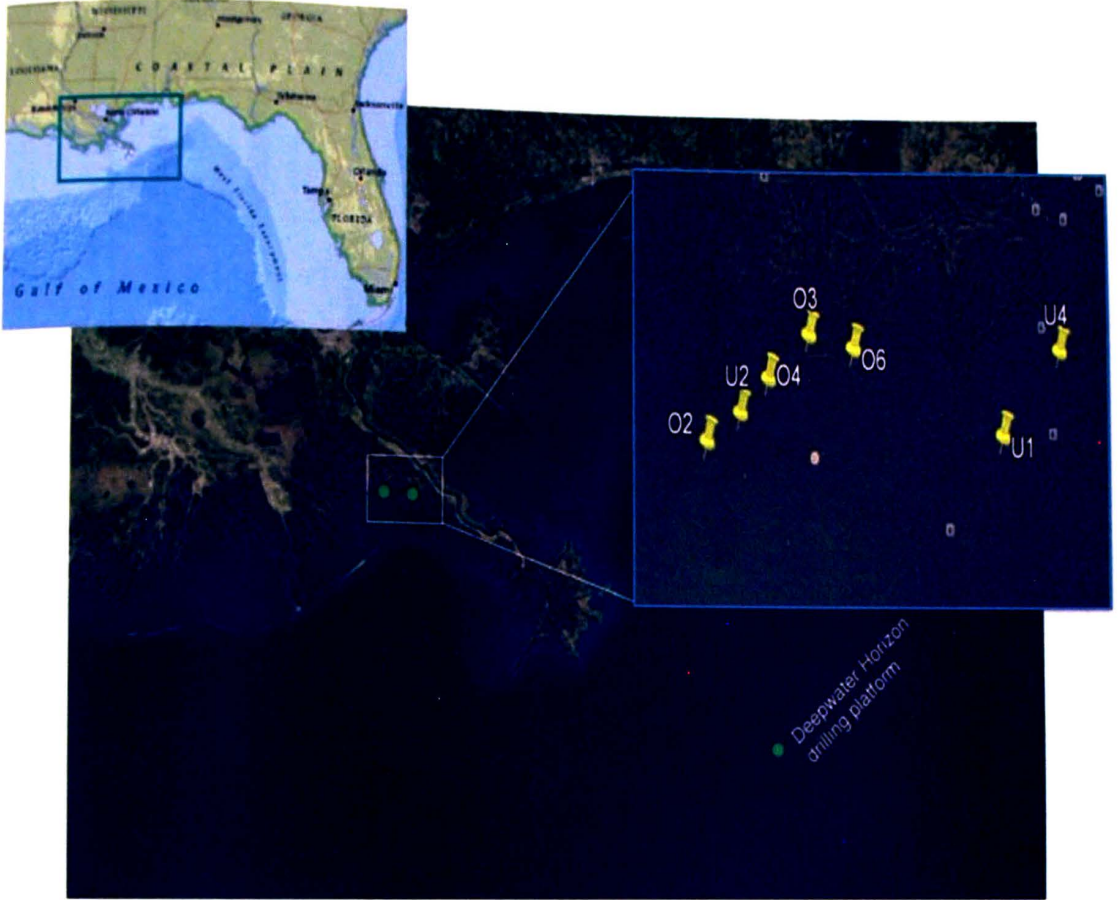


FIGURE 1. Location of study sites in Plaquemines Parish, Louisiana, 2012-2017. Modified from Bonisoli Alquati et al. 2016.



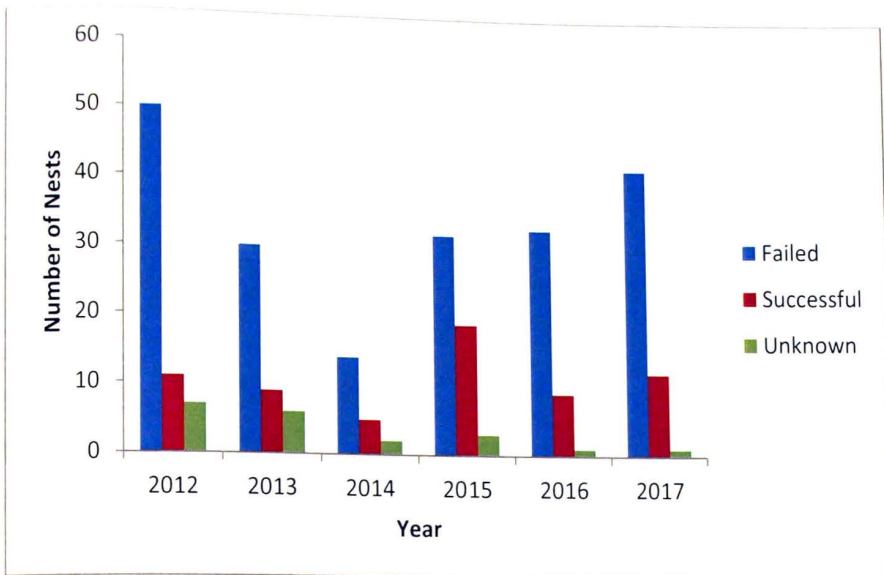


FIGURE 2. Seaside Sparrow nest fates from 2012 to 2017. There were three categories: failed, successful, and unknown.

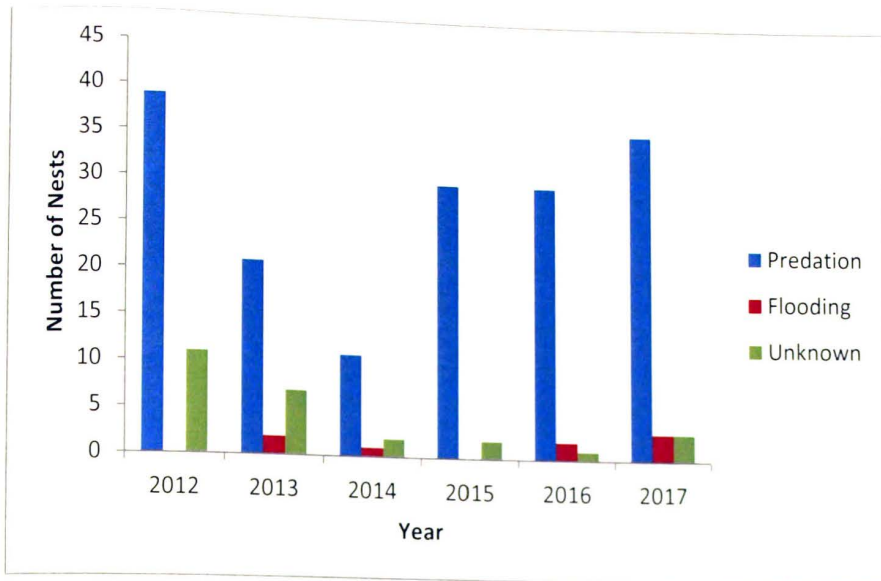


FIGURE 3. The causes of Seaside Sparrow nest failure from 2012 to 2017. The three categories were predation, flooding, or unknown cause.

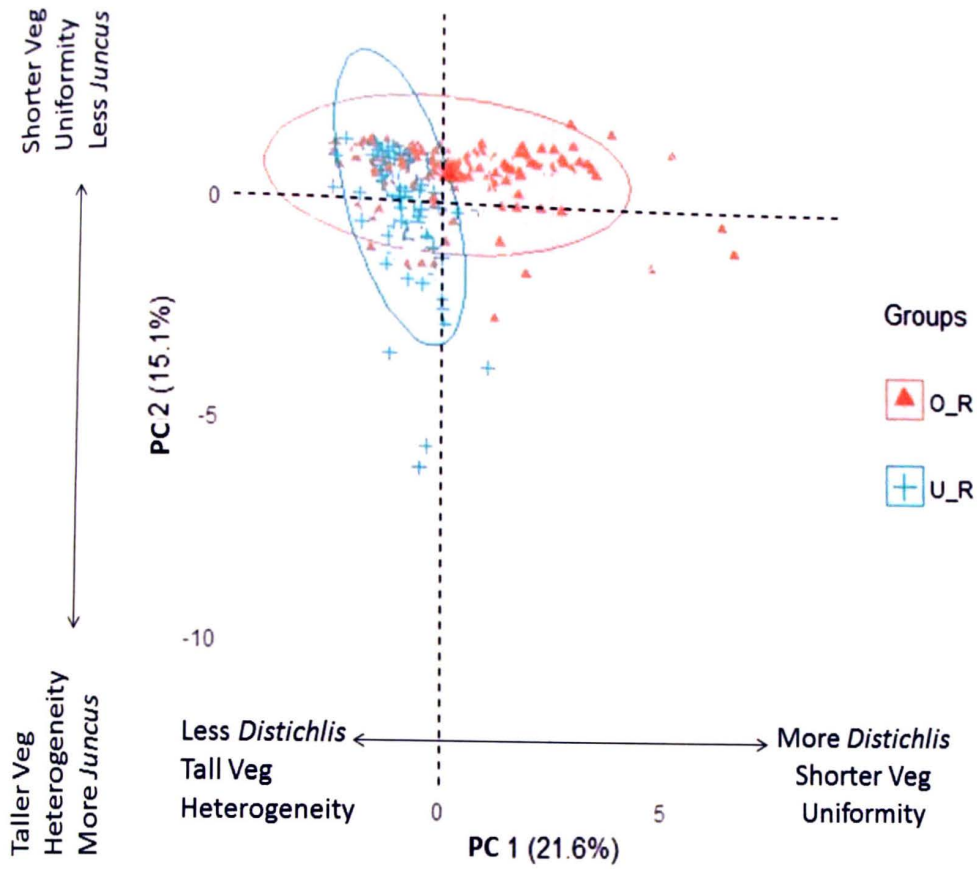


FIGURE 4. Principal components analysis of overall vegetation characteristics found in oiled (O\_R) and unoiled plots (U\_R). The blue-green cross and ellipse represents unoiled plots and the orange triangle and ellipse represents oiled plots.

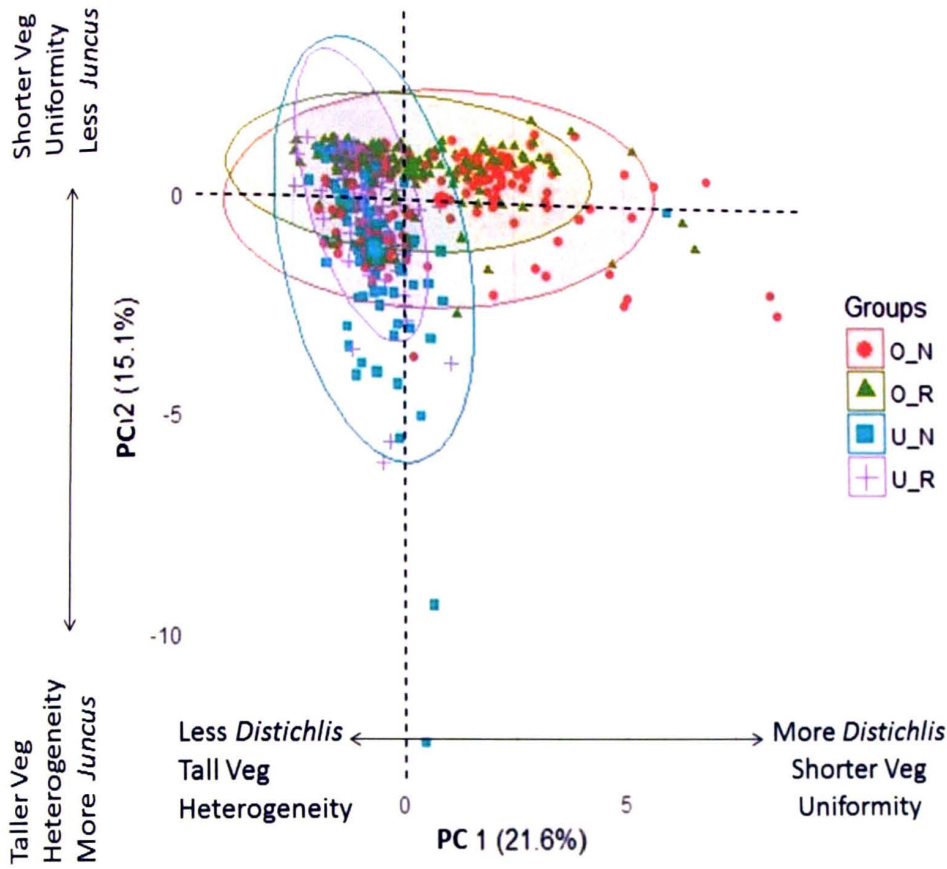


FIGURE 5. Principal components analysis of nests versus random points on oiled and unoiled plots. The orange circle and green triangle represent oiled nests and random points, respectively. The blue square and purple cross represent unoiled nests and random points, respectively.

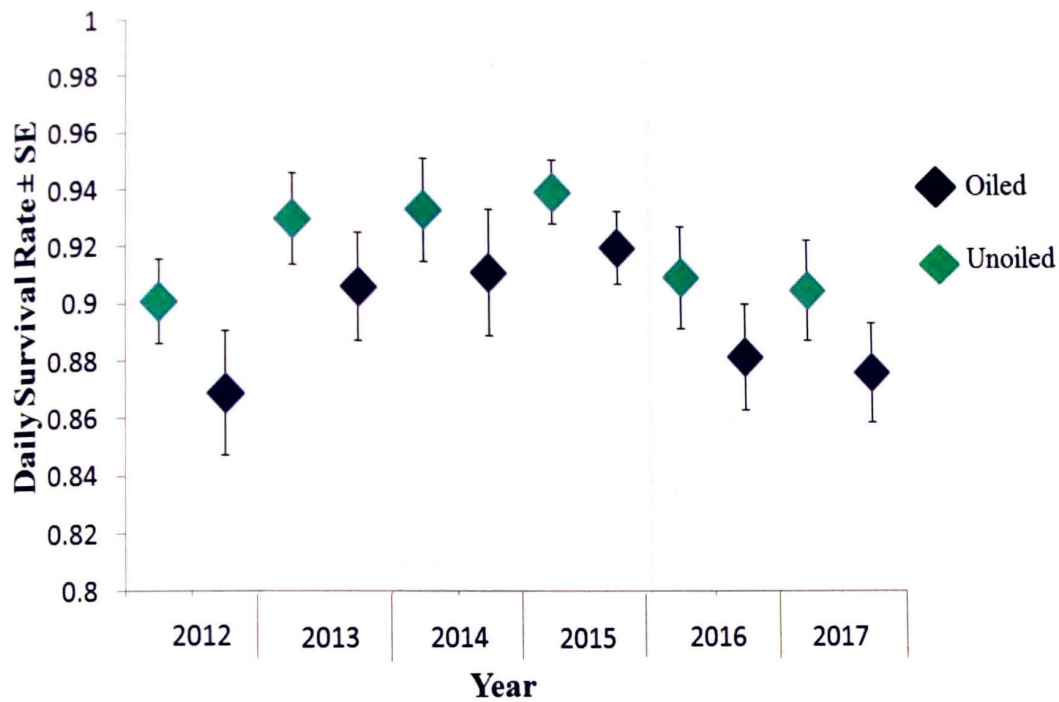


FIGURE 6. Daily nest survival rate between oiled and unoiled plots from 2012 to 2017.



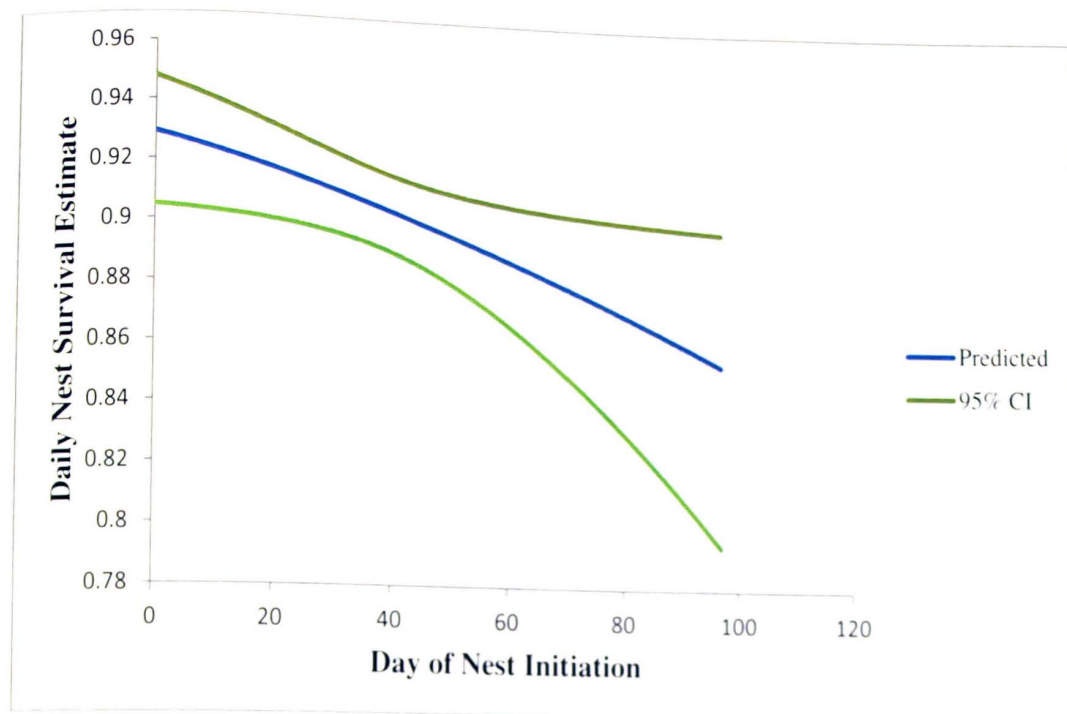


FIGURE 7. Daily nest survival rate decreases when the day of nest initiation is later in the season. Nest season progression is shown from 0 to 120 days.

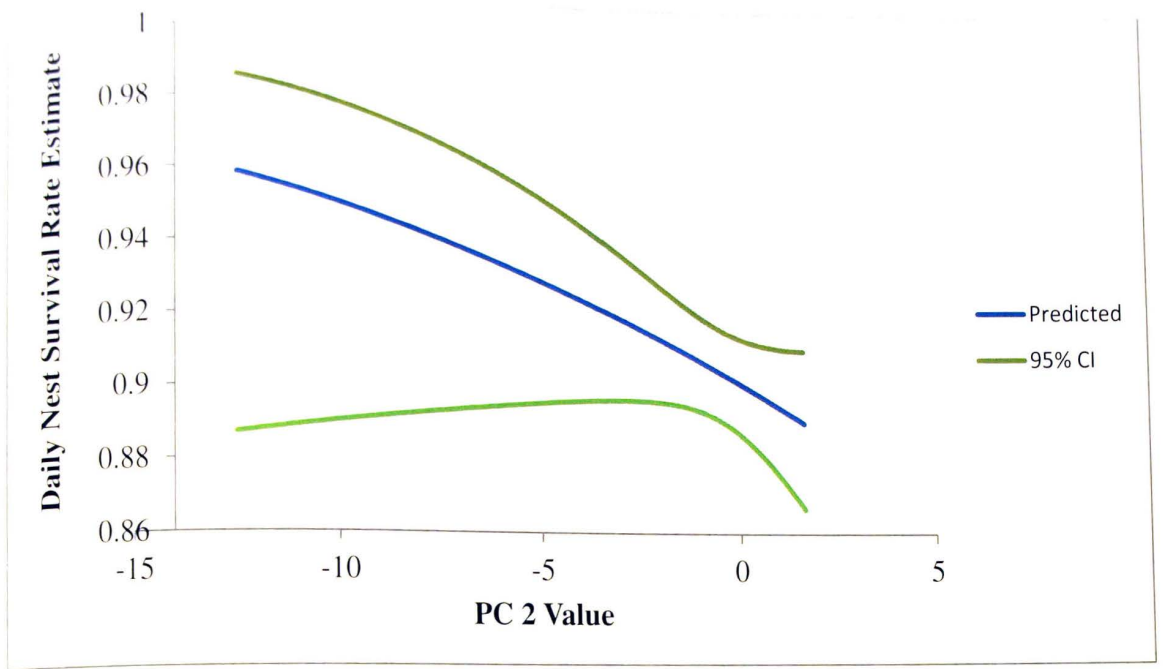


FIGURE 8. Daily nest survival rate decreases as PC 2 values increase.

## CHAPTER III

Predators of Seaside Sparrow (*Ammodramus maritimus*) nests in southeastern Louisiana

### Introduction

There are various factors like loss of habitat and habitat quality that can affect the population dynamics of avian species. In order to understand changes in population dynamics, data regarding life history traits like productivity and conditions that affect it are needed. One approach to better understanding factors influencing population changes is by studying nest success, which can be used as a proxy of avian productivity (Rotella et al. 2004). Nest success, or the probability that a nest survives to fledging, can help explain population level changes like reductions in younger individuals and the factors that are driving these changes like reduced hatching of young or poor habitat (Rotella et al. 2004). One of the most influential factors driving nest success is predation, and it is often the main cause of nest failure (Martin 1992). Nest predator identification, therefore, could be useful in understanding differences in population dynamics between areas and years.

A main goal of previous nest predation studies has been to identify specific nest predators. By using track-plates to identify predator tracks, it has been possible to identify several potential predator species near nests that had no evidence of these organisms depredating an actual nest (Cain et al. 2006). Nest predation risk has also been inferred by using radio-transmitters on snake species to track their activity level, and then associating snake behavior with nest success of birds nesting in the same area (Sperry et al. 2008). Clay eggs have aided in the identification of some nest predators like rodents in various habitats through analysis of bite marks (Skagen et al. 1999, Innes et al. 2015). In other instances, the cause of nest predation was inferred mainly by the knowledge of the presence of predators within a certain habitat (Post

1981, Johnson et al. 2012). These identification methods do not directly link predators to nest predation or predation events.

Video surveillance technology is useful in linking a predation event at a nest to a predator. Camera monitoring of nests has been used in conjunction with measures of nest success to identify nest predators and their associated habitats, which provides knowledge on how nest placement affects predation (Benson et al. 2010, Vasseur and Leberg 2014). Video surveillance has been used to analyze at what stage (incubation versus nestling) or what time of day a nest is likely to be depredated by certain predators (Benson et al. 2010, Gill et al. 2016). Predators that were most likely to prey on nests near habitat edges, and how far those predator edge effects extend into a habitat have also been identified with camera monitoring technology (Renfrew and Ribic 2003). Knowledge of main nest predators, their preferred habitats, and foraging habits is thus useful to understanding the drivers of nest success and, therefore, the population dynamics of birds.

Seaside Sparrows live in a relatively inaccessible and harsh environment known as the salt marsh on the Atlantic and Gulf coasts, which has made research on their nesting habits and nest predators difficult. The few studies of nest success in Seaside Sparrows have uncovered two main causes of failure for Seaside Sparrow nests on the Atlantic Coast: predation and flooding (Hunter et al. 2016). In fact, flooding was the primary cause of nest failure on the Atlantic Coast (Hunter et al. 2016). However, flooding seems less likely to cause nest failures in salt marshes along the Gulf Coast because they lack a strong and regular lunar tidal cycle (Greenberg and Maldonado 2006). Therefore, we suspect that the main cause of nest failure for Gulf Coast populations is predation, which is supported by our finding that 83% of all nest failures for Seaside Sparrows could be attributed to predation on our study sites (Chapter II). In order to

better understand what is influencing nest success of Seaside Sparrows along the Gulf Coast, we identified the main nest predators in this salt marsh system.

## Methods

We conducted camera monitoring from mid-March to June in 2016 and 2017 in Plaquemines Parish, Louisiana (see Fig. 1, Chapter II). We used a video monitoring system that could continuously film during both day and night, with a battery life of up to six days. Cameras were only placed on nests that were in the incubation period, and before brooding day 8 to reduce the chances of abandonment and force fledging (fledging due to disturbance before the actual fledge date; Seaside Sparrows typically fledge on brooding day 9), respectively. Batteries were exchanged every two to three days to maximize camera life. Once a nest failed or fledged, we removed the camera and examined the video for nest predators.

## Results and Discussion

We monitored a total of 20 nests from 2016 to 2017 with four in 2016 and 16 in 2017. We were able to confirm fledging for five nests between the two years. Fifteen nests failed, with one failure due to flooding, nine to predation, and five to unknown causes. A nest fate was classified as unknown when the camera was shifted, malfunctioned, or ran out of power, and we knew that the nest could not have fledged during that time period. We were able to assign nest predator identifications to nine nests. We identified three predators: American Mink (*Neovison vison*), Marsh Rice Rat (*Oryzomys palustris*), and Squareback Marsh Crab (*Armases cinereum*). Marsh Rice Rats preyed on five nests, American Mink preyed on four nests, and Squareback Marsh Crab preyed on one nest also being depredated by a Marsh Rice Rat (Table 1).

Marsh Rice Rats have long been thought to be one of the main nest predators of Seaside Sparrows because of their similar food sources and habitat needs, which could bring them into



direct competition with each other (Post 1981). However, the only published material on the subject had no empirical evidence to support the claim that Marsh Rice Rats were preying on Seaside Sparrow nests (Post 1981). In our video footage, Marsh Rice Rats depredated nests in the egg stage, and they did so at night (Table 1, Figure 1). Marsh Rice Rats are small enough to not dislodge or tear the nest during depredation events, even though they are almost twice as heavy as Seaside Sparrows (~47 g for Marsh Rice Rats vs. ~21 g for Seaside Sparrows) (Post 1981, Eubanks et al. 2011). In fact, despite the size discrepancy, Marsh Rice Rats easily fit inside the nest cup and fed on the eggs until only small shards were left in the nest. It may actually be advantageous for Marsh Rice Rats to be delicate with the nest structure because we observed them turning depredated Seaside Sparrow nests into nests for their own young. Therefore, Marsh Rice Rats may benefit not only from the food contents of the nest but also the nest structure itself. These findings highlight the need for caution when interpreting nest studies that did not use cameras to identify predators, because an empty, but intact, nest holds no obvious evidence to predator identity.

A predator that was not suspected of preying on Seaside Sparrow nests was the American Mink, which were not known to be common on our plots. Marsh Rice Rat and American Mink predation events are quite different. American Mink predation events took place both day and night (Table 1). American Mink also depredated nests at both the egg (2 nests) and nestling (2 nests) stages (Table 1, Figure 2). Mink typically tore Seaside Sparrow nests apart while depredating the nest, leaving no remains of eggs or nestlings. They would also feed on each nestling individually, which required multiple visits to the nest. American Mink preyed on nests with cameras with almost equal frequency in our study as Marsh Rice Rats and are apparently important nest predators in the salt marshes of Louisiana.

We also documented instances of multiple nest predators visiting the same nest within a single night. On one occasion in 2016, we observed (1) a Squareback Marsh Crab crush an egg during daylight hours, (2) a Marsh Rice Rat depredate the rest of the nest at night, (3) a different Marsh Rice Rat that had been ear-tagged in a different study cleaned up the remains in the bottom of the nest, and (4) a larger, unknown predator ripped down the nest but could not be identified. We documented another event in 2017 where two different Marsh Rice Rats visited a nest. Multiple predator visitations seem to occur somewhat regularly, especially when eggs have been crushed and olfactory cues are present (Benson et al. 2010). Without the use of cameras in our study, we would never have detected that one of the nest predators was a Squareback Marsh Crab, and this predation could have been attributed to a larger nest predator like Marsh Rice Rats or Mink. Our documentation of multiple nests predators demonstrates a need for caution when using nest contents to identify predators, especially when the nest suggests that a larger predator caused the entire predation event instead of a smaller, less obvious predator.

The information gained from this camera footage highlights the need for more in depth studies of Seaside Sparrow nest predators. We confirmed that Marsh Rice Rats are important nest predators of Seaside Sparrows. In addition, we documented that American Mink are a main nest predator for Seaside Sparrow nests, which had been suspected on the Atlantic Coast but also never confirmed (Hunter et al. 2016). There are many other potential nest predators in the salt marsh that were not caught on our monitoring systems like Red-winged Blackbirds (*Agelaius phoeniceus*), Marsh Wrens (*Cistothorus palustris*), and Raccoons (*Procyon lotor*) that are known to prey on other species' nests (Picman et al. 1993, Almario et al. 2009, Hunter et al. 2016). Once main nest predators are identified, further research can be conducted on their preferred habitat and densities to understand how these organisms are affecting nest success (Benson et al.

2010). Further research is needed to understand the most common nest predators in both the Gulf coast and Atlantic coast populations of Seaside Sparrows.

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TABLE 4. Predator identity, nest stage, plot, and timing for each nest predation.

Predator	Plot	Stage	Date (dd/mm/yyyy)	Time
Square Crab/2 Marsh Rice Rats	O6	Incubation	03/06/2017	12:24
Mink	O6	Nestling	28/05/2017	4:45
Mink	O3	Incubation	23/04/2017	7:06
Marsh Rice Rat	O6	Incubation	11/04/2017	21:45
2 Marsh Rice Rats	O2	Incubation	16/05/2017	21:47
Mink	O3	Nestling	21/05/2017	14:12
Marsh Rice Rat	O3	Incubation	04/06/2017	23:16
Mink	O3	Incubation	02/06/2017	6:15
Marsh Rice Rat	O6	Incubation	13/05/2017	1:26



FIGURE 9. Marsh Rice Rat depredates a Seaside Sparrow nest.



FIGURE 10. American Mink depredation on a Seaside Sparrow nest with nestlings.



FIGURE 11. Marsh Rice Rats depredating the same nest after a Squareback Marsh Crab had consumed an egg earlier in the day.