

THE REPRODUCTIVE AND FORAGING ECOLOGY OF BLACK SKIMMERS (*Rynchops
niger*) ON A BARRIER ISLAND REFUGE IN COASTAL LOUISIANA

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DEDICATION

I dedicate this thesis to my loving father, James D. Furfey, who taught me to work hard and persevere, and provided endless support to my career. My drive and passion to study wildlife started with you, papa Furf, when you brought back specimens from Central and South America, and told me stories about your world travels. You are a legend, and your pride shines on daily.

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TABLE OF CONTENTS

	Page
LIST OF TABLES.....	viii
LIST OF FIGURES	ix
CHAPTER	
I: GENERAL INTRODUCTION	1
<i>Focal Species</i>	7
<i>Study Objectives</i>	11
<i>Study Area</i>	12
<i>Chapter Outline</i>	14
LITERATURE CITED	16
II: NESTING EFFORT OF BLACK SKIMMERS (<i>Rynchops niger</i>) ON A BARRIER ISLAND REFUGE IN COASTAL LOUISIANA.....	22
ABSTRACT.....	22
INTRODUCTION	24
<i>Focal Species</i>	27
<i>Study Goals and Objectives</i>	31
METHODS	32
<i>Study Area</i>	32
<i>Breeding Pair Estimates</i>	34
<i>Site Tenacity</i>	34

<i>Nest Monitoring</i>	36
<i>Fledgling Density</i>	36
<i>Video Monitoring at Nests</i>	37
ANALYSES.....	37
RESULTS	38
<i>Colony Locations and Breeding Pair Estimates</i>	38
<i>Site Tenacity</i>	40
<i>Nest Fates and Fledgling Density Estimates</i>	41
<i>Camera Sampling</i>	43
DISCUSSION	44
<i>Skimmers Breeding on the IDBIR</i>	44
<i>Hatching Success</i>	47
<i>Causes of Nesting Failure</i>	49
LITERATURE CITED	55

III: FORAGING AND SPATIAL USE PATTERNS OF BLACK SKIMMERS
(Rynchops niger) NESTING ON THE ISLES DERNIERES BARRIER
ISLAND REFUGE, LOUISIANA.....68

ABSTRACT.....	68
INTRODUCTION	70
<i>Colonial Waterbird Foraging</i>	70
<i>Black Skimmers</i>	72
<i>Foraging Habitat Selection for Black Skimmers</i>	74
<i>Study Goals and Objectives</i>	75
METHODS	75
<i>Study Area</i>	75

<i>Trapping</i>	78
<i>VHF Telemetry</i>	79
<i>Global Positioning System (GPS) Data Logger</i>	81
<i>Video Monitoring at Nests</i>	82
ANALYSES.....	82
RESULTS	84
<i>Spatial Use Patterns</i>	84
<i>Diet and Prey Delivery Rates</i>	86
DISCUSSION	88
LITERATURE CITED	93
IV: GENERAL CONCLUSIONS.....	104
APPENDICES	
A. Measurements for Black Skimmers equipped with VHF Transmitters on the Isles Dernieres Barrier Refuge, 2011-2013	111
B. Banded 2011 and 2012 Skimmers re-sighted on the IDBIR in 2012 –2013.....	115
C. Historical Estimated number of breeding pairs on the IDBIR for each Island.....	116
D. Fish species collected from Black Skimmers captured on 30 June 2013 on West Raccoon Island.....	118
E. Fish species collected with seine net on East and West Raccoon Islands on 19 and 20 th of July 2011.....	119

LIST OF TABLES

	Page
Table 2.1: Black Skimmer colony size estimates per year and per island on the IDBIR, 2011–2013.....	60
Table 2.2: Hatching success of Black Skimmers breeding on the IDBIR, 2011	61
Table 2.3: Proportion of Black Skimmer nests that failed due to flooding, depredation or unknown causes on the IDBIR from 2011–2013	62
Table 3.1: Number of Telemetry Locations and Kernel Home-Range Estimates for Skimmers using the Isle Dernieres Barrier Refuge, 2011.....	97
Table 3.2: Distance from the nest traveled for male skimmer 0914-50478 equipped with GPS data logger	98
Table 3.3: Round-trip travel distances and duration for male skimmer, 0914-50478 equipped with GPS data logger.....	99

LIST OF FIGURES

	Page
Figure 1.1: The Isles Dernieres Barrier Island Refuge (IDBIR), located in Terrebone Parish, Louisiana. Displayed are Wine, Trinity, Whiskey, East and West Raccoon Islands	21
Figure 2.1: Main causes of nesting failure for Black Skimmers on the IDBIR from 2011-2013	63
Figure 2.2: Maximum high tide measurements on West and East Raccoon islands during the 2012 breeding season.....	64
Figure 2.3: Maximum high tide measurements on West and East Raccoon islands during the 2013 breeding season.....	65
Figure 2.4: Incubation differences between male and female skimmers nesting on the IDBIR using camera systems	66
Figure 2.5: Main predators associated with Black Skimmer nesting failure on the IDBIR 2011- 2013	67
Figure 3.1: Bow net set up on a Black Skimmer nest on East Raccoon Island	100
Figure 3.2: Data logger on a Black Skimmer showing the teas tape attachment method.....	101
Figure 3.3: Map displaying 50% and 95% kernel density use area estimates for all Skimmers radio-tracked on the Isles Dernieres Barrier Refuge, 2011 ...	102
Figure 3.4: Foraging trips of male skimmer 0914-50478 equipped with GPS data logger	103

CHAPTER I

GENERAL INTRODUCTION

Coastal Louisiana is among the most multifarious ecosystems in the world, yet has been subject to rapid change and biological decline throughout the last century. Louisiana's estuaries remain among the richest in the United States, comprising unique ecological communities of flora and fauna. This estuarine region is economically important due to abundant commercial and recreational resources including fisheries and petroleum production. Combined, these industries amount to approximately \$1 billion annual revenue for the region (Williams et al. 1997).

Louisiana's Gulf coast also supports the largest breeding concentrations of several waterbird species of concern, including the Piping Plover (*Charadrius melodus*), Snowy Plover (*C. alexandrinus*), American Oystercatcher (*Haematopus palliatus*), and Least Tern (*Thalasseus sandvicensis*, National Audubon Society 2010). A network of barrier islands in the region support wildlife including over 260 bird species. Birds use these islands as stopover habitat during migration, wintering, and breeding areas (Moore et al. 1990, NPS 2003). These barrier islands are of particular importance to several breeding waterbirds, such as Forster's Terns (*Sterna forsteri*) and Sandwich Terns (*Thalasseus sandvicensis*), with historical concentrations exceeding 50 percent of their total U.S breeding population (Spendelov and Patton 1998, Fontenot et al. 2012). Louisiana encompasses approximately 40 percent of the nation's coastal estuaries; the preservation of which has become a major

conservation challenge in light of accelerating degradation due to recent natural and anthropogenic disturbances (Martinez et al. 1995, Williams et al. 1997, Barras et al. 2003). Several studies have highlighted coastal Louisiana as an area expected to experience the greatest magnitude of sea level rise in the U.S. (Williams et al. 1997, Stone and McBride 1998). Williams et al. (1997) estimated that as much as 80 % of the nation's land loss has occurred in Louisiana alone. According to detailed forecasts of Louisiana's coast, the current coastal wetlands are 694 ha, and the 30-year projections show that this will be reduced down to 625 ha and 498 ha in 100 years (Coastal Wetlands Planning, Protection, and Restoration Act 1998). Should these predictions be realized, dynamic and irreversible changes will likely occur within Louisiana's coastal ecological communities, potentially resulting in severe to complete collapse of productivity for many species in the region. Ground nesting colonial seabirds and their preferred, low-elevation barrier island nesting grounds are particularly at risk.

Barrier islands are among the most important physical and biological features of low elevation coastal zones and are among the habitats most threatened by sea level rise. Functionally, at the coastal landscape level, these islands serve as natural barriers that protect the mainland, inland bays, estuaries, and lagoons from open ocean conditions by providing storm surge protection, breaking up wave activity, and reducing shoreline erosion (Stone and McBride 1998). Barrier islands are characterized by dynamic, elongate, and narrow chains of sand and sediment created primarily by wave energy, climate, tidal patterns, and local depositional characteristics (Davis and Hayes 1985, Martinez et al. 1995, Stutz and Pilkey 2002). Worldwide, barrier islands and their associated low gradient shorelines are highly influenced by regional sea-level fluctuations, periodic disturbances such as large storms,

sediment availability, and sediment transport (Woodroffe 2003, Stutz and Pilkey 2011). Current predicted trends in sea-level rise, storm intensity, and habitat fragmentation have led to growing concern over climate change effects on barrier island systems, including those found in the Gulf of Mexico.

The most extensive barrier island chains around the globe are found along highly exposed coasts. Stutz and Pilkey (2011) examined recent improvements in satellite imagery, topographic maps, and navigational charts, estimating that approximately 20,783 km of shoreline around the world support 2,149 barrier islands. Seventy-four percent of barrier island habitat is located in the northern hemisphere and the U.S coast of the Gulf of Mexico (Florida, Mississippi, Alabama, Louisiana, and Texas) composes the largest concentration of these islands (~ 405 islands), thus accounting for 24 percent of worldwide barrier island landmass (Stutz and Pilkey 2011). Louisiana's 639 linear km coastal zone includes approximately 25 islands, accounting for six percent of the entire Gulf coast complex (C. LeJeune, *pers. comm.*, Louisiana Dept. of Wildlife and Fisheries).

Crucial barrier island habitats along the Gulf of Mexico coast are currently being threatened by a mixture of climate change-related factors and anthropogenic disturbances. The alarming rate at which barrier islands are eroding, compared to what is known about their historical development and persistence, has led to predictions of uncertain long-term survival (Barras 2003, Penland 2005). Rapid increases in sea level, coupled with reduced sediment supply, can lead to islands breaking up and eventually, complete submergence (Penland et al. 1988).

The primary natural causes of barrier island deterioration in the northern Gulf of Mexico involve a mixture of increased winter storm intensity and hurricane frequency, changes in wind and wave conditions, reductions in sediment supply, and accelerated sea level rise (Dingler et al. 1993, Barras 2003). High wind energy and wave action associated with storms increase erosion and wash-out events along island shorelines; this effect is compounded by sea level rise. Major storms negatively and sometimes severely impact the ability of barrier islands to provide crucial hurricane protection for inland bays, marshes, and mainland shorelines (Martinez et al. 2009). Recent examples of storm impact include the 25 % land mass reduction documented on East Timbalier Island following Hurricane Andrew's landfall in 1992 (Debusschere et al. 2004). Because of the role barrier islands have for controlling storm surge in coastal marshes and bays, reduction or complete submergence could increase overall wave height and cause further damage to Louisiana's shorelines.

Barrier islands damaged or destroyed by large storm events can re-emerge during fair weather settings, though they often do not return to pre-storm conditions (Penland 2005). Conversely, increased wave action from minor winter storms can form new barrier islands where there is sufficient sediment deposition and create temporarily exposed sandy beaches. However, these smaller barrier island formations are particularly dynamic and unlikely to persist when exposed to storm surge associated with a strong hurricane (Stutz and Pilkey 2011). The combined effects of sea level rise and powerful storm systems could have devastating effects on Louisiana's coastal ecological communities, natural resources and economy. Coastal Louisiana is projected to lose over 1,200 square kilometers of land area over the next 50 years (Barras et al. 2003). Recently, Martinez et al. (2009) estimated that Louisiana's coast is eroding up to 100 square kilometers per year, and the barrier islands are

eroding at 8.2 meters per year (Martinez et al. 2009). During the last century, 90% of this shoreline degradation in Louisiana has been attributed to wave energy from hurricanes (Stone et al. 1997).

Direct (loss of habitat) and indirect (loss of prey base) effects of the deterioration of Louisiana's barrier islands and estuaries may result in dramatic impacts to colonial nesting waterbirds, making more thorough understanding of these hydrological and ecological relationships a high priority for waterbird conservation. Barrier island fragmentation and loss not only reduces breeding opportunities and success for waterbird populations, but could ultimately lead to further or accelerated population declines akin to those already observed in some species (e.g., Fontenot et al. 2012, Molina and Erwin 2006).

Colonial waterbirds are often studied as useful bio-indicators of environmental change due to their breeding and foraging habitat requirements, reliance on specific aquatic ecosystem functions, and their sensitivity to environmental contaminants (Kushlan 1993). Reduction and loss of coastal landmass from erosion has negatively impacted breeding waterbirds occupying the Chesapeake Bay region (Erwin et al. 2003, 2010). Erosion has negatively impacted Gull-billed Terns (*Gelochelidon nilotica*) in the Alabama, Mississippi, and Louisiana region (Erwin 2006). This review of different surveys on Gull-billed Terns (beginning in the 1970s) suggested the possibility of beach erosion and disturbances to estuarine breeding and foraging habitats are the primary threats to an already declining population and it is not unreasonable to predict similar impacts to other species, such as Black Skimmers (*Rynchops niger*).

Reduced availability and suitability of nesting habitat in coastal Louisiana may force waterbird populations to rely on alternative habitats, or on restored habitats initially lost due to hurricane impacts (Parnell et al. 1997, Erwin et al. 2003). Rooftop nesting and nesting on man-made dredge spoil islands has become a recent adaptation for colonial nesting waterbirds; however, reproductive success is often reduced in these alternative habitats (Gore and Kinnison 1991, Coburn et al. 2001, Cameron 2008). As reliance on these alternative habitats increases, improving nesting productivity has become an important management objective for the Gulf of Mexico. Successfully accomplishing this objective requires a greater understanding of factors that influence nest site selection and nest survival by waterbird species of concern.

In addition to natural processes, northern Gulf coast barrier islands and the associated ecological communities are threatened by anthropogenic disturbances. The most notable anthropogenic threats include releases of oil and other environmental contaminants, regional hydrologic modifications such as dredging, and commercial and recreational pressures. Regional hydrological modifications affect estuarine sediment transport characteristics; including erosion and deposition, throughout the Mississippi delta (Martinez et al. 2009). Sediment load reductions from coastal engineering as well as irrigational activities (modified land use along the Mississippi flood plain) have triggered barrier island responses varying from accelerated subsidence to island migration and break up (Stultz and Piley 2011). The compounding effects of these activities create physical and biological impacts to coastal habitats (including barrier islands) and the species that rely on them. These anthropogenic impacts are often poorly understood, are additive to those driven by naturally occurring environmental processes such as sea level rise, and compound the difficulty in understanding

unaltered system function and associated biological responses. The goal of this research was to explore the impact that one of these factors; the British Petroleum (BP) Horizon oil spill (2010) had on nesting effort, foraging rates, locations, and nest success of Black Skimmer colonies within the coastal Louisiana barrier island complex.

Accumulation of chemical contaminants; such as those associated with oil spills, can affect prey resource density and distribution, causing direct impacts to waterbird reproduction such as reduced size and number of eggs, and mortality of chicks. Indirect effects of oil spills include changes in food availability which can disrupt chemical balance in eggs and young, negatively affect the body condition of breeding adults, and decrease overall reproductive success (Szaro 1977, Custer and Mitchell 1983). Impacts of environmental contamination to waterbird populations can be both immediate and prolonged, thus demonstrating the need for short- and long-term monitoring within the affected areas. Irons et al. (2000) conducted a study nine years after the Exxon Valdez oil spill and found that there was a delayed population recovery for five waterbird species in oiled areas compared to non-oiled areas, likely a result of reduced prey abundance. The goal of this research was to explore the impact that one of these poorly understood anthropogenic factors; the British Petroleum (B.P.) Horizon oil spill (2010) had on nesting effort, foraging rates, locations, and fledging success of Skimmer colonies within the coastal Louisiana barrier island complex.

Focal Species

Black Skimmers (*Rynchops niger*), a ground-nesting species that relies on barrier islands for nesting and wintering habitat, may be among the most sensitive avian indicators of the effects of anthropogenic and climate-related disturbances within the Gulf coastal

system (Gochfeld and Burger 1994, Fontenot et al. 2012). Skimmers are piscivorous, colonial waterbirds that nest in various sized colonies in open coastal habitats along the Gulf and Atlantic coasts (Gochfeld and Burger 1994). Black Skimmers are classified on the National Audubon Society's 2007 watch list as a "Species of National Concern"; i.e., a species with the potential for population decline or becoming rare (National Audubon Society 2010). The U.S. Fish and Wildlife (2008) likewise listed Black Skimmers as a species of concern in six different regions nationwide, one of which is the Gulf coastal prairie. Skimmers are social waterbirds that rely specifically on low-elevation coastal habitats with less than 20% vegetation, and often in association with other nesting larids such as Gull-billed Terns (*Gelidon nilotica*) in the same habitat (Gochfeld and Burger 1994). Skimmers have received considerable attention due to their unique nocturnal tactile foraging behavior, and are often admired by beach-goers due to their charismatic nature. Nesting success is typically higher in larger, well-established colonies with successful colonies exhibiting high nest-site fidelity (76% return to the same colony site). Small colonies with lower nesting success typically relocate annually (Burger and Gochfeld 1990). There is a paucity of information on skimmer foraging behavior; specifically, when and where they forage, and what prey species they bring back to the nest (Gochfeld and Burger 1994). In Louisiana, virtually nothing is known about how breeding or wintering skimmers utilize habitat for foraging.

Portnoy (1977) reported that there were 37 skimmer colonies with an estimated 29,970 breeding pairs throughout the Alabama, Mississippi, and Louisiana region. This estimate showed that the largest concentration of breeding skimmers occupied the northern Gulf coast in comparison to the breeding colonies monitored in New Jersey, New York, and Virginia. In 2001, there were only an estimated 2,905 breeding pairs along southern

Louisiana distributed among 20 colonies, with about 145 pairs each (Michot et al. 2004). In the Gulf of Mexico, barrier Islands support approximately 64% of breeding habitat for skimmers, while 19% nest on shell berms in salt marshes and 17% nest on dredge deposition islands (Portnoy 1978, Clapp et al. 1983). The Gulf has supported the largest concentrations of breeding skimmers in the U.S. In 1988, 72% of the U.S. breeding population nested along the Gulf coast, and 62% of their regional breeding population was located on barrier island habitat in coastal Louisiana (Spendelow and Patton 1998). Breeding population censuses from 1983 to 1993 showed overall declines in skimmers utilizing barrier islands in coastal Louisiana, as well as annual variation in habitat use (Visser and Patterson 1994). Barrier islands are not only crucial for supporting breeding populations of Black Skimmers in the Gulf, but they also provide valuable wintering grounds. This basic monitoring of Black Skimmers and other waterbirds demonstrates the instability of barrier island habitat and its role in fluctuating population dynamics. Reduction of available nesting habitat has led Black Skimmers to use alternative habitats, specifically man-made dredge-spoil islands, shell berms, or even rooftops. Rooftop nesting has very low chances of success compared to ground nesting (Coburn et al. 2001).

According to current sea-level rise and erosion model predictions, there could be changes in the overall breeding ecology of skimmers as the availability of barrier islands diminishes. Similar to other colonial nesting waterbirds, skimmers are known to concentrate much of their breeding efforts on a relatively small number of sites. Stochastic events such as storms or flooding of barrier islands, their preferred and most productive nesting habitat, could lead to population declines through adult mortality or significant decreases in annual nesting success (Clapp and Buckley 1984, Raynor et al. 2013). Populations may suffer

considerable decline if they are unable to acclimate and adapt to habitat loss. Regional shifts or changes in their distribution have not been studied, but should receive attention in light of the impending effects of climate change.

Before the *Deepwater Horizon* oil spill, little was understood about how oiling affects skimmers. These birds often do not come into direct contact with oiled surfaces because they do not dive for prey, seemingly making them a low priority for understanding oil spill impacts. Their tactile feeding strategy of skimming the water's surface opens this species to direct ingestion of oil, in addition to ingestion of contaminated fish, and the feeding of contaminated prey to young. This could have both direct and indirect impacts on skimmer reproductive success, as well as other coastal waterbirds sharing the same habitat.

In addition to oil contamination, there are other sources of anthropogenic disturbances. Skimmers are particularly susceptible to colony disturbance by human activity. On the Gulf coast, recreational fishermen pose a threat by walking onto protected barrier islands during nesting season, sometimes directly through large nesting colonies (*pers. observation*). Human disturbances can have dramatic influences on skimmer establishment at a nesting site as well as reducing overall reproductive success. Pre-laying adults may abandon the nesting site due to stress from few to frequent human disturbances nearby during early colony establishment. Black Skimmers may also abandon nesting sites early in incubation (Safina and Burger 1983).

Climatic conditions and anthropogenic disturbances likely have a synergistic role for determining the future for skimmers on barrier islands. Habitat loss may arguably pose the biggest threat, but the degree to which anthropogenic disturbances such as a major oil spill

affect skimmers may also be a major factor in determining population responses in the Gulf. This is especially true since Louisiana may currently support the largest breeding population of skimmers in the U.S., and is experiencing the largest impacts of coastal land loss.

Study Objectives

Better understanding the complex breeding and foraging ecology of colonial waterbird species is critical for land managers not only in coastal Louisiana, but other locations throughout their range as many species struggle with habitat loss and other threats to their populations. I chose to focus this study on Black Skimmer (*Rynchops niger*, hereafter “Skimmer”) colonies within the Isles Dernieres Barrier Island Refuge (IDBIR), as the species and region are representative of these issues. Importantly, there is a paucity of information regarding their population and foraging ecology.

In this study, I attempted to answer the following questions:

1. What is the reproductive success of skimmers on the IDBIR?
2. What environmental and ecological factors influence skimmer breeding productivity?
3. What are the primary causes of nesting failure on the IDBIR?
4. How widely do individual nesting skimmers range while foraging during the incubation and chick rearing stage?

This project focused on the challenges that breeding skimmers face in a highly ephemeral habitat following a large-scale environmental disturbance, specifically on the IDBIR from 2011–2013 in the wake of the BP oil spill. An initial objective of this study was

to understand how skimmers respond to major threats such as an oil spill while investigating their breeding and foraging ecology. Understanding impacts of the BP oil spill on skimmer reproductive and foraging ecology could not be quantified and accomplished in the scope of this study, and was removed as an objective priority.

The first three study questions were studied by colony and nest monitoring, measuring hatching success rates and nest failures, and other associated nest behaviors. Study objective four was achieved through deployment of VHF transmitters and two GPS data loggers to monitor movements of captured birds and digital video recording (DVR) equipment to monitor nesting behavior and success. Recently, GPS loggers and other technology such as satellite transmitters have allowed a unique approach to understanding selected species and monitoring, especially on species with wide oceanic or coastal distributions that would otherwise be difficult to study. Avian research is increasingly conducted using these methods to determine habitat use and applied to modeling efforts (i.e., Kotzerka 2011) and has wide applications for conservation and management priorities. Camera systems were deployed at skimmers nests to improve our understanding of the breeding biology and the causes of nest failures in a human-impacted environment. This technique represents a unique approach to studying the reproductive ecology of skimmers primarily because of the opportunity to gather detailed coverage of nesting activities with minimal disturbance.

Study Area

Field research was conducted on islands in the Isles Dernieres Barrier Island Refuge (IDBIR; N 29° 03', W 90° 57' to N 29°05, W 90° 36'), located in Terrebonne Parish,

Louisiana (Figure 1.1). Although remote, and at times difficult to access with weather conditions (i.e, storms and wave action), this study area was chosen as a unique opportunity to study skimmers that have been utilizing the IDBIR as breeding and wintering habitat since historic accounts dating back to the 1970s (Fontenot et al. 2012). Baseline data of this population demonstrated considerable and steady habitat use among the islands (Raynor et al. 2013, Owen and Pierce 2013), and this establishment was considered reliable to study skimmer behavioral ecology during the study period.

The refuge is comprised of five barrier islands, which includes West and East Raccoon, Whiskey, Trinity, and Wine islands, and is managed by the Louisiana Department of Wildlife and Fisheries. The islands currently encompass approximately nine km² of barrier islands and are 13 km south of Cocodrie, Louisiana. The islands are separated from the mainland by Caillou Bay, Lake Pelto, and marshland (Figure 1.1). This land area is rapidly changing. Similarly to other regions on the Gulf, the IDBIR is currently suffering from land loss, which has mostly been caused by erosion, subsidence, storm damage, and hydrological modifications throughout the region. Studies have indicated that the IDBIR landmass has been reduced by 75% (Williams et al. 1997).

The refuge has also been dramatically impacted by hurricanes, particularly hurricane Andrew in 1992 and Katrina in 2005. What was formerly recognized on maps as Raccoon Island was split into two separate islands after Hurricane Andrew in 1992, and now referred to as East and West Raccoon Islands. Recent restoration efforts include dredge material application to create dune areas, vegetative plantings, and installation of 17 rock breakwaters on East Raccoon Island (Louisiana Office of Coastal Protection and Restoration 2010). Notably, the coastal Wetlands Planning, Protection, and Restoration Act (CWPPRA, 1998)

reported that the body of water between the IDBIR and marshland reaches considerable wave heights during storm conditions because of the loss of barrier island land mass. Their predictions suggest that wave height could increase anywhere between 0.2 and 0.6 m under storm conditions, and the maximum wave heights will occur on Wine Island, the easternmost land mass on the refuge (CWPPRA 1998). Hurricanes and other hydrological factors have reduced Wine Island's landmass to approximately 1.5 ha, and it continues to decrease in size (Curtiss 2013). These wave scenario predictions and dramatic effects of storms demonstrate the fragility of these barrier islands and their uncertain future.

Skimmers on the IDBIR share nesting habitat with several other waterbird species, specifically Gull-billed Terns (*Gelochelidon nilotica*), Royal Terns (*Thalasseus maximus*), Sandwich Terns (*Thalasseus sandvicensis*), Laughing Gulls (*Leucophaeus atricilla*), and Brown Pelicans (*Pelecanus occidentalis*). Raynor et al. (2013) found that waterbird populations historically nesting on the IDBIR were decreased by half in response to hurricane Ike and Gustav in 2008. The same response is seen in nesting skimmers on the refuge. East and West Raccoon Islands were the only islands to support breeding skimmers throughout the duration of this study.

Chapter Outline

This thesis has three main chapters which explore Skimmer habitat use, breeding productivity, and foraging movements on the IDBIR.

Chapter 2, "*Nesting Effort of Black Skimmers (Rynchops niger) on the Isles Dernieres Barrier Island Refuge (IDBIR), Louisiana*" examines skimmer colony size estimates, and

includes nest monitoring and nest fates on the IDBIR. The IDBIR population is well suited to study trends in reproductive success because skimmers have been monitored in detail on the refuge since 2008, allowing for a 6-year data set with consistent methodology. This chapter highlights the importance for long-term data sets on a little understood colonial waterbird species.

Chapter 3, “*Foraging and Spatial use Patterns of Black Skimmers (Rynchops niger), Nesting on the Isles Dernieres Barrier Island Refuge, Louisiana*” investigates the foraging patterns of breeding skimmers by utilizing VHF telemetry and supplemented by one GPS data logger. Home range sizes, diet composition and prey delivery rates were examined. VHF telemetry and GPS data loggers are critiqued and compared to each other and to recently emerging technology for suitability in obtaining fine scale skimmer location, activities, and movements.

Chapter 4, “*General Conclusions*” summarizes results found in this study and focuses on their reproductive success, breeding behavior, and foraging patterns. This chapter includes a discussion on the importance of flooding and predation to reproductive success, highlights the information gained from using camera systems at nests, and compares VHF and GPS data logger techniques for gaining data on skimmer foraging movements. Lastly, this chapter highlights how this research can be used for future studies on skimmers in the northern Gulf of Mexico.

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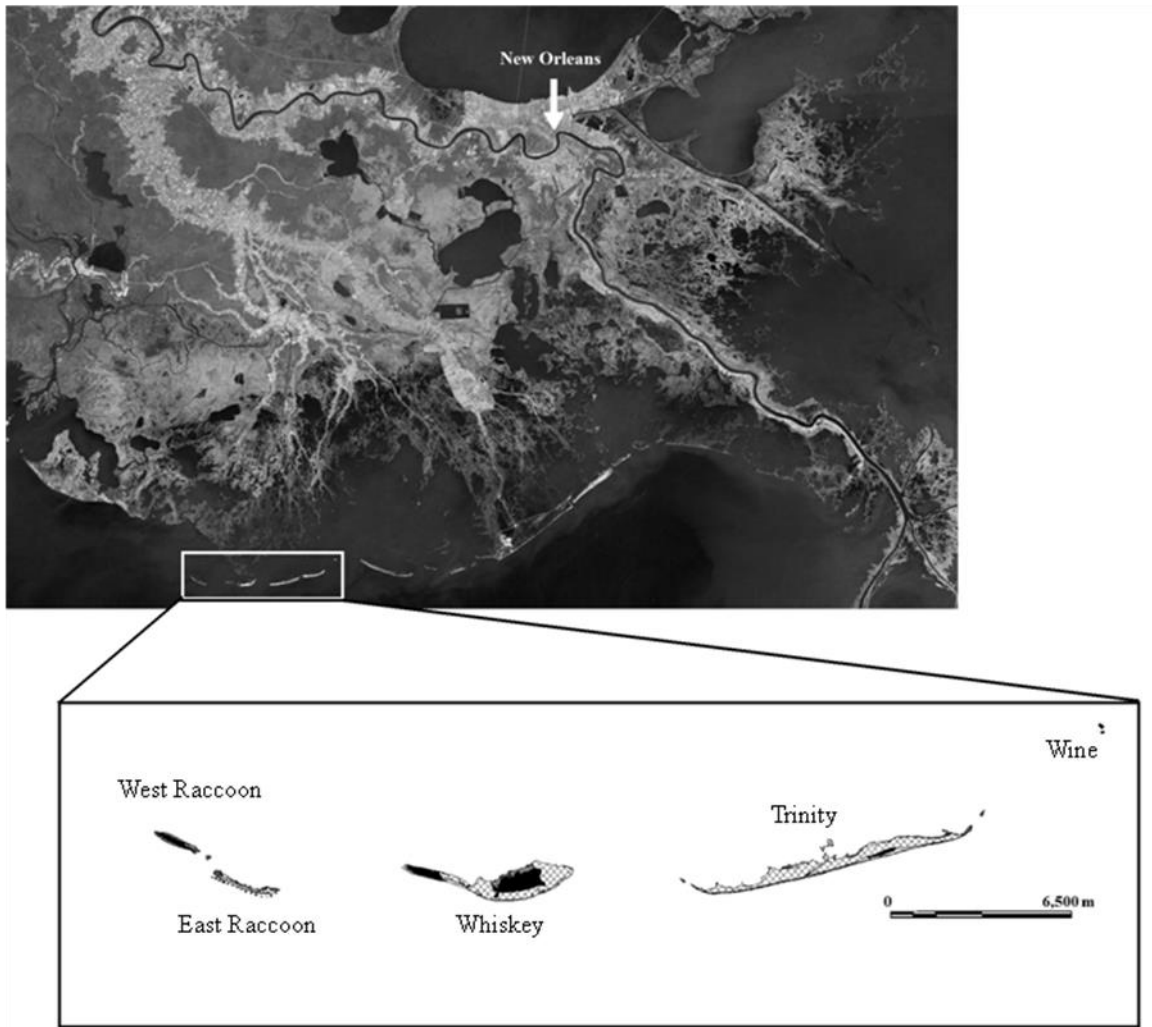


Figure 1.1. The Isles Dernieres Barrier Island Refuge (IDBIR), located in Terrebone Parish, Louisiana. Displayed are Wine, Trinity, Whiskey, East and West Raccoon islands. Map provided by Curtiss (2013).

CHAPTER II

NESTING EFFORT OF BLACK SKIMMERS (*RYNCHOPS NIGER*) ON A BARRIER ISLAND REFUGE IN COASTAL LOUISIANA

ABSTRACT

The Isles Dernieres Barrier Island Refuge (IDBIR) represents an ecologically sensitive area that is historically important habitat for wintering and breeding waterbirds, and is currently threatened by habitat loss, disturbance, and climate change. The northern Gulf of Mexico coastal habitat is particularly important to colonial nesting waterbirds such as Black Skimmers (*Rynchops niger*), a representative species that relies on barrier island habitat for more than half their nesting grounds. This study employed colony surveys, nest daily survival rates, and video recorders to gain new insight into reproductive ecology (including site selection, nesting effort, and nest success) of skimmers on the IDBIR from 2011–2013.

The refuge contains five barrier islands and, during each of the 3 successive years, Black Skimmers attempted to nest on four of the five islands. West Raccoon Island supported the largest colonies (550–1,191 nests), followed by East Raccoon (48–487 nests), and Wine Island (6–55 nests). Whiskey Island could not support nests likely due to mammalian predation pressure. Successful nesting occurred only during 2011 and was restricted to two sites (West and East Raccoon Islands). Complete reproductive failure occurred at all sites in 2012 and 2013 due to flooding. During 2011, 61% of the 62 nests monitored hatched young

successfully, while 34% of nests failed due to abandonment, predation, or flooding. Of the total 396 monitored nests in 2011–2013, 88% (353 nests) failed before hatching (68.75% flooding, 6.25% predation, 13.25% other causes). More long-term data are needed on reproductive output to evaluate skimmer population trends, threats, and future outlook for the species.

INTRODUCTION

The Gulf of Mexico coastline of the United States is one of the most important areas of the U.S. for colonial waterbird species, many of which are experiencing population declines (Fonot et al. 2012). Some of the largest aggregations of colonial waterbirds nest along the northern Gulf of Mexico, and most of these populations have been periodically monitored since the 1970s (Fonot et al. 2012). An inventory conducted along the Gulf in 1975 estimated an aggregate of 650,000 breeding waterbirds comprised of 15 species, compared to only 250,000 birds of 14 species counted along the entire Atlantic coast (Portnoy 1978). These surveys also showed that the northern Gulf of Mexico's coastline supported the highest percentages of U.S. breeding populations for Black Skimmers (*Rynchops niger*, 44%), Forester's Tern (*Sterna forsteri*, 52%), and Sandwich Terns (*Thalasseus sandvicensis*, 77%, Fotentot et al. 2012).

Coastal Louisiana is well known for being one of the most recognizable areas that support a high density of breeding colonial waterbirds across a variety of coastal habitats. Ecological challenges impacting Louisiana's coastal zone are representative of threats facing other Gulf coastal regions. Louisiana stands out as the nation's leader for being subject to an alarming rate of coastal land loss (Williams et al. 1997, Stone and McBride 1998), leading to uncertainty for the future success of waterbird colonies that utilize the region. Louisiana's coastline has become fragile, subject to increased erosion from a mixture of coastal development, oil and gas exploration, and natural events (Martinez et al. 2009). Increased subsidence rates, sea level rise, and storm activity have been re-shaping and reducing habitat previously available for nesting waterbirds. Presumably, combined effects of habitat alterations and associated reduced estuarine productivity could be the primary mechanism of

population declines for many waterbird species, yet specific causal factors have not been extensively studied in all species.

Within the past few decades there has been an emphasis on studying waterbird nesting site selection, habitat requirements, and nesting success rates. This is largely due to increasing interest in the subject as habitat loss is documented and wetland restoration efforts are increasingly implemented (Penland et al. 2003, Louisiana Coastal Wetlands Conservation and Restoration Task Force and the Wetlands Conservation and Restoration Authority 1998). There remain a multitude of questions concerning waterbird habitat selection, breeding synchrony, and predation rates. A more complete understanding of nesting biology is necessary to address conservation needs, yet there are a myriad of investigative challenges. Among the more challenging aspects of studying colonial waterbird reproduction are that colonies are often difficult to access and are sensitive to disturbance associated with surveying. Human observer disturbance has been shown to negatively impact colony establishment and productivity (Safina and Burger 1983, Carney and Sydeman 1999); though implementing improvements in traditional monitoring protocols can reduce the extent of disturbance. Additional challenges arise from the variability in nesting success among breeding populations. Coastal colonial waterbirds may nest in varying extremes of coloniality, ranging from a few individuals (e.g. Anhingas) to hundreds of breeding birds (e.g., Wood Storks, Ibis, Herons). Waterbirds may also nest in dense or loose aggregations, in mixed species or single species colonies, and are often species specific or dependent upon habitat resource availability (Kushlan 1993, Frederick and Ogden 2011). Thus, there are many variables to take into account for studying waterbird populations and factors contributing to their success or failure.

Documenting population trends and distribution of colonial waterbirds may serve a larger function than simply managing for the success of these species. Colonial waterbirds represent potential bio-indicators of a variety of environmental variables such as climate or habitat change and can be useful in assessing overall ecosystem health. Factors that support the use of colonial waterbirds as indicators includes their reliance on specific breeding and foraging habitat, responsiveness to changes in aquatic ecosystem function, and demonstrated sensitivity to environmental contaminants (Kushlan 1993). Nesting effort and success are reliable and measurable indicators of habitat suitability and overall population status and trends within waterbird or seabird communities (Diamond et al. 2003). Waterbirds often have high variability in annual reproductive success and colony residence, which are thought to be a response to local habitat suitability conditions such as food availability or predation (Bildstein 1990, Gordan et al. 2000). These factors as well as other extrinsic mechanisms might be a result of climatic patterns including tropical storms, drought, or El Nino events; all of which may affect breeding success (Monticelli et al. 2007, Raynor et al. 2013). A more complete understanding of factors that influence waterbird reproductive success is necessary to better understand not only species population trends, but also to assess the potential value of these species as bio-indicators.

The degradation or complete loss of coastal habitats clearly poses a threat to birds inhabiting the northern Gulf of Mexico and has become a high priority for waterbird conservation. Rapid habitat loss in coastal Louisiana may force waterbird populations to rely on alternative habitats, or on restored habitats (Parnell et al. 1997, Erwin et al. 2003). Rooftop nesting and nesting on man-made dredge spoil islands has become a recent nesting adaptation for colonial nesting waterbirds; however, reproductive success is often reduced in

these alternative habitats (Gore and Kinnison 1991, Coburn et al. 2001, Cameron 2008). As the reliance on less suitable alternative habitats becomes more of a widespread phenomenon, the possibility for improving nesting productivity has become an important management objective for the northern Gulf of Mexico. Accomplishing this objective requires a more complete understanding of reproductive dynamics in affected species.

This study employed colony surveys, nest monitoring, and nest video sampling to gain insight into Black Skimmer reproductive ecology, including site selection, nesting effort and nest success of Black Skimmers on the IDBIR from 2011–2013. I measured hatching success to better understand reproductive effort and compare these findings to what has been previously documented for this refuge and region (e.g. Dinsmore 2008, Owen and Pierce 2013, Raynor et al. 2013). I expect to find that skimmers are declining on the refuge, and will have low reproductive success due to regional climatic changes, sea level rise, storm events, and anthropogenic disturbances.

Focal Species

One species that is particularly reliant on coastal habitats along the Northern Gulf of Mexico and appears to be in decline is the Black Skimmer (*Rynchops niger*, hereafter “skimmer”). Skimmers are unique and highly social waterbirds that rely specifically on low-elevation coastal habitats with less than 20% vegetation, and often in association with other nesting larids such as Gull-billed Terns (*Gelidon nilotica*, Gochfeld and Burger 1994). Skimmers have received considerable attention due to their unique nocturnal foraging strategies, and are often admired by beach-goers due to their particularly charismatic nature.

Prior experimental studies of skimmers have primarily focused on breeding synchrony, habitat selection, and nesting-associated behaviors (e.g., Erwin 1977, Burger and Gochfeld 1990, Burger 1992), while leaving other factors of skimmer population ecology poorly understood (e.g. Florida Fish and Wildlife Commission Report 2011). Annual nesting success is generally poor as compared to other colonial waterbirds sharing the same nesting areas, species such as Common Terns (*Sterna hirundo*) or Royal Terns (*Thalasseus maximus*), and is mostly attributed to microhabitat differences. The salt marsh and beach areas that skimmers generally nest in are lower in elevation, are more vulnerable to tidal flooding (Burger 1990). Nesting success is usually higher in larger, well-established colonies with successful colonies exhibiting high nest site fidelity (76% return to the same colony site where they previously bred successfully; Gochfeld and Burger 1994). There are very little data to support site philopatry in skimmers, and what is known is from banding efforts conducted more than two decades ago in New York (Gochfeld and Burger 1994). These results may not be applicable to other regions or current conditions. Small colonies with lower nesting success typically relocate annually (Burger and Gochfeld 1990). In most years, only about 50% or less adults raise young to fledgling, and rarely do more than two chicks fledge the nest (Burger and Gochfeld 1990). This estimate is based on a single study in New York, and has not been confirmed elsewhere in their range (Gochfeld and Burger 1994). Clapp et al. (1982) suggested that skimmers can live up to 20 years and longevity is an important consideration when assessing long-term population dynamics. However, this finding may be outdated, and both longevity and reproductive span are uncertain and currently debated among avian researchers.

Compared to other colonial waterbirds, skimmers are uniquely capricious in colony formation and establishment and colony persistence is highly influenced by disturbances such as flooding, predation, or even survey activities (Burger 1982, Safina and Burger 1983). Several interrelated behavioral and environmental factors influence colony stability and sites are often completely abandoned during early nesting stages; though subsequent nesting attempts often occur (Screiber and Screiber 1978, Erwin 1980, Safina and Burger 1983). Cases where colony disturbance does not result in abandonment may still adversely affect the duration of incubation (typically 21-23 days) and prolong risk exposure during this vulnerable stage (Burger and Gochfeld 1990). Flooding or predation early in nesting cycles commonly occur throughout skimmers breeding range (Erwin 1977, Gordon et al. 2000, Owen 2010). When an entire colony or part of a colony is flooded from heavy rain or tidal action, they are more likely to re-nest at that site than in situations where depredations occur (Burger 1982). Re-nesting is a common strategy for skimmers, yet results in successively reduced clutch size when occurring multiple times within the same breeding season (Burger and Gochfeld 1990). Minimizing these intermediate disturbances to skimmers colonial nesting activities should be part of any management effort that strives to increase species abundance within the Gulf coast complex.

Skimmer nesting habitat preference includes open, low elevation sandy beaches that are often close to shore, leaving nesting colonies susceptible to tidal and storm flooding (Burger 1982, Burger 1990, Gochfeld and Burger 1994, Owen and Pierce 2013). Eggs are tolerant of fresh water flooding for up to 24 hours, while saltwater immersion causes egg mortality within a few hours (Gochfeld and Burger 1994). Dinsmore (2008) recently reported that overwash events accounted for 20% of nesting failures in Mississippi. Similar

events and resulting failure were documented in coastal Louisiana by Owen and Pierce (2013). In addition to flooding effects, predation rates are highly variable and often a significant source of nest failures and colony abandonment. Documented egg depredations are from Ruddy Turnstones (*Arenaria interpres*), American Oystercatchers (*Haematopus palliatus*), Boat-tailed Grackles (*Quiscalus major*), and Raccoons (*Procyon lotor*). Chick depredations mostly include Norway Rats (*Rattus norvegicus*), Herring Gulls (*Larus smithsonianus*), Laughing Gulls (*Leucophaeus atricilla*), and Fish Crows [(*Corvus ossifragus*), Burger 1990, Gochfeld and Burger 1994, Dinsmore 2008].

Banding birds for mark re-capture studies is a common tool for understanding several aspects of avian populations, such as their movements and survivorship (e.g., *Dendrioca caerulea*, Sillet and Holmes 2002), habitat use and demography (e.g., *Dryocopus pileatus*, Noel 2011), and growth rates (e.g., *T. maximus* and *T. sandvicensis*, Owen 2010). On the IDBIR, skimmers have been banded since 2011. Re-sights of banded skimmers are valuable for understanding site tenacity and the potential value the IDBIR is for breeding skimmers. Returning to the same site every year has its advantages since breeding activities can begin earlier as less time is needed to find a new place to nest (Burger and Gochfeld 1990). Burger and Gochfeld (1990) studied skimmers nesting in Barnegat Bay, New Jersey, and from re-sighting banded birds, found that turnover rates and colony stability was about the same between marsh and sand colonies. They also found colony size to be an important factor in determining colony turnover rates, where single skimmers were more likely (60% of cases) to join other existing groups than to start a new colony on their own. If there was more than one pair at a site, there were equal chances for skimmers to either abandon and join another group or stay there to form a new colony. They reported that in this region (New

York and New Jersey) colonies that had 128 or more pairs remained stable throughout a 13-year study period (Burger and Gochfeld 1990). Continuing banding efforts, as there was in the scope of this study, will allow further insight into factors that influence site fidelity or return rates, and minimum annual survival rates.

Study Goals and Objectives

The goal of this research was to expand what had been previously known about skimmer nesting ecology on barrier island habitat; specifically, colony sizes, nesting success, and productivity for skimmers in the northern Gulf of Mexico. This was accomplished in the following three objectives. 1) breeding pair estimates were gathered to gain information on short-term breeding population trends and colony establishment on the refuge, 2) banding and re-sighting marked birds provided the opportunity to understand site tenacity and the potential value of the refuge to breeding skimmers, and 3) nest fates and causes of nesting failure were determined by weekly nest monitoring and camera sampling at nests.

The IDBIR supports some of the largest nesting colonies located in Louisiana. Data prior to 2011 were collected on breeding productivity, nest site selection, and extrinsic factors affecting reproductive success (Raynor et al. 2013, Owen and Pierce 2013). These baseline data provide an excellent opportunity to evaluate short-term trends of skimmer nesting on the refuge. Importantly, these data will be used to continue implementing long-term monitoring plans based on systematic counts and productivity estimates at some of the most prominent nesting sites in the United States.

METHODS

Study Area

Field research was conducted on the islands in the Isles Dernieres Barrier Island Refuge (IDBIR), (N 29° 03', W 90° 57' to N 29° 05', W 90° 36'), located in Terrebonne Parish, Louisiana. The refuge is managed by the Louisiana Department of Wildlife and Fisheries and includes five barrier islands: West and East Raccoon, Whiskey, Trinity, and Wine islands. The IDBIR currently encompasses approximately nine km² of barrier island habitat, and are 13 km south of Cocodrie, Louisiana. The islands are separated from the mainland by Caillou Bay, Lake Pelto, and marshland (Figure 1.1). The IDBIR is currently undergoing change associated with land loss caused by erosion, subsidence, storm damage, hydrological and restoration modifications and throughout the region. Wine Island; the eastern most island on the refuge, is the most extreme example. Wine Islands' landmass has been reduced from approximately 10 ha in the 1990s to a current size of 1.5 ha, and continues to decrease in size (Curtiss 2013, A. Pierce, *pers. comm.* Nicholls State University, LA). In addition to the comparatively slow effects of regional hydrologic and sea level changes are the dramatic and immediate impacts associated with hurricanes, particularly hurricane Andrew in 1992 and Katrina in 2005. What was formerly recognized as Raccoon Island was split into two separate islands after Hurricane Andrew in 1992, and now referred to as East and West Raccoon Islands. Recent restoration efforts include application of dredge material to create dune areas, vegetative plantings, and installation of 17 rock breakwaters on East Raccoon Island (Louisiana office of Coastal Protection and Restoration 2010).

East and West Raccoon Islands were the only islands to support breeding skimmers throughout the duration of this study, and therefore, I concentrated research efforts on these islands. Tidal marshlands are approximately 10 km directly north of East and West Raccoon Islands, and Calliou Bay is in between the refuge and the coastal marshland. Caillou Bay has tidal fluctuations similar to most coastal areas along the northern Gulf coast. Low tides reach -0.12 m and high tides reach up to 0.44 m during the breeding months for skimmers, especially during lunar phases, particularly full moons (NOAA 2013, station ID 8763506). Salinity levels for Calliou Bay during the breeding months (June and July) varied throughout this study, ranging from a maximum of 28.5 ppt (2012) and a minimum of 6.2 ppt (2011; USGS 2013).

The IDBIR supports skimmer colonies among nesting habitat shared with several other waterbird species, specifically Gull-billed Terns, Royal Terns, Sandwich Terns, Laughing Gulls, and Brown Pelicans (*Pelecanus occidentalis*). Royal and Sandwich Terns form dense mixed species colonies along the dune and vegetation line along East Raccoon Island. Laughing Gulls are scattered among the low lying vegetation along the island, mostly within grass thickets, and on the perimeter of the tern colonies. Brown Pelican nesting concentrations are sporadic and occur predominantly along the thickest vegetation, mostly on Black Mangroves (*Avicennia germinans*), on the middle of East Raccoon Island. Skimmers and Gull-billed Terns nest in close association on the IDBR and were the only species nesting on West Raccoon Island; which likely is not suitable for other species due to the near non-existent vegetation and frequency of flooding.

Breeding Pair Estimates

Skimmer nesting was monitored on the IDBIR from May until August 2011–2013. All islands were scouted from late May to early June, to look for and record signs of colony formation. If there was a large congregation of skimmers that were not loafing on the shorelines and were observed to be distributed in pairs, early colony establishment was suspected. To minimize disturbance, nesting colonies were confirmed by observing pairs build nest scrapes at a distance as well as visually confirming the presence of nest scrapes during brief visits (<10 min). Multiple colonies were monitored as several locations showed signs of early nest scrape construction, but were later abandoned. I defined a skimmer nest as a scrape with at least 1 egg and recorded the UTM coordinates, approximate number of nests, and number of breeding pairs in the area.

Site Tenacity

Skimmers were trapped using both mist nets and a radio-controlled bow net (Superior Bow Net and Design). Trapping occurred on East and West Raccoon Islands in all years of this study. Birds were sampled between 3 June and 19 July in 2011, 3–14 June in 2012, and 25–30 June in 2013 (Appendix A). Caution was used on trapping days because of sensitivity to disturbance during early colony initiation. Trapping sessions began at least a week and a half after colony formation. Sixty-millimeter mesh mist nets were deployed on West Raccoon Island at night during peak foraging activity (1900-2400 hrs). Six nets were opened at one time; each net was 2.6 meters high and nine meters wide (Avinet product # RT09). Nets were erected along the shoreline, approximately 200 m away from the active colony.

Nets were placed either on the Gulf side or bay side of the western end of the island according to observations of skimmer flights. Skimmer decoys were used to help attract skimmers to the area where the nets were placed. Nets were checked at approximately five-minute intervals to minimize the time skimmers were in the net and to release any by-catch. Mist nets were not used on East Raccoon Island because of the high density of other colonial waterbird species nesting near skimmers, which would have resulted in a high rate of by-catch and disturbance.

A bow trap was used on East Raccoon Island because of the small colony sizes and because of the high density of terns breeding in the area. A radio-controlled bow net was buried in the sand around an active nest. When the adult returned to the nest and resumed incubation posture, the net was triggered and skimmer captured. Bow net trapping occurred during early morning hours (0800-1000) to reduce the likelihood of the eggs overheating when adults were away from the nest. To minimize disturbance, no more than three skimmers were trapped at the colony per trapping session.

Each skimmer captured was banded with a USGS aluminum band and a unique combination of color bands for future identification. Specifically, one leg was banded with two color bands, and the other leg was banded with one color band plus one aluminum USGS band with a unique identification number (Appendix A). Morphological measurements were recorded to determine sex. Measurements included mass, wing chord, upper and lower bill length, bill depth, and tarsus length. Age and sex of the birds were determined following Pyle (2008). For all birds, the culmen (female <62mm, male >62 mm), bill depth (female <25.7 mm, male >25.7 mm), and wing chord (female <373 mm, male >373 mm) were the characteristics used to distinguish males from females (Pyle 2008). Mass was also used, but

because there was some overlap between sexes, wing and bill measurements provided a more accurate determination of sex.

Nest Monitoring

I replicated the protocols of prior monitoring of skimmers on the IDBIR described by Raynor (2013) and Owen (2013). Wooden stakes were selectively placed approximately 0.2 m away from individual nests that had one or more eggs. Each nest marker stake was numbered for later identification. Nests were monitored at least once weekly to measure nest success. Specifically, nests were checked for new eggs, and presence of chicks or evidence of nest failure was recorded. Weekly monitoring of nest status continued until nest termination, either success or failure. Suspected causes of nest failure was recorded as predation, flooding, abandonment, or undetermined reasons. During nest monitoring, the total numbers of nests with each colony were also counted.

Fledgling Density

Single transects were established running the length of East and West Raccoon islands to estimate fledgling density during the peak fledgling period (4–7 August 2011). Transects were surveyed once on the same day with a single observer. Transects were conducted during morning hours (0800–1200) when birds were loafing. East Raccoon Island's transect measured 2.1 km, and West Raccoon Islands transect length was 1.5 km. Length, width, and surface area of the island were determined using a handheld GPS receiver. I used the total number of birds encountered as my estimate of fledgling density. To minimize double counting birds, I counted only the fledglings that flew past while walking

transects, and fledglings that were loafing at a distance. The lateral distance from which fledglings were observed was estimated and recorded.

Video Monitoring at Nests

Cameras were deployed at active nests that had two or more eggs using Sony Infrared (waterproof high resolution infra-red zoom camera, Super Circuits PC331-IR, Austin, TX), that continuously recorded throughout deployment. Cameras were placed on wooden stakes set in the ground approximately two meters from the nest. Cameras were powered by two deep-cycle marine batteries housed in waterproof cases (Pelican 1460, Orion Case L.L.C) buried >100 m away from the colony. Video was recorded by a DVR system (H. 264 Micro Digital Video Recorder) with 32GB SD memory cards (Transcend 32GB class 10 SDHC Flash Memory Card). I typically replaced memory cards every 3–5 days to ensure continuous sampling without exhausting the cards' memory space, however this was not always possible due to logistical limitations. Batteries were replaced at least once a week. Video from the SD cards was uploaded and viewed with the DVR's viewing software Standard Digital Review [SDR (V 14-4, Seorim Technologies, Korea)] and stored on an external hard drive. Observers reviewed video to record nesting ecology and associated behaviors including adult attendance rates, causes of nest failures, disturbance, and prey delivery rates.

ANALYSES

Mayfield (1975) nest survival estimates were used to determine the daily survival rate (DSR) and hatching success of the nests monitored. A successful nest was defined as a nest that hatched at least one chick. Mayfield analyses allows for computing the accumulative

probability that any given nest survives, or hatches at least one chick, over the incubation period. For skimmers, this interval is approximately 23 days (Burger and Gochfeld 1990). Since sampling on nests cannot be done on every single day, the exact day nests failed are often unknown, and Mayfield analyses uses only the days that are known given the two possible outcomes, failure or success.

After transect sampling for counting hatch year birds, program DISTANCE 5.0 (Thomas et al. 2006) was utilized to adjust for imperfect detectability and to estimate overall fledgling density for both East and West Raccoon islands. Incubation data including total time each individual spent on the nest were recorded by camera systems. Differences in incubation times between males and females were tested with a Shapiro normality test and were found to be non-normal ($P = 0.02$). A paired rank-signed Wilcoxon test was thus used to determine if there is a median difference in incubation time between males and females.

RESULTS

Colony Locations and Breeding Pair Estimates

Colony formation on the IDBIR initiated in early to mid- May for all three seasons. Among years, the date of the earliest egg-laying ranged from May 11–27. Mean colony initiation date for 2011 was 26 May (± 11 days), 2 June for 2012 (± 6 days), and 11 June for 2013 (± 10 days). Nest initiation times were the same for all islands with the exception of the 2011 nesting season during which skimmers began nesting on West Raccoon Island approximately 10 days before observing the first eggs laid on other islands. The number of colonies and their locations on the refuge were variable for all seasons. Over the three years,

skimmers nested on Wine Island, western Whiskey Island, West Raccoon Island, and East Raccoon Island (Table 2.1, Appendix C). East and West Raccoon Islands were the only islands to support breeding skimmers in every year of the three-year study period. All years combined, eighty-five percent ($n = 13$) of colonies failed, and only 15% successfully hatched young.

Whiskey Island supported ten nests in 2011 with 115 pairs settling for colony establishment. All nests failed and depredation by coyotes (*Canis latrans*) appeared to be the cause based on eggshell fragments and coyote tracks leading into the developing colony. In subsequent years, this island was abandoned as a nesting site. Wine Island also failed to successfully support breeding skimmers from 2011–2013. Nine nests occurred on Wine Island in 2011 but all failed within 12 days. Two nesting failures occurred from avian nest depredations and were indicated by small holes in eggshells. Nest initiation coincided with the peak breeding period for Royal and Sandwich Terns. Subsequently, the relatively large number of tern fledglings on Wine Island resulted in tern crèches commonly trampling over the skimmer colony. Competition for nesting space also occurred on East Raccoon Island, but was not as severe as Wine Island. There were no other species nesting on Wine Island in 2012, and skimmers increased their reproductive effort to 55 nests, all of which failed from flooding early in the nesting season. There were no skimmers or scrapes observed in 2013.

East and West Raccoon Islands endured several flooding events that impacted both nesting and re-nesting attempts; however, these were the only islands on the IDBIR that consistently supported breeding skimmers with some reproductive output. The highest rate of re-nesting occurred in 2013 on East Raccoon Island, where five small colonies (range 5–151

nests) washed out early enough in the season for subsequent re-nesting one week later, resulting in two colonies (range 5–30 nests).

The breeding population at individual colonies was variable, ranging from eight to 1,191 pairs. Breeding pair estimates on the refuge declined 13% from 2011 to 2012, and 48% between 2012 and 2013. West Raccoon Island supported the largest number of breeding pairs throughout the three-year period, consistently having a single large colony that fluctuated from 43–1,191 breeding pairs. The number of breeding pairs on West Raccoon increased as the nesting season progressed throughout mid to late June, whereas colonies on other islands experienced declines or complete abandonment during the same period. The largest colony West Raccoon supported occurred in 2011 ($n = 1,191$ nests), but was reduced by half in 2013 ($n = 572$). East Raccoon typically had several sub-colonies early in the nesting period with as many as four separate coincident colonies in 2013. These smaller sub-colonies were not successful and were abandoned early following flooding events.

Site Tenacity

Forty-seven skimmers were banded on East Raccoon Island and West Raccoon Island in 2011 ($n = 12$) and 2012 ($n = 35$). On East Raccoon Island, six males and six females were banded. Fifteen males and 17 females were captured on West Raccoon Island, and three hatch-year birds for which the sex could not be determined. Skimmers banded in 2011 and 2012 returned to both East and West Raccoon islands to breed in 2013. From 2011 and 2012 collectively, 53% were re-sighted in 2013 on East and West Raccoon Islands ($n = 25$), 14 of which were confirmed with active nests. By island, fewer birds were re-sighted on East

Raccoon Island (30%) than West Raccoon Island (67%) in 2013. One bird was re-sighted loafing on Whiskey Island during the non-breeding season. Fourteen skimmers were re-sighted nesting on the same island they were banded on, and the remaining 13 birds were re-sighted on different islands they were banded on (Appendix B). Three skimmers were re-sighted more than once but nested on different islands during the 2013 breeding season during re-nesting attempts. Birds could not be re-sighted in 2012 due to the small window available for re-sighting nesting birds prior to flooding impacts that caused colonies to disband. Therefore, banded birds nesting both in 2012 and 2013 collectively could not be determined.

Nest Fates and Fledgling Density Estimates

Throughout this study, the only year skimmers successfully hatched young was 2011. East Raccoon had 48 skimmer nests with eggs by 6 June 2011. Of the five nests monitored, three failed (60%) and two hatched young successfully. West Raccoon had 1,191 nests by 13 June 2011. Of the nests monitored ($n = 57$), 32% failed (C.I. 7.25–56.75), while 68% were successful. With the limited sampling of nests from East Raccoon Island, the daily survival rate was combined for both islands. The daily survival rate was 0.973 ($n = 62$) for both colonies (Table 2.2).

Fledgling surveys were done only once on the 7th of August. During this time, four fledglings were detected on East Raccoon Island, and five fledglings were observed mortalities. A total of 231 fledglings were counted on West Raccoon Island. These transect survey results were analyzed using program Distance (Thomas et al. 2006) to adjust for imperfect detection, indicating an estimated 155 fledglings present on West Raccoon Island

(95% C.I. = 104–348 fledglings). The area on West Raccoon Island where skimmer fledglings were present was estimated to be 29.8 ha, and the nesting colony covered 14.5 ha. Given that an estimated 155 fledglings survived to early August, and there were at least 1,191 nests on West Raccoon, each nest attempt produced 0.13 fledglings. On East Raccoon Island, four fledglings were documented from 48 nests. The sample size of fledgling detections ($n = 4$) was too small for imperfect detection of East Raccoon Island. This colony was relatively small compared to West Raccoon Island, and we surveyed 6.6 ha of the area for the presence of fledglings; the active nesting colony covered an estimated 2.1 ha.

Based on weekly nest monitoring with stakes across all years, 88% ($n = 353$) of 396 monitored nests failed before hatching. Flooding (68.75%), predation (6.25%), and unknown or other causes (13.25%) were sources of hatching failure (Table 2.3, Figure 2.1). Flooding events occurred on all islands and was the leading cause of nesting failure on the IDBIR in 2012 and 2013, causing complete reproductive failure for both years. A mixture of seasonal storms, tide and wave action lead to over-wash events that push water over large portions of the islands. All colonies experienced complete wash-outs, and in most extreme cases, resulted in colonies being entirely submerged. In 2012, all nests failed ($n = 1,092$) between 14 and 27 June, and no skimmers re-nested afterwards (Figure 2.2). There were two separate periods for which skimmers nesting on the IDBIR had complete wash-outs during the 2013 breeding season (Figure 2.3). Nests were washed out between 7 and 12 June ($n = 393$ failed nests), and after re-nesting, between 3 June and 6 July ($n = 549$ failed nests). Tidal information was collected from Caillou Bay/Raccoon Point, Station ID 073813498 (USGS 2014) to determine tide heights at which colonies experienced wash-outs. The minimum

high tide level that guaranteed nesting failure for both East and West Raccoon Islands in 2012 was 0.71 m and 0.74 m in 2013 (Figures 2.2 and 2.3).

Avian and mammalian predation caused failure for 6.25% of monitored nests ($n = 396$) across the three-year study period, though this mortality was inconsequential during the second and third year since all colonies ultimately flooded. Predation was variable across years and among nesting sites. Twenty-five of the monitored nests were depredated throughout the study period, and of these 25 nests, 12% of nests were in 2011, 24% in 2012, and 64% in 2013. Predation was recorded more on East Raccoon Island ($n = 18$) than on West Raccoon Island ($n = 7$). During 2011, the only year colonies persisted to fledgling, predation was highest on West Raccoon Island ($n = 2$), followed by East Raccoon Island ($n = 1$). Avian depredations accounted for 16.7% ($n = 10$) of all documented predation-caused nesting failure. Mammalian predation was not a common cause of nesting failure on the IDBIR from 2011–2013 and was only documented on East Raccoon Island in 2013. Weekly nest monitoring documented 16 depredated nests from nutria (*Myocaster coypus*), each nest containing 1–4 eggs. The first nutria depredations were recorded on 5 June and resulted in complete colony failure by 25 June.

Camera Sampling

Cameras were placed at 17 total nests, and 13 were successful in recording nesting data. Data recorded from four nests were unsuccessful in 2011 because tidal flooding resulted in SD cards being destroyed with moisture damage. Camera systems were not deployed in 2012 as flooding occurred before colonies were sufficiently established to allow for

deployment. Four cameras recorded nesting activities in 2011, and nine nests were recorded in 2013. Camera monitoring continued throughout incubation to nest termination, either a nest failure or the young leaving the nest. Approximately 1700 hours of video was recorded during the two nesting seasons. Of the four nests recorded in 2011, two nests successfully fledged four chicks (two per nest). Nests recorded in 2013 ($n = 9$) was of the incubation stage only because wash out events caused complete nest failure and colony abandonment prior to hatching. From these limited data collected in 2011 and 2013, females spent an average of six more hours incubating than males, and this difference in incubation rates was non-significant (females = 35 hrs, [95% C.I.=16.31-54.00], males = 29 hrs [95% C.I.=10.31-48.00], $W = 80.5$, $P = 0.86$, Figure 2.4).

Importantly, cameras documented Nutria three times on East Raccoon Island depredating skimmer nests during 2100– 0500 hrs (Figure 2.5). Camera systems also recorded disturbance events at nests that did not directly result in chick or egg mortality but may have contributed to failures. Ghost crabs (*Ocypode quadrata*) commonly approached and harassed skimmers off nests but predation was not observed and this was only documented in 2013 (Figure 2.5). Nest disturbance from fishermen was also recorded and occurred regularly, on average, once every 3 days (range 5 minutes–4.5 hours where entirely colony was flushed and off nests). Additionally, a single instance of chick mortality associated with intraspecific aggression was recorded; wherein an incubating female skimmer killed a chick that had wandered from another nest.

DISCUSSION

Skimmers Breeding on the IDBIR

The locations of nesting colonies have shifted several times on the refuge over the last five breeding seasons and this recent distributional shift reflects the challenges skimmers face in ephemeral habitats (Raynor et al. 2013, Owen and Pierce 2013). Availability of suitable nesting space, flooding, interspecific competition, and predation all play large roles for colony site selection on the refuge. The variation in the egg-laying period seen in 2011–2013 reflects seasonal flooding impacts and subsequent re-nesting attempts. Of all nesting colonies documented in this study ($n = 13$), only two hatched young because of over wash events associated with high tides and storm action.

The number of breeding pairs reported in this research is difficult to compare to prior records of skimmers nesting on the IDBIR. Records of waterbird breeding populations have reported skimmers on the IDBIR since 1978 (Fontenot et al. 2012; Appendix C). However, different methods were used during monitoring as techniques were improved, and not every year has been consistently sampled until recently. From years that have been sampled, skimmers have reported to have nested on all islands on the refuge. However, the only years skimmers were counted on every island on the IDBIR was in 1983 and 1994 (Fontenot et al. 2012), and in 2008 (Raynor et al. 2013). The largest congregation of breeding skimmers recorded was on Whiskey and Wine islands in 1997 (Fontenot et al. 2012; Appendix C). In previous studies on the IDBIR (Raynor et al. 2013, Owen and Pierce 2013), Raccoon island supported 1100 breeding pairs in 2008, while Whiskey Island supported the largest skimmer colonies in 2009 and 2010, with 780 pairs counted in 2009 and 450 pairs in 2010. On the

contrary, East and West Raccoon Islands supported most of the breeding population of skimmers throughout this study. The greatest abundance of breeding pairs recorded on East and West Raccoon Islands was in 2011, an estimate of 1,250 pairs. There does not seem to be a trend in population estimates on the IDBIR since 1978, likely because of inconsistent sampling and differences in sampling methods (Fontenot et al. 2012). In this study, the total number of nests, regardless of failure, showed that reproductive effort was comparable across years, even though colony sizes were reduced from 1,239 pairs in 2011 to 572 pairs in 2013 (Table 2.1). This may be a result of early nesting failure from flooding impacts, and these colonies could have continued to expand if nesting was not interrupted.

No skimmers have been observed breeding on Whiskey Island since May 2011. Incidentally, we observed two coyotes chasing loafing Reddish Egrets (*Egretta rufescens*) and Laughing Gulls on the western tip of the island in 2012, this location is where skimmers had nested in previous years. This apparent response to predation has been seen in several other studies, indicating that predation has a higher influence on colony site selection than environmental effects such as flooding (e.g. Burger and Gochfeld 1990). Previous to this research, predation activity on Whiskey Island was found to increase from 3% of failed nests in 2009 to 21% of failed nests in 2010 (Owen and Pierce 2013). Although this island had supported some of the largest breeding colonies documented within the IDBIR (Fontenot et al. 2012), it is unlikely that skimmers will select this area for nesting in the future unless mammalian predators are excluded.

Although there is a limited sample size ($n = 27$), banding efforts and re-sights in this research help to support the idea that adult skimmers may return to the same nesting areas year after year regardless of nesting failure from flooding impacts (Burger and Gochfeld

1990). During the non-breeding season, one skimmer was re-sighted loafing on Whiskey Island in 2011, and two banded skimmers were observed loafing on the east end of West Raccoon Island in February 2012 (D. Curtiss, *pers. comm.* Nicholls State University, LA). Of the three hatch year birds banded in 2011, no banded juvenile birds were re-sighted throughout the three-year study period. A possible exception was a Florida observation made in 2012, but conditions may have been poor for the observer because the reported band color combination was flip-flopped on the right leg (J. Goyette, *pers. comm.*, Biodiversity Research Institute, ME). Return rates of adults to the same nesting sites demonstrates the importance of the IDBIR to breeding skimmers in the Gulf of Mexico, or could reflect that there are limited nesting areas available. It is not reported in the literature whether or not site tenacity exists more on barrier island habitats than other nesting habitats, and should be examined as breeding habitat is diminished.

Hatching Success

Skimmer hatching success has showed high annual and inter-colony variability, similarly to other studies (Erwin 1977, Burger and Gochfeld 1990, Dinsmore 2008). The IDBR hatching success variability is similar to what has been reported in the literature for skimmers in other locations. Mallach and Leberg (1999) reported skimmer hatching success rates from 63–93% in the Atchafalaya Delta Wildlife Management Area, Louisiana. Similar variability in hatching success rates has been shown with colonies in New Jersey (54%; Burger 1981), Mississippi (0–100%; Dinsmore 2008), and Virginia (79%; Erwin 1977). Burger and Gochfeld (1990) found substantial annual variation with 38% of colonies experiencing complete nesting failure, as seen in this study during the 2012 and 2013

breeding seasons. Thus, variability in nesting success is well-documented, and poses a challenge for determining the role of climate change and anthropogenic disturbances on skimmers.

Compared to data collected by Owen and Pierce (2013) in the two years prior to this study, skimmers had the highest hatching success in 2009 (1-84%) compared to 2010 (5-42%). Skimmers only hatched young on two islands in this study, but Owen and Pierce (2013) documented skimmer hatching success on East and West Whiskey Island and Wine Island in addition to West and East Raccoon Islands. According to Owen and Pierce (2013), the highest hatching success occurred on East Whiskey Island (2009; 85%) and West Raccoon Island (2010; 43%). Overall, in 2010 there was a decline in estimated success (22%, $n = 167$), and nest success seemed to improve (53.3%, $n = 62$) in 2011.

Although skimmers may have relatively good hatching success some years, as seen on the IDBIR in 2009 and 2011, the number of fledglings that survive will be a better indicator of population level responses. Prior to 2011, fledgling estimates were not measured and could not be compared to the fledgling estimates found in this study. The reproductive success reported in 2011 on the IDBIR (0.13 fledglings per nest on West Raccoon Island and 0.083 fledglings per nest on East Raccoon Island) is considerably lower than in other studies. Productivity ranged from 0.25–0.91 New York colonies from 1976–1979 (Burger and Gochfeld 1990), 0.4 in Virginia (Erwin 1977), 1.2 in South Carolina (Blus and Stafford 1980), and 1.1 in Texas colonies (Custer and Mitchell 1987). However, the estimates reported in this study are limited to a single day of transect sampling and are likely invaluable information on skimmer fledgling estimates during that year. Future studies should incorporate multiple sampling days with repeated transect surveys and multiple

observers to gain a more accurate representation of fledgling densities and improve detection probability. Fledgling survival as a measure of complete reproductive success should be a priority for monitoring skimmers on this refuge and elsewhere.

Causes of Nesting Failure

Flooding and predation are documented as the main causes of nesting failure in most studies for skimmers (e.g., Burger 1990, Gochfeld and Burger 1994, Owen and Pierce 2013) and I came to similar conclusions for this study. Distinguishing actual causes of nesting failure for skimmers across their breeding range is difficult to determine, primarily because most studies on their breeding biology involve broad categories of nesting failure rather than specific cases. Weekly nest monitoring may not always yield adequate data on proximate causes of nesting failure, and rather gives a better estimate of hatching success. Employing DVRs at skimmer nests on the IDBIR revealed that nest fates are not as clear to researchers during weekly monitoring.

For instance, there was one nest that was monitored with a camera in 2011 on West Raccoon Island that recorded both flooding and avian predation. This nest had three eggs, and was in the middle of the incubation stage. The flooding was minor from what appeared to be heavy rainfall rather than tidal flooding. The adult female tending to this nest left after a distressed chick from another nest attempted to seek cover from this incubating female. Within two minutes of nest desertion, Laughing Gulls investigated but did not depredate the nest. The first egg was taken by a juvenile Laughing Gull within that hour, followed by Ruddy Turnstones (Figure 2.5) and adult Laughing Gulls depredating the two remaining eggs (Figure 2.5). The nest was not visited by any adult skimmers until after the nest was

destroyed, and was entirely depredated within 2.5 hours of the female's nest abandonment. If this nest was monitored once a week with nest marker stakes, the cause of nesting failure would presumably be flooding based on the absence of eggs and flattened sand surrounding the nest area. This camera footage showed that causes of nesting failure are complicated, and the nest predations from Laughing Gulls are the ultimate cause of nesting failure rather than flooding.

Camera systems were beneficial in this study for gathering more information about skimmer nesting ecology on the IDBIR that was not expected in the beginning of the project. Camera systems identified predators, suggested incubation differences between males and females, and recorded intra-specific mortality, as well as human disturbances to the nesting colonies. Camera systems identified the two avian species responsible for skimmer nesting failure, and weekly nest monitoring would not be sufficient enough to gain that information. It is possible that there are other avian species that are depredating on skimmer eggs or chicks that were not documented in this study [e.g., Herring Gulls (*Larus argentatus*), Burger and Gochfeld 1990].

Camera systems also recorded an intra-specific mortality event with a nesting adult female and a chick from another nest. There was no apparent instance of begging for food, and the location of the nest from which the depredated chick came from was unknown. This behavior has been recognized in skimmer nesting but there is no extensive information on how often or under what condition this territorial nesting behavior occurs (Gochfeld and Burger 1994).

Ghost crabs were revealed as another species contributing to skimmer nest disturbances (Figure 2.5). Ghost crabs were only documented to investigate skimmer nests in 2013 on East Raccoon Island, however, were not identified as a source of nesting failure. In most cases, Ghost crabs would scavenge nests that were already abandoned or depredated. Ghost crabs also chased skimmers with fish, and subsequently pirating fish that were dropped by skimmers. Ghost crabs are known to depredate chicks and eggs of other seabird species, such as Piping Plovers (*Charadrius melodus*, Loegering et al. 1995). On multiple occasions, particularly in 2013, Ghost crab burrows were seen in the vicinity of skimmer nests used during previous visits. Owen and Pierce (2013) identified Ghost crabs to be one of the main causes of nest predation on the IDBIR in years previous to this research. More research is needed to quantify impact of Ghost crabs as potential predators to skimmer nests on barrier islands.

Louisiana Department of Wildlife and Fisheries (LDWF) have taken notice of human disturbance on the IDBIR, specifically disturbance associated with local fishermen walking in proximity to protected nesting colonies. This disturbance has become problematic and challenging for land managers because of the inaccessibility of the IDBIR for routine monitoring. Camera systems recorded the frequency of human disturbances at skimmer colonies, most of which seemed to be recreational fisherman walking through or in the proximity of skimmer nests, both on East and West Raccoon Islands. Surprisingly, nest disturbance occurred regularly, on average, once every 3 days (range 5 minutes–4.5 hours of disturbance). Although not an objective in this study, the high disturbance frequency from recreational fishermen may be more of a problem than previously thought. These disturbances from fishermen did not seem to cause colony abandonment, but could adversely

affect the length of skimmer incubation time, and ultimately prolong the risk of exposure for nesting skimmers on this refuge (Safina and Burger 1983, Burger and Gochfeld 1990).

The most crucial information gathered from camera systems were of nutria depredations on skimmer nests on East Raccoon Island that has never been recorded on the IDBIR (Figure 2.5) or elsewhere in the literature to my knowledge. Nutria have been recorded as established on Whiskey, Trinity, and East Raccoon Islands, but have been noted to be most abundant and destructive on East Raccoon Island (Cassidy LeJune, *pers. comm.*, Louisiana Department of Wildlife and Fisheries, LA). Nutria are suspected to be more numerous on East Raccoon Island because there are a lack of predators, such as the coyotes that are present on Trinity and Whiskey Islands. An estimated 300 or more nutria have been eradicated from East Raccoon Island alone over the last three years (Cassidy LeJune, *pers. comm.*, Louisiana Department of Wildlife and Fisheries, LA), mostly because of their destruction to native vegetation. Recent marsh restoration projects have involved new plantings of species such as smooth cord grass (*Spartina alterniflora*), which is suspected as the most preferred food source for nutria. Refuge managers have expressed concern over nutria as a threat to the success of these projects. Eradication efforts on East Raccoon Island were performed in Spring 2013, and it was suspected that in the process of the eradication, any remaining nutria were pushed out of their normal range on the island and settled closer to western end of the island where large concentrations of skimmers and other waterbirds nest (Cassidy LeJune, *pers. comm.*, Louisiana Department of Wildlife and Fisheries). These colonies may have become more accessible to nutria that took nests after learned exploitation of an abundant food resource.

The nutria depredations recorded in 2013 occurred only at night over a 20-day period, and were responsible for most of the nesting failure on East Raccoon Island prior to flooding. I suspect that a single nutria was responsible for the nesting failure on this island based on footage times and simultaneous footage of different recorded nests. However, there are more than one nutria currently on East Raccoon Island. Nutria depredations may become a problem in the future for nesting waterbirds on this island. Other invasive rodents, such as *Rattus rattus*, are well known for their impacts on ground and burrow-nesting seabirds by depredating eggs and chicks (Bradley and Marzluff 2003). Several sources have identified invasive rodents to be one of the largest threats to the persistence of seabird colonies, thus, invasive rodent control has become an important conservation priority (Jones et. al 2007). Further study is needed on nutria movements on and between islands, diet composition, and population sizes on the IDBIR.

Aside from predation, flooding events had the strongest impact on breeding skimmers throughout this study. Importantly, flooding-related nesting failures were found to increase on every island except for East Raccoon Island in prior research, and accounted for 8% of nesting failures in 2009 and 22% in 2010 (Owen and Pierce 2013). Flooding impacts were considerably higher in this study, accounting for up to 90.5% of nesting failure in 2013 (Figure 2.1). These flooding impacts coupled with sea-level rise and erosion creates challenges for habitat management. A mixture of high wind, wave, and storm action makes accessibility to this refuge difficult, and subsequently, consistent monitoring efforts challenging. In cases where the colonies cannot be accessed, camera systems were beneficial after techniques were improved in 2013. Camera system failure and damage to SD cards caused by flooding resulted in fate of four nests being indeterminable. DVR systems and

batteries were housed in sealed plastic containers in 2011 and were easily tipped over from heavy rain and flooding. Techniques were improved by protecting DVR and battery systems in waterproof Pelican cases. This new development led to only 1 SD card being destroyed by flooding, while all other camera systems were successfully protected ($n = 10$). Camera systems recorded the entire washout event in late June 2013, narrowing down the date of colony failure between the 21st and 24th June. With inaccessibility to the refuge during these high wind and wave conditions, camera systems help to elucidate which times colonies failed, and confirm flooding impacts on skimmer colonies during this time. Lastly, continued monitoring of skimmer populations by using camera systems will be a beneficial strategy for managing skimmers, and understanding disturbance, predation and over-wash rates throughout their range.

Recent efforts of monitoring waterbird communities have led to growing concern over many beach nesting birds. Managing for greater reproductive success for skimmers has become more of a problem since their nesting habitat preferences leave them highly susceptible to flooding, predation, and disturbance. There is a great need for predator control on the IDBIR. Returning to the same nesting locations annually may be because there are no other places to nest regardless of increasing flooding pressure. More long-term data are needed for understanding skimmer trends across the Northern Gulf of Mexico, and annual monitoring efforts should continue as this species could possibly experience rapid declines in the near future.

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Table 2.1. Black Skimmer colony size estimates per year and per island on the IDBIR, 2011–2013.

Year	Island			Total
	Wine	East Raccoon	West Raccoon	
2011	12	48	1191	1251
2012	55	487	550	1092
2013	0	30	542	572

Table 2.2. Hatching success of Black Skimmers breeding on the IDBIR, 2011.

Island	Number of Nests Counted	Nests Monitored	Failures	Hatched	DSR^a
Wine	12	0	0	0	0
West Whiskey	10	0	0	0	0
East Raccoon	48	5	3	2	0.947
West Raccoon	1,191	57	18	39	0.974
TOTAL		62	33.90%	66.10%	0.973

^aDSR=Daily Survival Rate (Mayfield 1978)

Table 2.3. Proportion of Black Skimmer nests that failed due to flooding, depredation or unknown causes on the IDBIR from 20011–2013.

Year	Nests Sampled	Nest Fate				Total
		Hatched	Flooded	Depredated	Unknown	
2011	62	0.661	0.145	0.048	0.145	1
2012	136	0	0.632	0.044	0.324	1
2013	196	0	0.918	0.082	0	1

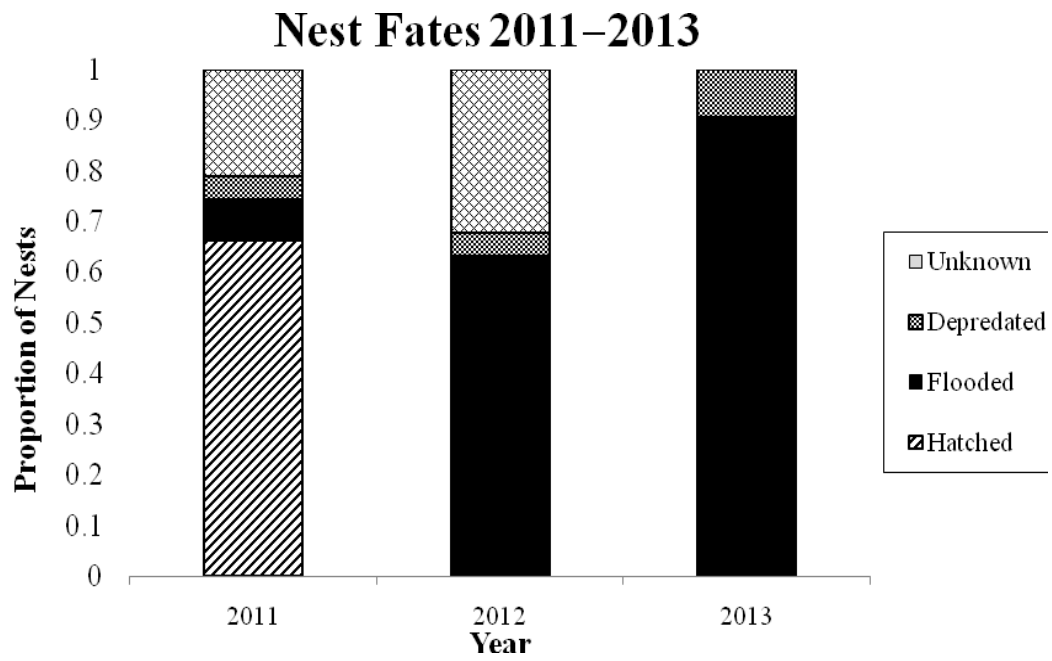


Figure 2.1. Main causes of nesting failure for Black Skimmers on the IDBIR from 2011-2013.

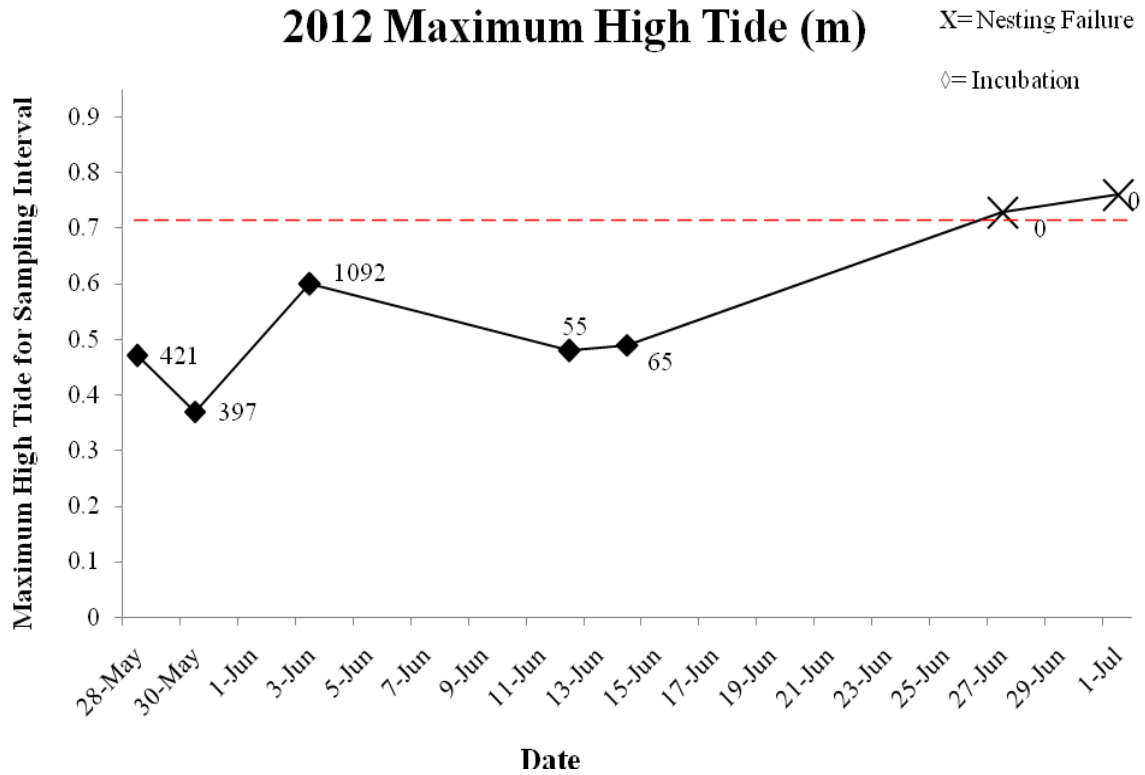


Figure 2.2. Maximum high tide measurements on West and East Raccoon islands during the 2012 breeding season. Numbers above symbols are the sum number of nests, defined as scrapes with eggs, counted for Wine, East and West Raccoon Islands. Between 3 June and 12 June there was a drop in the number of nests from flooding, but did not wipe out entire colonies. The dashed line represents the lowest high tide recorded during the sampling period at which all nests failed (0.71 m). Tidal information collected from Caillou Bay/Raccoon Point, Station ID 073813498 (USGS 2014).

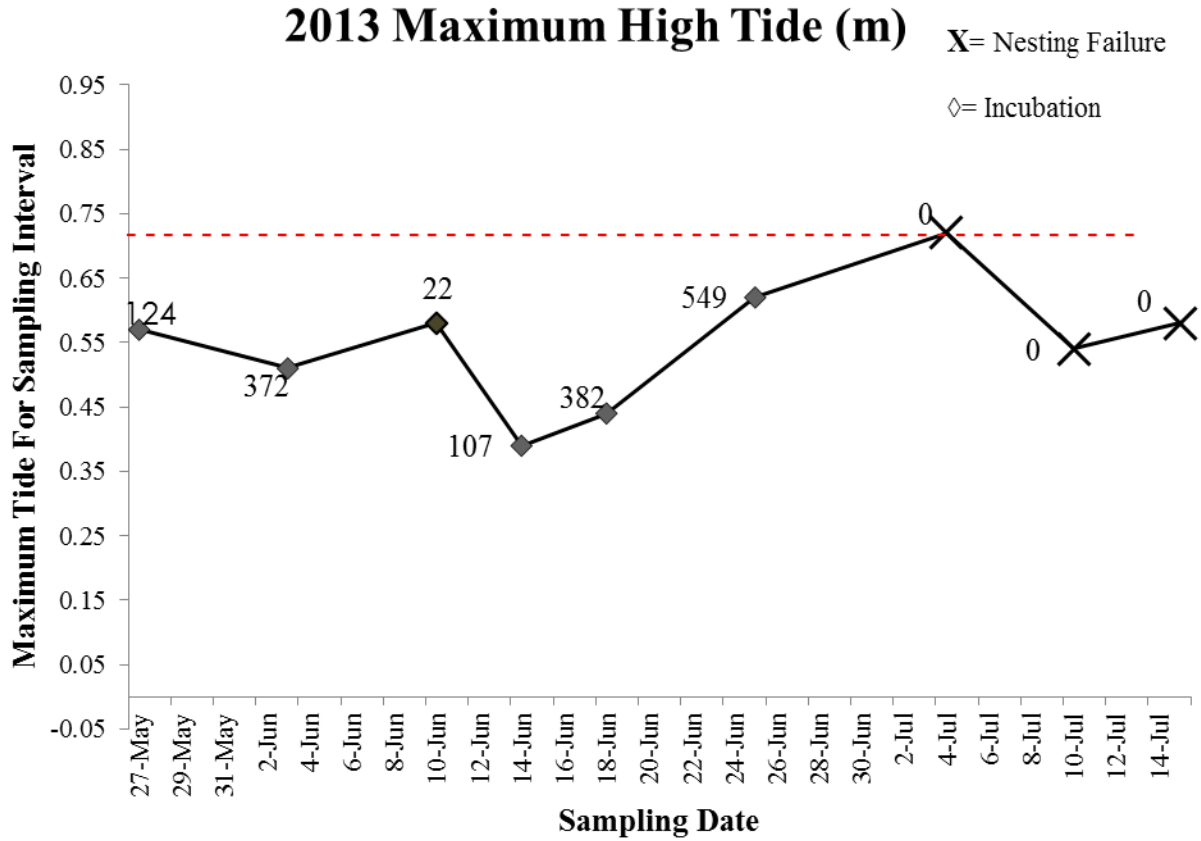


Figure 2.3. Maximum high tide measurements on West and East Raccoon islands during the 2013 breeding season. Numbers above symbols are the sum number of nests counted for East and West Raccoon Islands. The dashed line represents the lowest high tide recorded during the sampling period at which all nests failed (0.74 m). Tidal information collected from Caillou Bay/Raccoon Point, Station ID 073813498 (USGS 2014).

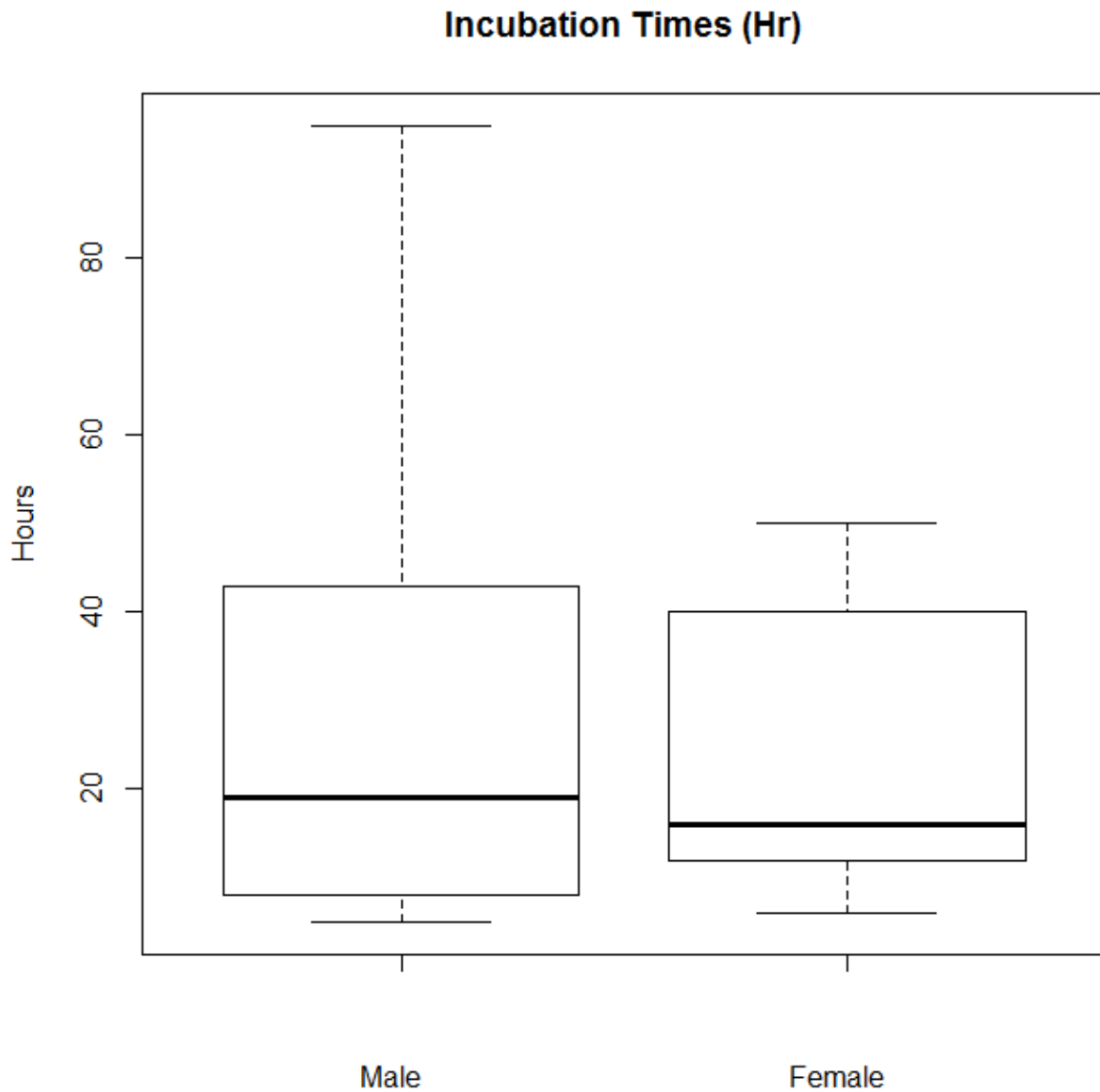


Figure 2.4: On average, females spent 6 more hours incubating than males (females=35 hrs, [95% CI=16.31-54.00], males=29 hrs [95% CI=10.31-48.00]). Data is from nests recorded with video cameras both in 2011 ($n = 4$) and 2013 ($n = 9$), and there is no mean difference in mean incubation times between males and ($W = 80.5, P = 0.86$).



Figure 2.5. Main predators associated with Black Skimmer nesting failure on the IDBIR 2011- 2013: Laughing Gull (a), Ruddy Turnstone (b), Nutria (c), Ghost Crab (d)

CHAPTER III

FORAGING AND SPATIAL USE PATTERNS OF BLACK SKIMMERS (*Rynchops niger*) NESTING ON THE ISLES DERNIERES BARRIER ISLAND REFUGE, LOUISIANA

ABSTRACT

Black Skimmers (*Rynchops niger*) are colonial waterbirds with a unique tactile foraging strategy in which they dip their longer lower mandible in the water while skimming the waters' surface to catch prey. Similar to that of many coastal birds, there is a paucity of information on skimmer foraging ecology, specifically what prey species they deliver to the nest and where they forage. I monitored the foraging ecology of skimmers on the Isles Dernieres Barrier Island Refuge (IDBIR) in coastal Louisiana from May-August 2011– 2013. In this study, I employed radio telemetry, one GPS data logger, and camera systems as methods for gathering information about skimmer movements during the breeding season. Skimmers fed young mostly at night (63% feedings occurred at night; $n = 38$) with a mean food provisioning rate of 2 fish per hour, each a single prey delivery. Females made more prey deliveries (66%) to nests than the males ($n = 38$ total feedings). In total, 67 skimmers were captured, 46 of which were equipped with radio transmitters. I recorded 203 radio locations, most of which were within 800 m of the colonies. Of these, 26 locations (10%) were documented at dusk and at night when skimmers are actively foraging. According to kernel density estimates, the mean home-range size was 50 ha and ranged from 10.62 to

243.78 ha (SD = 74 ha, $n = 11$). I determined that conventional VHF telemetry methods were biased and ineffective for tracking skimmer foraging movements because birds could not be detected beyond 800 m of nesting colonies, and therefore I used GPS data loggers in 2013. From one skimmer sampled with a GPS data logger, 15% of 202 locations were identified as foraging activity according to time of day and elevation. This male made 14 trips directly north of the breeding colony, and traveled a maximum distance of 16.4 km (mean = 8.3km, SD= 5.4 km) from the breeding colony. On average, this bird traveled 23.8 km for round-trip foraging trips (range 0.06–34.44 km). Finally, trapping methods provided a means of gathering information on selected prey species. In total, seven of 67 (10%) skimmers captured were carrying fish, which primarily included Pogie (*Brevoortia partornus*), Mullet (*Mugil cephalus*), and Silverside (*Menida peninsulae*). These data on movements and diet provide valuable insight into skimmer habitat use on the refuge, which may be representative for other skimmer colonies throughout the Northern Gulf of Mexico.

INTRODUCTION

Colonial Waterbird Foraging

Colonial breeding occurs in 29 of 129 families of birds, primarily in seabirds, of which 90% of seabird families nest in groups (Lack 1968). Access to food resources and foraging in groups are important for colonial nesting birds (Krebs and Davies 1971). One of the proposed benefits of coloniality is in individuals locating food resources and passing along information about the location and quality of the resource to conspecifics (Krebs and Davies 1971, Ward and Zahavi 1973, Burger and Gochfeld 1990), which could be important for several species of waterbirds nesting in coastal habitats because of the highly unpredictable nature of food resource availability. Sharing information about foraging sites may be more strongly developed in seabird species that span larger pelagic areas (e.g., tropical ranging Gannets and Boobies), compared to species that are more spatially restricted in evanescent, coastal habitats (e.g., Terns and Gulls; Erwin 1978).

During the nesting season, waterbirds must make trips to and from the nest to deliver prey to young, sometimes multiple times a day. The demands of nesting might affect the spatio-temporal distribution of foraging sites and prey selection (Kushlan 1978), which has been well-documented in several waterbird species (Krebs 1974, Kushlan 1976, Custer & Osborn 1978, Smith 1995). Distance traveled from the breeding colony may depend on the nesting stage, as shown in some seabirds in similar habitats (e.g., Kittiwakes; Kotzerka 2011). Although there is interspecific variation in the distance waterbirds may travel, there is potential for individual variation and for foraging distance to be correlated with colony (Erwin 1983, Burger and Gochfeld 1990) and brood size (Smith 1995, Brunn and Smith

2003). Distance traveled from the “central place”, or breeding colony, may change as prey resources shift in size and distribution, or in response to the demands of nestlings (Burke and Moterecchi 2009). When prey resources are low, foraging time and distance should be increased, as predicted by the central place foraging theory (Rosenberg and McKelvey 1999).

Abiotic factors such as wind, tides, and storms can influence foraging patterns. One study on Common Terns (*Sterna hirundo*) nesting in Jamaica Bay, New York, an United States east coast estuary, found that foraging consistently occurred during high tides and was also correlated with wind direction and velocity, temperature, and cloud cover (Burger 1982). Additionally, changes in prey abundance can influence nesting success. Studies on Common and Roseate Terns (*Sterna dougallii*) showed that higher prey availability influenced timing of egg-laying, allowed for a larger clutch size, increased prey delivery rates, and lead to faster chick development (Safina et al. 1988).

This study focuses on the foraging patterns of one colonial waterbird species, Black Skimmers, nesting on a barrier island refuge. The goals are to identify what habitat Black Skimmers are foraging in, how far they travel from the nesting colony to forage, and what prey species they are foraging on. Telemetry was employed as a method of obtaining information about Black Skimmer foraging movements. Very High Frequency (VHF) transmitters and Global Positioning System (GPS) data loggers were used to monitor the movements of birds, as well as camera recording equipment to monitor nesting behavior and prey delivery rates.

Black Skimmers

Black Skimmers (*Rynchops niger*, hereafter “skimmers”) are piscivorous, colonial waterbirds that nest in various sized colonies in open coastal habitats along the Gulf and Atlantic Coasts of North America (Gochfeld and Burger 1994). Skimmers rely specifically on low-elevation coastal habitats with less than 20% vegetation, and often in association with other nesting species of family Laridae in the same habitat, such as Gull-billed Terns (*Gelidon nilotica*, Gochfeld and Burger 1994). Their lower mandible is a few centimeters longer than the upper mandible, and they use the lower mandible to skim the surface of the water to catch small fish at the water’s surface. While skimming, when the lower mandible comes in contact with a fish, the skimmer’s head and neck turn downwards and the bill snaps closed to secure the fish. Captured fish are held horizontally in the bill as the skimmer travels to a loafing or feeding location to consume the fish (Gochfeld and Burger 1994). This tactile foraging method is unique among waterbird species. Males and females have different culmen lengths and bill depths (culmen: males >62 mm, females < 62 mm, bill depth: males >25.7 mm, females < 25.7; Pyle 2008), and it is unclear whether there are differences between sexes in their prey selection and habitat utilization.

The existing data on skimmers have been mostly focused on selected aspects of their breeding biology, such as colony formation, habitat selection, and nest structure (e.g., Burger and Gochfeld 1990, Gochfeld and Burger 1994). The migration patterns and foraging ecology of skimmers are poorly understood throughout their distribution, which extends from coastal northeast U.S. to the southern Yucatán Peninsula of Mexico (Gochfeld and Burger 1994). Anecdotal observations indicate that skimmers forage in a variety of aquatic habitats, including tidal waters of bays, estuaries, lagoons, rivers, salt marsh pools, creeks, and ditches

(Valiela 1984, Gochfeld and Burger 1994). Black and Harris (1983) reported that prey abundance and composition did not explain skimmer selection of feeding areas in Cedar Key, Florida. However, their sampling of prey abundance was limited to two sites used relatively heavily by skimmers compared to two sites where they did not observe any skimmer foraging. Black and Harris (1983) speculated that other variables such as human disturbance or intra- and inter-specific competition could influence the selection of feeding areas, but these factors were not examined. One study in Virginia suspected that the regional decline in skimmers' main prey items, particularly Atlantic Needlefish and Menhaden, led to significant chick starvation in the colony, which decreased reproductive success (Gordon et al.2000).

There are several abiotic factors that may influence skimmer foraging patterns. A study in Jamaica Bay, New York, found that skimmers generally roosted during high tide, and fed in the channels of salt marshes at low tide (Burger 1982). Skimmers in this region were sharing nesting habitat with Common Terns, which had opposite foraging patterns to that of skimmers. Burger and Gochfeld (1990) suggested that feeding cycles may vary greatly with tidal and lunar phases, with peak foraging activity occurring during low tides and 2 hours before high tides. However, this information is according to anecdotal observations and has not been studied. Erwin (1977) suggested that skimmers feed on spatially uniform resources according to the temporal distribution of feedings at nests (Erwin 1977).

According to very little information gathered along the eastern U.S coast, skimmers eat a variety of small fish species including Killifish (*Funudulus sp.*), Mullet (*Mugil spp.*), Herrings (*Clupea sp.*), Silversides (*Menidia sp.*) Pipefish (*Sygnathus sp.*), and small crustaceans that range from 3–2 cm in length (Burger and Gochfeld 1990). One study

observed that skimmers forage >8 km from nesting colonies in New York, and 5.2 km from the breeding colony in Georgia (Tomkins 1951). However, no data are available on the preferred or most productive foraging habitat used by skimmers, and which prey species they forage on in the northern Gulf of Mexico has not been well studied. It was suggested that skimmer chicks in Louisiana were only fed Silver Seatrout (*Cynoscion nothus*), Sand Smelt (*Atherina sp.*), Mugil *sp.*, Spanish Mackerel (*Scomberomorus maculatus*), and Bluefish (*Pomatomus saltatrix*) (Arthur 1921).

There is little to no information on prey resources and their abundance in the region, and it is unknown whether or not prey resources are threatened. Thus, this should be a management objective for piscivorous waterbirds nesting throughout the northern Gulf of Mexico region, especially with fish populations being among the most sensitive to ecological stresses. For example, hypoxia is an ongoing threat to the northern Gulf of Mexico's marine resources (Rabalais et al 2009). Depletion of oxygen levels in the water column in the Mississippi basin from exuberance of nutrients and eutrophication has resulted in a "dead zone" where many aquatic organisms cannot survive. Extensive research has shown how it may impact fish populations throughout the northern Gulf of Mexico (e.g., Rabalias et al 2009). Fish populations may decline or change distribution (Chesney and Baltz 2001), which may impact skimmers and other waterbirds in the area, and ultimately reduce overall reproductive success and habitat utilization (Safina et al. 1988, Gordan et al. 2000).

Foraging Habitat Selection for Skimmers

The theoretical framework to explain spatial use in waterbirds is generally lacking. Our understanding of foraging movements and habitat use has recently been expanded given

the improvement in tracking techniques, such as satellite and GPS telemetry methods (e.g., Land et al. 2008, Meyer 2011, Bryan et al. 2012). Most assessments of habitat selection involve comparing habitat use with habitat availability (e.g., Rosenberg and McKelvey 1999). Skimmers make foraging trips to and from the nest multiple times a day during the incubation stage and for several days after chicks hatch. Skimmer chicks are semi-precocial and may wander from the nest shortly after hatching (3-5 days) but do not fledge from the colony for approximately 28-30 days after hatching (Gochfeld and Burger 1994). Because the adults make trips to and from a single nesting location or fixed point during foraging trips, skimmers can be considered single-load central-place foragers (Rosenberg and McKelvey 1999). One of the predictions of central-place foraging is that birds forage close to the breeding colony and only travel farther if closer resources are depleted.

Study Goals and Objectives

The objectives of this research are to 1) identify key foraging habitat used by breeding skimmers, 2) to estimate home range sizes, 3) to determine the maximum distance traveled from nesting colonies, and 4) to identify prey resources being delivered to the nest. Data from VHF transmitters and one data logger were used to identify the preferred foraging areas used by breeding skimmers on the Isles Dernieres Barrier Island Refuge. Camera systems are utilized to determine prey delivery rates and other nesting behaviors.

METHODS

Study Area

Field research was conducted on the islands in the Isles Dernieres Barrier Island Refuge (IDBIR), (N 29° 03', W 90° 57' to N 29° 05', W 90° 36'), located in Terrebonne Parish, Louisiana. The refuge is managed by the Louisiana Department of Wildlife and Fisheries and includes five barrier islands: West and East Raccoon, Whiskey, Trinity, and Wine islands. The IDBIR currently encompasses approximately nine square kilometers of barrier island habitat, and is 13 km south of Cocodrie, Louisiana. The islands are separated from the mainland by Caillou Bay, Lake Pelto, and marshland (Fig. 1.1). The IDBIR is currently suffering from land loss, which has mostly been caused by erosion, subsidence, storm damage, and hydrological modifications throughout the region. Wine Island, for example, is the eastern most island on the refuge. Hurricanes and other hydrological factors have reduced the landmass of Wine Island from a historical area of approximately 10 ha to a current size of 1.5 ha, and continues to decrease in size (D. Curtiss 2013, A. Pierce *pers. comm.* Nicholls State University). The refuge has also been dramatically impacted by hurricanes, particularly hurricane Andrew in 1992 and Katrina in 2005. What was formerly recognized as Raccoon Island was split into two separate islands after Hurricane Andrew in 1992, and now referred to as East and West Raccoon Islands. Recent restoration efforts include application of dredge material to create dune areas, vegetative plantings, and installation of 17 rock breakwaters on East Raccoon Island (Louisiana office of Coastal Protection and Restoration 2010).

East and West Raccoon Islands were the only islands to support breeding skimmers throughout the duration of this study, and therefore, I concentrated foraging research efforts on these islands. Tidal marshlands are approximately 10 km directly north of East and West Raccoon Islands, and Caillou Bay is between the refuge and the coastal marshland. Caillou Bay has tidal fluctuations similar to most coastal areas along the northern Gulf coast. Low tides reach extremes of -0.12 m and high tides reach up to 0.44 m during the breeding months for skimmers, especially during lunar phases, particularly full moons (NOAA 2013, station ID 8763506). Salinity levels for Caillou Bay during the breeding months (June and July) varied throughout this study, ranging from a maximum of 28.5 ppt (2012) and a minimum of 6.2 ppt (2011; USGS 2013).

Skimmers on the IDBIR share nesting habitat with several other waterbird species, specifically Gull-billed Terns, Royal Terns, Sandwich Terns, Laughing Gulls, and Brown Pelicans. Although there are interspecific foraging behavior differences, it is unknown how much overlap of foraging habitat exists among these species. Brown Pelicans will dive for food in areas of concentrated fish and likely do not concentrate foraging efforts in the same areas as skimmers. All tern species plunge-dive for their food and may pick off surface prey when it is available. All species, with the exception of skimmers, commonly follow commercial shrimp boats in the Terrebonne Basin area. All of these species typically concentrate their foraging efforts during the day with the exception of Royal Terns that may also feed at night (Buckley and Buckley 1972).

Trapping

Skimmers were trapped using both mist nets and a radio-controlled bow net (Superior Bow Net and Design). Trapping occurred on East and West Raccoon Islands in all years of this study. Birds were sampled between 3 June and 19 July in 2011, 3–14 June in 2012, and 25–30 June in 2013 (Appendix A). Trapping sessions began at least a week and a half after colony formation to minimize impact of disturbance during early colony initiation. Sixty-millimeter mesh mist nets were deployed on West Raccoon Island at night during peak foraging activity (1900-2400 hrs). Six nets were opened at one time; each net was 2.6 meters high and nine meters wide (Avinet product # RT09). Nets were erected along the shoreline, approximately 200 m away from the active colony. Nets were placed either on the Gulf side or bay side of the western end of the island according to observations of skimmer flights. Skimmer decoys were used to help attract skimmers to the area where the nets were placed. Nets were checked at approximately five-minute intervals to minimize the time skimmers were in the net and to release any by-catch. Mist nets were not used on East Raccoon Island because of the high density of other colonial waterbird species nesting near skimmers which would have resulted in a high rate of by-catch and disturbance.

A bow trap was used on East Raccoon Island because of the small colony sizes and because of the high density of terns breeding in the area. A radio-controlled bow net was buried in the sand around an active nest. When the adult returned to the nest and resumed incubation posture, the net was triggered and skimmer captured. Bow net trapping occurred during early morning hours (0800-1000) to reduce the likelihood of the eggs overheating

when adults were away from the nest. To minimize disturbance, no more than three skimmers were trapped at the colony per trapping session.

Each skimmer captured was banded with a USGS aluminum band and a unique combination of color bands for future identification. Specifically, one leg was banded with two color bands, and the other leg was banded with one color band plus one aluminum USGS band with a unique identification number (Appendix A). Morphological measurements were recorded to determine sex. Measurements included mass, wing chord, upper and lower bill length, bill depth, and tarsus length. Age and sex of the birds was determined following Pyle (2008). For all birds, the culmen (female <62mm, male >62 mm), bill depth (female <25.7 mm, male >25.7 mm), and wing chord (female <373 mm, male >373 mm) were the characteristics used to distinguish males from females (Pyle 2008). Mass was also used, but because there was some overlap between sexes, wing and bill measurements provided a more accurate determination of sex.

VHF Telemetry

In addition to recording morphological measurements, the first skimmers captured during each field season were equipped with VHF radio transmitters (Holohill Inc., Ontario, Canada) weighing less than 8 g (<3% of body mass; Meyburg and Meyburg 2009). To attach the transmitter, I used the modified figure-eight harness technique (Rappole and Tipton 1991). The transmitter rested on the birds lower back and was secured around the upper legs with elastic thread that should degrade over time. Transmitters were tied on snug enough to stay secure while not constricting leg movement, and loose enough where you could fit a pencil between the bird's body and the elastic leg loops. During release, the skimmers often

walked away before flying. This ensured the transmitter attachment was not restricting their movement, either walking or in flight. In addition, transmitters were applied as quickly as possible to minimize handling time and stress on the bird. Twenty-seven marked birds were re-sighted as they were actively foraging and feeding nestlings throughout the season and subsequent years, and none showed any signs of adverse effects related to the transmitter harness design (Appendix B).

A combination of H, yagi, and omni antennas were used for tracking each bird throughout the study period, and I attempted to document at least 30 locations for each marked bird. An omni antenna was placed on the highest location of the boat, and a scanning receiver was programmed to cycle through all frequencies to help detect birds while traveling to and from the islands. The omni-antenna helped to find several birds that had departed from the breeding colony. Once the omni-antenna detected a bird that was away from the colony, I attempted to triangulate its location by using the yagi antenna from the boat. Triangulations from the boat were unsuccessful because recorded locations resulted in a large amount of error that would not have been suitable for home range analyses. Birds were not tracked within 1 hour of its previous recorded location, and 10% of the locations were documented during times of active foraging (e.g., 1900- 2400).

According to anecdotal observations of active skimmer colonies, foraging activity mostly occurred from dusk until dawn. Once an individual bird was detected, three observers that were posted at different locations on the islands (spaced >150 m apart) used two-way radios to communicate its location, and then recorded their azimuths simultaneously to improve the probability of obtaining an accurate location. If possible, observers made two separate triangulations in quick succession (<3 min) and the location with the lowest error

polygon was used in subsequent analysis. The range limit for detecting transmitters was approximately 800 m.

Global Positioning System (GPS) Data Logger

According to preliminary data from 2011, I determined that conventional telemetry may bias results by under-representing foraging movements that are farther from nesting sites. Observers were unable to detect foraging skimmers beyond the detection range while on the refuge, and as a result, data gathered from VHF was limited to 800 m around the nesting colony. Therefore, I used Global Positioning System (GPS) data loggers to minimize this bias and to potentially gain a more accurate understanding of skimmer movements. GPS loggers can only be deployed and retrieved during the incubation period, whereas birds can be fitted with radio-transmitters throughout the breeding season. Ideally, both GPS and VHF methods can be used simultaneously for comparative and complimentary methodology. GPS satellite transmitters were not used because they exceeded the minimum weight requirement (> 16 g) for skimmers to carry without adversely impacting their movement or survival.

Each miniGPS unit (earth&OCEAN Technologies GmbH, Kiel, Germany) weighed 10.5 g (waterproof casing included). Skimmers selected for GPS data logger attachment were >350-g and were trapped using bow nets on nests. One bird equipped with GPS data loggers was recaptured 4-5 days after initial capture and attachment. Units were attached to the feathers on the back using Tesa tape® (Wilson and Wilson 1989; Figure 3.2). This technique has been used on a variety of seabird species, and has been especially useful for diving species such as kittiwakes and puffins (Kotzerka 2011). GPS data loggers were programmed to take locations once every 15 minutes from 1900-0730 (what I suspected to be peak

foraging time), and once every 60 minutes from 0730-1900. These locations were stored in the GPS units and then downloaded after they were retrieved from the bird.

Video Monitoring at Nests

Cameras were selectively deployed at active nests that had two or more eggs. I used Sony Infrared (waterproof high resolution infra-red zoom camera, Super Circuits PC331-IR, Austin, TX), that continuously recorded throughout the nesting period. Cameras were placed on wooden stakes set in the ground approximately two meters from the nest. Cameras were powered by two deep-cycle marine batteries housed in Pelican cases buried >100 m away from the colony. Video was recorded by a DVR system (H. 264 Micro Digital Video Recorder) with SD memory cards. The memory cards were replaced every 3-5 days to ensure continuous sampling without exhausting the cards' memory space. Batteries were replaced once a week or more often, as needed. Video from the SD cards was uploaded and viewed with the DVR's viewing software Standard Digital Review [SDR (V 14-4, Seorim Technologies, Korea)] and stored on an external hard drive. Observers reviewed video to record several nest behaviors, including prey delivery rates and potentially identifying what prey species are delivered to the nest.

ANALYSES

Using the recorded azimuths and geographic coordinates of receiver sites, I estimated the location of the bird by using program Locate II (1990). Tracking locations were discarded if error ellipses on VHF locations were too large (>1 ha). Once all locations were approved for each bird, I used ArcGIS 9.3.1 to display the spatial locations of tracked birds on the

islands using 2010 NAIP imagery of Terrebonne Parish. ABODE (Laver 2005), an ArcGIS tool, was used to determine fixed kernel density estimates to identify core foraging areas on a landscape level. Minimum convex polygons were not used because they are often misleading in determining an organism's home range, by including areas that organism is not actually using (Worton 1989, Seaman and Powell 1996). I did not analyze birds that had less than 15 locations, as it would not likely accurately represent the birds' home range (Land 2008, Anich et al. 2010). I used a Least Squares Cross Validation (LSCV) as a smoothing parameter estimate to determine the appropriate probability use contours and quantify spatial use patterns (Horne and Garton 2006). The mean error ellipse size was 0.28 ± 0.32 ha.

Information downloaded from the GPS data logger in 2013 was compared qualitatively to data collected with VHF telemetry locations from 2011 to assess the degree of accuracy and/or bias of the radio telemetry locations. GPS locations were filtered to remove unrealistic positions such as those associated with a speed of 50km/h, or positions recorded after recapturing the logger. Foraging locations were differentiated from non-foraging locations as those that were not near the nest, and were recorded at elevations which indicate foraging behavior and occurred between 1700 and 0730. With statistical program R and data gathered from VHF locations in 2011, I used Wilcoxon rank sum test to determine whether there were differences in home range sizes and/or distance traveled from nests between male and female skimmers. I also used statistical program R with package "adehabitatHR" to calculate the kernel density estimate for the skimmer equipped with the GPS transmitter. This estimate was also used with LSCV as smoothing parameter.

With the limited information gathered from birds and their fish prey caught in mist nets, I ran a Wilcoxon rank sum test to see if there is a difference in the size of fish males and

females are preying upon. To see if larger birds selecting larger prey, I pooled the data and ran a Spearman's correlation test. Data was not collected on the lower bill length in 2013, so I used mass as bird size variable.

RESULTS

Spatial Use Patterns

A total of 67 skimmers were captured from 2011 to 2013, and 46 of these (21 males and 25 females) were equipped with radio-transmitters (Appendix A). Mist nets were useful for catching large number of skimmers during evening netting sessions ($n = 49$ birds). However, bow nets were very effective for selectively targeting individual skimmers for capture at nests ($n = 18$). The mean handling time for all birds was 17 minutes (SD = 9 minutes). In 2011, three fledglings were captured, for which the sex could not be determined.

The fates of four transmitted birds (20%) were unknown in 2011. These birds were fitted with transmitters on the 3rd, 9th, and 19th of June 2011. Immediately following transmitter attachment, I obtained only one location for two skimmers (USGS band numbers 0994-21323 and 0994-21328; Table 2.1). For two other birds (USGS band numbers 0994-21339 and 0994-21340), I detected signals two and five days after trapping, but I did not detect signals later during that field season. During the 2012 and 2013 breeding seasons, nesting colonies failed due to flooding during the late incubation stage. The skimmers equipped with transmitters ($n = 26$) could not be tracked following colony abandonment. The quantity of location data obtained from these birds was not sufficient for home range analysis.

I displayed all telemetry locations on maps in ArcGIS and separated diurnal and nocturnal locations. According to camera data analysis, most prey were delivered to young at night; thus, I assumed that night locations probably represented foraging movements while daytime locations on and near the islands most likely reflected loafing movements. VHF data could only be gathered in 2011 because tagged birds in 2012 and 2013 ($n = 26$) experienced nest and colony failures, and were not present on the refuge after transmitter attachment. Based on information gathered in 2011 only ($n = 16$), the estimated mean home range size for skimmers that had enough locations documented was 50.01 ha and ranged from 10.62 ha to 243.78 ha ($SD = 74$ ha, $n = 11$, 7 females, 4 males; Table 3.1). Ten percent of the locations gathered from the 11 birds that had sample sizes large enough for home range analyses were recorded at night (between 1900 and 0700 hrs), and probably represented foraging activity. Overall, actively nesting birds tagged on this island ($n = 10$) spent their time in relatively close proximity to nesting sites (Figure 3.3). There was no difference ($P = 0.18$) between the males home range sizes (107 ha; $n = 4$) and females (21 ha; $n = 7$). There was also no difference ($P = 0.58$) in the mean distance traveled from the nest for males (0.65 km, $n = 4$) versus females (0.86 km, $n = 7$).

During the last week of incubation in 2013, two skimmers were tagged with GPS data loggers using bow nets. Sampled birds were targeted from a distance using spotting scopes to locate healthy nesting skimmers attending a nest, which were greater than 350 g. Both skimmers were bow trapped on 27 June 2013, and were males that were both processed within nine minutes. One male was recaptured four days after its initial capture on the nest. In this same trapping event, the female returned to the nest for incubation within ten minutes after net deployment. The second male skimmer fitted with a GPS logger could not be

recaptured because only the female attended to the nest until trapping attempts were forfeited due to the high risk of heat stress on the nest (approximately 1000 hours). Flooding destroyed the breeding colony two days after the last re-capture trapping attempt, so this transmitter could not be retrieved. However, during re-trapping attempts, this male was observed several times in close proximity to the nest and the breeding colony with other loafing and preening skimmers. The one GPS data logger recorded five days of data, of which 15% of the data points ($n = 202$) were identified as foraging locations according to time of day and elevation. Fourteen round-trip foraging trips were made directly north of Caillou Bay and the breeding colony (Figure 3.4), and the maximum recorded distance traveled from the breeding colony was 16.4 km (Table 3.2). On average, this male traveled approximately 23.8 km for round-trip foraging trips (SD = 10 km; range 0.06–34.44 km). Trip duration varied from 46–180 minutes (mean = 82 minutes, SD = 36 minutes) for complete trips (Table 3.3). The mean flight speed during foraging trips was 24.3 km/h (SD=13). This male foraged equally during high (43%, $n = 6$) and low tides (43%, $n = 6$). Fourteen percent of foraging trips occurred midway between high and low tides ($n = 2$). The estimated home range size for this one GPS outfitted bird was 855 ha.

Diet and Prey Delivery Rates

Capturing skimmers at night using mist nests proved to be an excellent method of obtaining data on the fish preyed upon by skimmers. On 30 June 2013, seven birds (4 females, 3 male) captured with mist nets had prey loads and regurgitations consisting mostly of Atlantic Silverside (*Menidia menidia*; $n = 17$; Appendix D). Other fish species collected included Needlefish (*Strongylura marina*, $n = 3$), Pogie or Gulf Menhaden (*Brevoortia*

patronus; $n = 8$), and Striped Mullet (*Mugil cephalus*; $n = 1$). Several anecdotal observations were made of skimmers bringing *S. marina* back to the colony. There was no difference between males ($n = 10$) and females ($n = 19$) in the size of prey they were returning to the colony with ($P = 0.64$, $W = 84.5$), and no correlation between the size of the bird and the size of fish captured ($P = 0.56$, $n = 29$).

Based on camera footage collected during the only year skimmers hatched young (2011), skimmers fed young mostly at night (63% of 38 feedings occurred at night) with a mean food provisioning rate of 2 fish per hour with one fish prey item each feeding. Females made more prey deliveries (66%) to nests than the males. Camera footage at night was not sharp enough to detect what specific prey species were delivered to the nest.

Cameras deployed in 2013 captured footage of males food provisioning females while incubating. Of the nests recorded in 2013 ($n = 9$), five nests recorded adults bringing back fish prey to the nest, and were all recorded at night (21:00-06:00). Males returned to the nest more often with a fish after a foraging trip, accounting for 88% of observations ($n = 22$). Males brought back fish to the nest to supplement incubating females in all of these observations. Females only brought fish back to the nest twice, one resulting in a Ghost Crab (*Ocypode quadrata*) stealing the fish after an aggressive interaction. No observations were made of females returning to the nest to supplement males. This pair bonding behavior was not recorded on nests with chicks in 2011.

DISCUSSION

Results from this study show two highly effective trapping methods for skimmers that can be used for future studies. Bow traps were extremely effective for targeting individuals on the nest, and seem to be effective for re-capture of specific individuals as well. Mist nets were useful for catching several skimmers at night, and may be a beneficial strategy for future studies that involve measuring and marking skimmers. The modified figure 8 harness design used for VHF attachment was good for temporary transmitter placement and tracking short distances for a limited period of time. All re-sights in 2013 of birds tagged in previous years showed that the elastic thread allowed the birds to lose the transmitter over time, and appeared not to impair their mobility. The tesa tape method used to attach data loggers was also effective. No data was lost during the five day period and the logger was retrieved off the recaptured bird without problems. The skimmer that was not re-captured was observed several times after GPS attachment and appeared to be resuming regular nesting activities. This suggests that both VHF and data logger attachment methods did not negatively affect nesting skimmers.

Despite an extremely limited sample size, some insight was gained on skimmer foraging movements that were previously unknown in this region. Several radio-tagged birds were inconsistent in their movements due to the limitations of the VHF telemetry. Several skimmers were apparently often away from the colony and I was unable to get sufficient number telemetry locations (Table 3.1). The failure to detect the radio signals may have been due to the birds traveling beyond detection limit (>800 m), the transmitter falling off the bird into the water, or transmitter malfunction. The majority of the locations were taken from the islands or from the boat next to the breeding colony, so if a skimmer commonly foraged

>1 km from the refuge, I would have a low probability of documenting those locations.

While commuting from LUMCON to the nesting islands, the omni-antennas were useful for scanning for all radio signals, but only documented one bird >1 km from nesting islands.

Signals detected away from the breeding colony and boat triangulations resulted in too much error and were discarded, and found that tracking skimmers at night from a boat was not a feasible method for obtaining those data. Habitat utilization analyses could not be performed to look at what areas were preferred foraging areas for skimmers based on this limited sample size.

There are several limitations to studying skimmer foraging movements on the IDBIR during the breeding season, mostly due to weather constraints. The only VHF data recorded was in 2011, and although skimmers were equipped with VHF transmitters in 2012 and 2013, their movements were unpredictable because of the lack of nesting because of flooding impacts. Nesting failure in 2012 and 2013 made it impossible to gather information on home range use over a three-year period since skimmers failed to nest. In the few opportunities for nighttime telemetry collecting, signals were lost on all birds from the islands. These attempts were after the nesting failure, and where these birds were foraging or loafing during the day is unknown. There were very few re-sights of banded birds from those two seasons loafing on the refuge following flooding impacts. Based on this information, other locations in the region besides the IDBIR seem to provide good loafing and foraging areas. GPS data loggers would be beneficial to identify habitat being used by skimmers not actively nesting during the breeding season.

Due to the constraints aforementioned with VHF telemetry methods, comparisons in home range and distances traveled from the nest could not be compared across years. Future

studies should consider the relationship between foraging patterns and nesting success, and the use of GPS loggers are recommended for accomplishing this. Utilizing GPS loggers is a beneficial technique that allows for monitoring skimmers nocturnal foraging activity during the incubation period that VHF telemetry may not be able to accomplish (e.g., Kotzerka 2011). GPS data loggers reduced bias involved with VHF telemetry and were a better representation of skimmer activities. Comparisons between the estimated home range from the one GPS male (855 ha) versus the VHF skimmers in 2011 (50 ha) suggests that the VHF data is not as valid as the GPS data. Tracking limitations with using VHF telemetry underestimates their home range and how far skimmers nesting on the IDBIR are traveling for foraging trips. Distances traveled from the breeding colony were further than what was detected with the VHF telemetry. However, with a small sample size, it is unclear whether this foraging distance would be a pattern among other skimmers in the same breeding colony, or if there is intra variation in foraging distance. Foraging locations may vary according to the breeding period, but I could not make these comparisons from the lack of data in 2012 and 2013. Skimmers in 2011 may have been traveling less distance because of the demands of nestlings, as seen in other seabirds such as Albatross (Weimerskirch et al. 1993). The GPS data from the single male did not have nestlings, possibly allowing for more time in foraging during the incubation period. This distinction could not be made during this study, and is important for evaluating the relationship between prey availability and foraging patterns in skimmers. Furthermore, there may be patterns in skimmer habitat use and abiotic factors such as tidal fluctuations that I was unable to detect in this research, likely because of the limited sample size. There was no detectable influence and this may be due to minimal tidal

fluctuations around the refuge compared to larger east coast tidal patterns (Burger and Gochfeld 1994).

Several fish prey species were collected by capturing birds in mist nets that may help in identifying skimmer foraging habitat. Fish were also collected with seine nets along the shoreline on West and East Raccoon Islands by Dr. Rich Grippo (R. Grippo, Arkansas State University, unpub. data). The fish he collected showed Striped Killifish and Atlantic Silversides as the most abundantly collected fish while sampling along the shorelines during the 19 and 20th of July 2011 (Appendix E). Based on what little is known about habitat preferences for these species (US Fish and Wildlife Service 1983), fish collections were not a useful guide for foraging habitat. Gulf Menhaden are a pelagic planktivore described as a marsh edge species, and has been the most abundant species found in fisheries landings since 1969 (Chesney and Baltz 2001). Gulf Menhaden are predominant in the region as a species commonly inshore in shallower waters during the warmer months and migrating further offshore during the winter. Gulf Menhaden, as well as Needlefish, Striped Mullet, and Atlantic Silverside are all described as being ubiquitous in their distribution and habitat preference throughout the northern coastal Gulf region. All of these species inhabit intertidal creeks, marshes, and estuarine habitats (H. Blanchet, Fisheries Biologist, Louisiana Department of Fish and Wildlife, *pers.comm.*). Many of these species, particularly Atlantic Silverside, spawn during lunar and tidal phases, commonly occurring during high tides and full moons. Local abundance may have a lot of temporal variation due to localized movements following tidal patterns for many of these species (US Fish and Wildlife Service 1983). Data from the GPS data logger show that foraging occurred during both low and high

tides, and albeit a small sample size, may suggest different results than what was previously reported by Burger and Gochfeld (1990) of skimmers foraging during peak low tides.

Results from this study demonstrate that conventional VHF telemetry are likely ineffective for tracking skimmer foraging movements. Data are extremely limited for a species that forages singularly rather than in a group. Furthermore, the telemetry methods used in this study in conjunction with the camera systems highlights the importance of a nocturnal foraging strategy for skimmers. Many of the smaller prey resources may become more available at night, or strongly dependent on lunar and tidal phases (US Fish and Wildlife Service 1983). Although many of the feedings to chicks occurred at night, several were also during the daytime, highlighting that skimmers foraging patterns may change after chicks hatch. Males provisioning females during the incubation period may strengthen their pair bond, and may also help in transferring information about the quality of food resources in the area. Finally, continued research is needed to identify where skimmers are foraging, and prey abundance should be measured in Caillou Bay and other areas surrounding skimmer breeding habitat to evaluate the importance of these prey resources to overall nesting productivity.

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Table 3.1. Number of Telemetry Locations and Kernel Home-Range Estimates for Skimmers using the Isle Dernieres Barrier Refuge, 2011.

USGS Band Number	Number of locations	Date of First Telemetry	Bandwidth^a	Home- range Size (ha)^c	Date of Last Telemetry Location^d
0994-21321	11	3 June 2011	–	–	3 August 2011
0994-21322	19	3 June 2011	2787.559	243.78	7 August 2011
0994-21323	1 ^b	3 June 2011	–	–	3 June 2011
0994-21324 ^e	23	3 June 2011	223.7811	22.72	7 August 2011
0994-21325	11	3 June 2011	–	–	16 July 2011
0994-21326	19	10 June 2011	198.5256	17.37	4 August 2011
0994-21327	30	10 June 2011	159.1283	10.62	1 August 2011
0994-21328	1	9 June 2011	–	–	9 June 2011
0994-21329	15	9 June 2011	183.76	17.37	19 July 2011
0994-21330	21	10 June 2011	195.8182	17.57	7 August 2011
0994-21331	32	10 June 2011	208.8339	19.90	1 August 2011
0994-21332	19	10 June 2011	192.4587	21.20	19 July 2011
0994-21333	30	10 June 2011	215.1549	18.01	4 August 2011
0994-21334	28	15 June 2011	292.8221	39.76	7 August 2011
0994-21335	9	9 June 2011	–	–	7 August 2011
0994-21336 ^f	16	19 June 2011	1150.705	143.83	4 August 2011
0994-21337	14	19 June 2011	–	–	7 August 2011
0994-21338	13	19 June 2011	–	–	7 August 2011
0994-21339	2	19 June 2011	–	–	19 June 2011
0994-21340	8	28 June 2011	–	–	12 July 2011
All birds	321		713.3876	50.01	

^aBandwidth: Smoothing factor (h) selected for determining kernel density estimates for each bird.

^bNumber of locations: We did not estimate home range size for birds with <15 locations (Anich et. al 2010).

^cMean Spatial Area (ha) according to mean 95% use contour.

^dLast date of telemetry data collection was 7 August 2011.

^e0994-21324; see Figure 2.

^f0994-21336; see Figure 3.

Table 3.2. Distance from the nest (West Raccoon Island) traveled for male skimmer 0914-50478 equipped with GPS data logger.

Trip	Date	Time	Distance from Nest (km)
1	27-Jun-13	23:58	11.55
1	27-Jun-13	0:13	8.57
1	27-Jun-13	0:28	1.7
2	28-Jun-13	2:46	9.5
3	28-Jun-13	22:33	6.36
3	28-Jun-13	22:48	12.76
4	29-Jun-13	2:27	0.19
4	29-Jun-13	2:42	6.69
4	29-Jun-13	2:57	6.65
5	29-Jun-13	4:55	7.21
6	29-Jun-13	10:02	0.05
6	29-Jun-13	11:05	0.21
7	29-Jun-13	18:10	16.43
7	29-Jun-13	19:15	15.67
8	29-Jun-13	22:24	7.29
8	29-Jun-13	22:39	12.89
9	30-Jun-13	3:15	12.59
9	30-Jun-13	3:31	14.38
9	30-Jun-13	4:00	16.21
9	30-Jun-13	4:15	13.78
10	30-Jun-13	16:51	0.04
11	30-Jun-13	21:48	8.78
11	30-Jun-13	22:03	10.57
12	1-Jul-13	0:55	3.19
12	1-Jul-13	1:10	10.83
12	1-Jul-13	1:25	14.59
13	1-Jul-13	4:26	0.21
13	1-Jul-13	4:41	7.37
13	1-Jul-13	4:52	13.01
13	1-Jul-13	5:28	8.38
14	1-Jul-13	7:28	0.06

Table 3.3. Round-trip travel distances and duration for male skimmer, 0914-50478 equipped with GPS data logger.

Trip	Total Trip Length (km)	Travel Time (min)
1	23.2	78
2	19.6	46
3	25.7	53
4	13.8	60
5	14.6	60
6	0.26	60
7	34.5	180
8	31.9	78
9	34	135
10	0.1	60
11	24.6	75
12	30.5	80
13	32.7	97
14	0.06	90



Figure 3.1. Bow net set up on a Black Skimmer Nest on East Raccoon Island.



Figure 3.2. Data logger on a Black Skimmer showing the Tesa® tape attachment method.

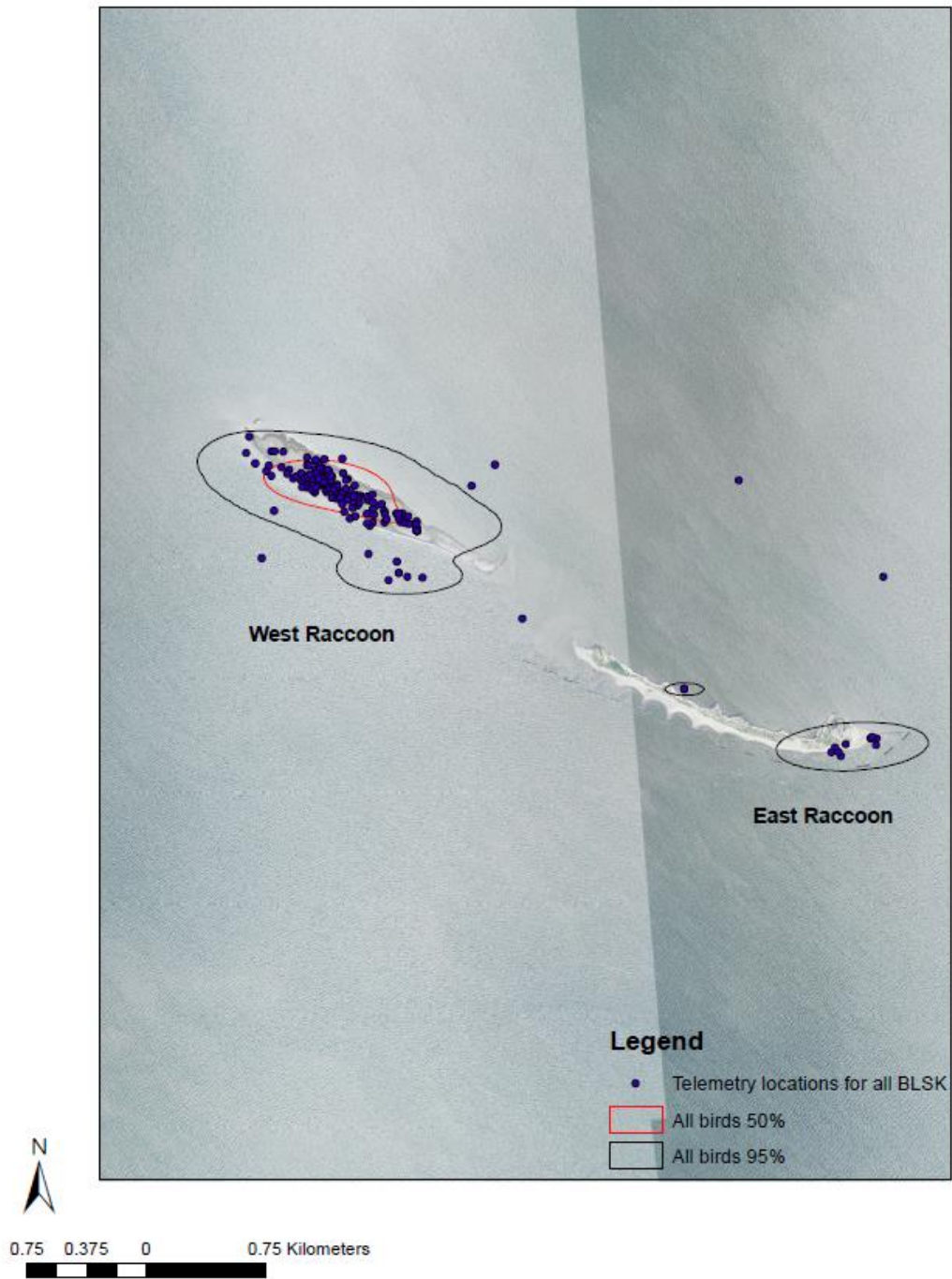


Figure 3.3. Map displaying 50% and 95% kernel density use area estimates for all Skimmers radio-tracked on the Isles Dernieres Barrier Refuge, 2011.

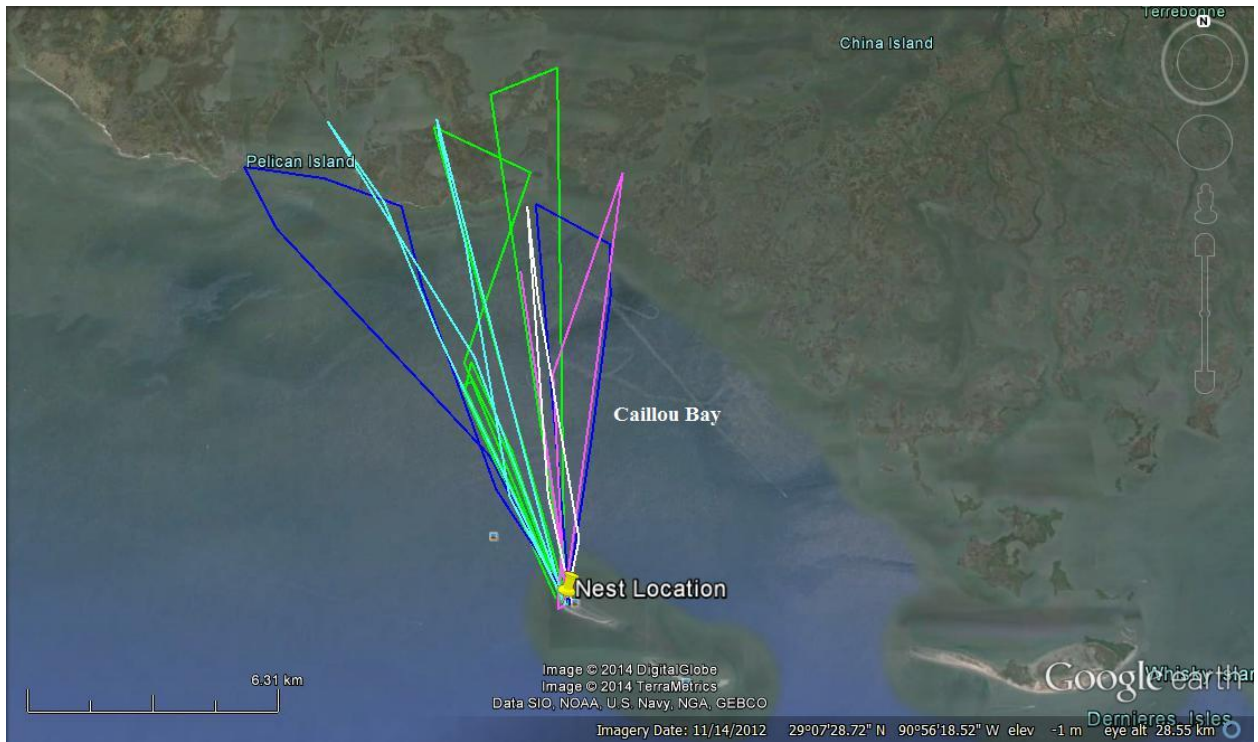


Figure 3.4. Foraging trips of male skimmer 0914-50478 equipped with a GPS data logger from the nesting colony on West Raccoon Island in 2013.

(“*Isles Dernieres Barrier Island Refuge*”, 29° 07'28.72' N, 90° 56'18.52' W. Google Earth. Date Accessed: April 2014).

CHAPTER IV

GENERAL CONCLUSIONS

Colonial waterbirds are exposed to many ecological stressors that limit their ability to reproduce and provide food for offspring. This study showed the challenges one colonial waterbird, Black Skimmers, face in a highly ephemeral habitat, and the impacts of unpredictable weather patterns on their annual reproductive success. I measured the reproductive success, breeding behavior, and foraging patterns of Black Skimmers on a barrier island refuge that is facing the same climatic and anthropogenic threats as other areas throughout their range. These threats may be magnified along the northern Gulf coast as sea level rise and other natural climatic pressures have dramatic impacts on their main nesting habitat. How skimmers respond to these pressures was a goal of this study, and the two-year reproductive loss highlights the importance of understanding long-term trends in skimmer population dynamics.

Although there is nesting space available, skimmers abandoned Whiskey Island likely due to the presence of Coyotes early in the 2011 breeding season, which had previously supported some of the largest concentrations of nesting skimmers (Owen and Pierce 2013, Raynor et al. 2013). Owen and Pierce (2013) recognized the presence of Coyotes impacting nests on the IDBIR, but were not documented as a source of complete colony abandonment. Wine Island, another important breeding location for skimmers, has a landmass that has

recently been substantially reduced. Wine islands size and low elevation increases the opportunity for nesting failure from wave action and tidal flooding. Other waterbirds nesting on Wine Island in 2011 showed the effects of inter-specific competition, as nesting space was crowded and tern creches' often disturbed the small skimmer colony. Owen and Pierce (2013) found similar results with skimmers nesting on Wine Island in the two years previous to this study. The presence of nesting skimmers on Wine Island in 2011 and 2012 is important, but the low hatching success shows that this island is likely unstable for supporting breeding skimmers in the future. Thus, the presence of mammalian predators and availability of nesting space likely has a large influence on colony site selection.

The net reproductive success measured in this study was lower than expected due to the unpredictability of flooding impacts on the IDBIR. Flooding occurred every year and on all islands except for Whiskey Island. Based on the unpredictability of storms, flooding seemed to have less of an influence compared to predation on where skimmer chose for nesting sites. This is important for management if this behavior pattern in colony site selection is common for other locations throughout their range. If predators are excluded, flooding and nesting space may be the only limiting factors to reproductive success. This study showed that regardless of the variability in flooding impact (i.e., flooding accounting for less than 10% of total nesting failure in one year versus 100% nesting failure in other years), skimmers will continue to use those sites as nesting areas more so than in cases where there is high predation pressure, as seen on Whiskey Island. Therefore, predation and coastal land loss may pose the largest threat for skimmer nesting colony establishment, whereas flooding may be the most important factor for skimmer nesting success.

Sampling skimmer nests with nest marker stakes and the subsequent Mayfield nest success analysis used was valuable for gaining information on hatching success and comparing this to the reproductive data gained in years previous to this study. However, information gathered from nest camera sampling suggests that caution should be used in determining causes of nesting failure with weekly or bi-weekly nest checks. There is a tradeoff, however, because nest marker stake sampling allows for a larger sample size compared to camera sampling. Specific predators cannot always be identified, and several factors may be associated with the proximate cause of nesting failure that would be difficult to determine with weekly nest monitoring alone. Avian depredations accounted for a small amount of nesting failure in this study, but may be underestimated. Any nests that were abandoned upon arrival may have been depredated or flooded, and any nests that did not show any signs of causes for nesting failure were marked as “unknown”. Predation may have been more than what was measured in 2012 and 2013 if flooding was not the ultimate cause of colony failures. I was unable to distinguish the percent failures caused by Laughing Gulls versus other species of avian predators in this study, and this unknown information is important for understanding the role of predation on skimmer colonies in the Gulf of Mexico. This could be accomplished with nest camera sampling, and it is beneficial to capture information that regular visits from observers cannot reliably gather. Nest camera sampling methods should be considered in future studies that seek to determine the role of predation, flooding or other disturbances on skimmer reproduction.

Nutria disturbances and predation on East Raccoon Island was an important finding in this study that was not expected, and has not been documented in the literature, to my knowledge. No information is currently available on nutria impacts on waterbird colonies

throughout their range. The rate at which approximately 50 nests were destroyed by what was suspected as a single nutria is alarming, and should be noted as a potential source of nesting failure where nutria are established with nesting waterbirds. Further research is needed on nutria movements and their role in waterbird nesting success throughout the refuge.

The study represents the first time radio-telemetry has been employed with skimmers during the breeding season, in part, because of the challenges in capturing and tracking the birds on barrier island habitat. Trapping skimmers posed a challenge because of their foraging behavior over the water's surface, unpredictable movements, and sensitivity to human disturbance. Mist nets and decoys set up at night captured a large amount of skimmers at one time, and can be used for future banding or monitoring methods. The remote-controlled bow net was extremely effective for targeting incubating adults. The timing of trapping was important, especially for bow nets, because of the stress involved in capture. Trapping was only considered during the later stages of colony formation to reduce the changes of this disturbance causing colony abandonment. It is crucial for the captured bird to return to the nest to resume normal nest behaviors, and there was no evidence to support that any skimmers abandoned their nest or experienced nesting failure as a result of trapping stress. One nest with a banded male that was equipped with a VHF transmitter was recorded with a camera in 2011. Normal nesting activities were recorded, and provided additional support for effective trapping techniques. The male from this nest returned to the nest within three hours of being trapped and equipped with a VHF transmitter, and this nest successfully fledged two chicks.

Skimmer foraging movement information gathered from VHF telemetry was beneficial for identifying skimmers at nests and gaining an idea of their short range movements (<800 m) from the nesting colony. However, the kernel density estimates gained from the VHF telemetry in 2011 are likely unreliable, and represent a biased result on skimmer home range sizes. More importantly, the use of VHF transmitters was found to have many limitations for studying a colonial nesting waterbird on barrier islands. An immediate challenge is their nocturnal foraging behavior, and the opportunity to track skimmers at night on a barrier island from shore was limited based on weather and tidal constraints, as well as the detection range limit for marked birds. Secondly, since birds equipped with VHF transmitters were nesting birds, I expected more reliable signals around the islands. Although birds were equipped with transmitters in 2012 and 2013, observers were unable to gain any signal because they could not be detected on the IDBIR after flooding events that caused complete reproductive failure. Based on 1-3 visits to the refuge after flooding events, these birds likely re-located to other islands elsewhere in the Gulf that could not be detected in the scope of this study. If the birds were not on the islands, field studies were abandoned for that breeding season shortly after flooding events. Lastly, signals from birds equipped with VHF transmitters could only be detected so far (< 800 m), and any locations documented were biased. The sampling bias poses a challenge in interpreting home range results, and different techniques should be used in the future.

GPS transmitters were an option to explore how to gain accurate and un-biased information on skimmer foraging in 2013. The cost associated with using GPS data loggers to understand bird movements is that the bird must be recaptured to download the data, as well as the loggers themselves being more expensive than traditional VHF transmitters. This

is challenging because the bird must be captured at a time that is not too early to cause nest abandonment, and then recaptured before eggs hatch. Adult nesting skimmers must be recaptured on the nest before eggs hatch because skimmer chicks often leave the nest 2–5 days after hatching, and at that stage, the skimmer would be difficult to find and re-trap. For 5–7 days of data logger sampling, this timing of trapping and re-trapping must be on target with the nesting stage. On the other hand, there are many beneficial aspects of GPS data loggers. The sealed capsule and attachment technique seemed to be successful for skimmers, and there were no issues with logger damage or a logger falling off the two sampled skimmers. In addition to attachment, the information captured by the logger includes variables that cannot be measured with conventional telemetry, such as elevation, speed, and direction. This information gathered from one recaptured skimmer provided a more accurate representation of skimmer foraging movements because of the reduced observer bias and programmed sampling times (every 15 minutes). Surprisingly, this one male skimmer made consistent foraging trips directly north of the nesting colony in coastal marshland habitat multiple times a night. The distances traveled and duration for each independent foraging trip was more than expected, and leads to further questions about skimmer foraging patterns in the Gulf of Mexico.

Despite a limited sample size, there was more information gained on skimmer foraging patterns that was previously unknown. Home ranges were calculated for nesting males and females based on VHF transmitter data, sampling methodologies were found to be biased and unreliable, and a new technique of using a GPS data logger provided a better representation of skimmer movements. Furthermore, some data was collected on specific fish prey being consumed by skimmers that can be of use in future studies (Appendix D), as well

as prey delivery rates at nests. More reliable research is needed on where skimmers are foraging, specific prey items, how much each prey item constitutes the skimmer diet, and prey abundance to gain a more complete picture of how skimmers are foraging in patchy, unpredictable environments. This may be a priority for northern Gulf coast waterbirds if resources are depleted coupled with the rapid changing or depleted habitat structure throughout the region. Long term data sets on skimmer reproduction and prey abundance are needed to further evaluate the relationship between prey density and nesting success. Finally, this study justifies the need for continued, detailed monitoring in areas where skimmers are threatened with rapid habitat loss. Skimmer reproductive ecology and foraging movement results found in this study will provide valuable insight on skimmer habitat use not only on the IDBIR, but also at other localities throughout the Gulf region.

APPENDIX A. Measurements for Black Skimmers equipped with VHF Transmitters on the Isles Dernieres Barrier Refuge, 2011-2013.

Capture Date	Location ^a	USGS band #	Top Right	Bottom Right	Top Left	Bottom Left	Mass (g)	Wing Chord (mm)	Culmen (mm)	Lower Bill length (mm)	Bill Depth (mm)	Sex ^b	Age ^c
3 June 2011	WRI	0994-21321	Red	Red	Yellow	Metal	290	300+	57.1	–	–	F	ASY
3 June 2011	WRI	0994-21322	Red	Yellow	Yellow	Metal	235	300+	75.7	79.8	–	M	ASY
3 June 2011	WRI	0994-21323	Red	Black	Yellow	Metal	320	300+	74	100	–	M	ASY
3 June 2011	WRI	0994-21324	Red	White	Yellow	Metal	385	300+	76.2	98.3	29	M	ASY
3 June 2011	WRI	0994-21325	Red	L. Blue	Yellow	Metal	365	300+	76	108	31.3	M	ASY
9 June 2011	WRI	0994-21326	Red	Green	Yellow	Metal	390	400	69.7	110.9	29.7	M	ASY
9 June 2011	WRI	0994-21330	Yellow	White	Red	Metal	273	350	58.1	79.5	24.5	F	ASY
9 June 2011	WRI	0994-21329	Yellow	Black	Red	Metal	225	355	58.9	81	22.5	F	ASY
9 June 2011	WRI	0994-21328	Yellow	Red	Red	Metal	310	330	61	81.5	25	F	ASY
9 June 2011	WRI	0994-21327	Yellow	Yellow	Red	Metal	355	375	73.5	99.6	30	F	ASY
9 June 2011	WRI	0994-21331	Yellow	L. Blue	Red	Metal	253	358	58.5	81.6	22.5	F	ASY
9 June 2011	WRI	0994-21332	Yellow	Green	Red	Metal	295	37.4	60.5	77.2	25	F	ASY
9 June 2011	WRI	0994-21333	Black	Black	Yellow	Metal	280	360	58.5	78.5	23.7	F	ASY
9 June 2011	WRI	0994-21334	Black	White	Yellow	Metal	285	357	63.8	75.8	24.1	F	ASY
9 June 2011	WRI	0994-21335	Black	Black	Yellow	Metal	315	372	59.5	89.8	25.2	F	ASY
18 June 2011	ERI	0994-21336	Black	Green	Yellow	Metal	395	394	75.7	98.1	27.1	M	ASY
18 June 2011	ERI	0994-21337	Black	Yellow	Yellow	Metal	375	394	77.3	104.7	25.4	M	ASY
19 June 2011	ERI	0994-21338	White	White	Red	Metal	360	352	56.3	78.8	22.4	F	ASY
19 June 2011	ERI	0994-21339	White	Red	Red	Metal	400	407	71.5	105.2	29.4	M	ASY
28 June 2011	ERI	0994-21340	White	Black	Red	Metal	370	385	71	99.2	26.7	M	ASY

^aLocation: WRI= West Raccoon Island, ERI= East Raccoon Island.

^bSex: F= Female, M= Male.

^cAge: ASY= After-second year (Pyle 2008).

APPENDIX A. Measurements for Black Skimmers equipped with VHF Transmitters on the Isles Dernieres Barrier Refuge, 2011-2013.

Capture Date	Location ^a	USGS band #	Top Right	Bottom Right	Top Left	Bottom Left	Mass (g)	Wing Chord (mm)	Culmen (mm)	Bill Depth (mm)	Sex ^b	Age ^c
3 June 2012	WRI	0914-50465	Green	Green	Green	Metal	340	410	70.1	26.9	M	ASY
12 June 2012	ERI	0914-50466	Green	Pink	Green	Metal	285	327	61.9	23.1	F	ASY
12 June 2012	ERI	0914-50467	Green	Blue	Green	Metal	290	358	59.3	22.6	F	ASY
12 June 2012	ERI	0914-50468	Blue	Green	Green	Metal	360	392	69.2	27	M	ASY
14 June 2012	ERI	0914-50469	Green	Red	Green	Metal	370	410	77.9	28.3	M	ASY
14 June 2012	ERI	0914-50470	Red	Green	Green	Metal	290	365	60.1	24	F	ASY
14 June 2012	ERI	0914-50471	Green	Yellow	Green	Metal	275	347	61	23.3	F	ASY
14 June 2012	ERI	0914-50472	Green	White	Green	Metal	285	361	57.8	23.6	F	ASY

^aLocation: WRI= West Raccoon Island, ERI= East Raccoon Island.

^bSex: F= Female, M= Male.

^cAge: ASY= After-second year (Pyle 2008).

APPENDIX A. Measurements for Black Skimmers equipped with VHF Transmitters on the Isles Dernieres Barrier Refuge, 2011-2013.

Capture Date	Location ^a	USGS band #	Top Right	Bottom Right	Top Left	Bottom Left	Mass (g)	Wing Chord (mm)	Culmen (mm)	Bill Depth (mm)	Sex ^b	Age ^c
25-Jun-13	WRI	0914-50473	Blue	Blue	Green	Metal	370	370	72.6	30	M	ASY
25-Jun-13	WRI	0914-50474	Purple	Purple	Green	Metal	265	340	59.2	23.1	F	ASY
27-Jun-13	WRI	0914-50475	Green	Purple	Green	Metal	290	342	60.4	23.3	F	ASY
27-Jun-13	WRI	0914-50477	Pink	Pink	Pink	Metal	286	345	61.5	26	F	ASY
30-Jun-13	WRI	0914-50479	Green	Green	Pink	Metal	285	348	56.3	23.3	F	ASY
30-Jun-13	WRI	0914-50480	Green	Blue	Pink	Metal	320	378	73.1	32	M	ASY
30-Jun-13	WRI	0914-50481	Blue	Blue	Pink	Metal	270	330	63.3	25.1	F	ASY
30-Jun-13	WRI	0914-50482	Yellow	Blue	Pink	Metal	350	360	70.4	31.4	M	ASY
30-Jun-13	WRI	0914-50483	Red	Red	Pink	Metal	340	400	69.1	29.9	M	ASY
30-Jun-13	WRI	0914-50484	Red	Blue	Pink	Metal	400	390	74.6	31.2	M	ASY
30-Jun-13	WRI	0914-50485	Blue	Blue	Blue	Metal	320	380	68.1	31.7	M	ASY
30-Jun-13	WRI	0914-50486	Blue	Red	Blue	Metal	285	345	56.2	23.2	F	ASY
30-Jun-13	WRI	0914-50487	Blue	Pink	Blue	Metal	320	340	59.1	25.4	F	ASY
30-Jun-13	WRI	0914-50488	Blue	Purple	Blue	Metal	315	365	60.1	24.6	F	ASY
30-Jun-13	WRI	0914-50489	Blue	Green	Blue	Metal	300	345	56.7	24.5	F	ASY
30-Jun-13	WRI	0914-50490	Yellow	Blue	Blue	Metal	330	378	67.9	30.2	M	ASY
30-Jun-13	WRI	0914-50491	Purple	Purple	Blue	Metal	380	400	75.8	342	M	ASY
30-Jun-13	WRI	0914-50492	White	Purple	Blue	Metal	345	390	74.5	28.5	M	ASY
27-Jun-13	WRI	0914-50476 ^d	Green	Yellow	Blue	Metal	370	390	69.6	28.5	M	ASY
27-Jun-13	WRI	0914-50478 ^d	Blue	Blue	Purple	Metal	395	372	69.8	29.1	M	ASY

^aLocation: WRI= West Raccoon Island, ERI= East Raccoon Island.

^bSex: F= Female, M= Male.

^cAge: ASY= After-second year (Pyle 2008).

^d0914-50478, 0914-50478= BLSK equipped with GPS data logger

APPENDIX A. Information for Black Skimmers not equipped with VHF Transmitters on the Isles Dernieres Barrier Refuge, 2011

Capture Date	Location ^a	USGS Band #	Top Right	Bottom Right	Top Left	Bottom Left	Mass (g)	Wing Chord (mm)	Culmen (mm)	Lower Bill (mm)	Bill depth (mm)	Sex ^b	Age ^c
19 July 2011	WRI	0994-21341	White	Light Blue	Metal	Red	235	356	56	71.5	20.7	F	ASY
19 July 2011	WRI	0994-21342	White	Green	Red	Metal	225	260	43	50.7	17.5	U	HY
19 July 2011	WRI	0994-21343	White	Red	Yellow	Metal	375	397	66	100.1	27.6	M	ASY
19 July 2011	WRI	0994-21344	White	White	Yellow	Metal	395	370	66.4	103.5	39.9	M	ASY
19 July 2011	WRI	0994-21345	White	Black	Yellow	Metal	350	395	66.4	91.5	28.7	M	ASY
19 July 2011	WRI	0994-21346	White	Green	Metal	Yellow	250	358	59.2	77.8	21.8	F	ASY
19 July 2011	WRI	0994-21347	White	Light Blue	Yellow	Metal	250	360	56.1	75.6	22.2	F	ASY
19 July 2011	WRI	0994-21348	Green	Metal	White	Blue	350	330	54.4	75.6	23.3	U	HY
19 July 2011	WRI	0994-21349	Metal	Green	White	White	280	356	52.8	69.4	20.3	F	ASY
19 July 2011	WRI	0994-21350	Green	Metal	White	Black	265	365	58.2	79.5	22.6	F	ASY
19 July 2011	WRI	0994-21351	Green	Metal	White	Green	360	395	73.4	94.1	27.8	M	ASY
19 July 2011	WRI	0994-21352	Green	Metal	Black	Black	360	385	72.5	93.3	26.6	M	ASY
19 July 2011	WRI	0994-21353	Green	Metal	White	Red	315	392	65	71.1	27.3	M	ASY
19 July 2011	WRI	0994-21354	Green	Metal	Black	Red	265	361	56.6	74.9	22.6	F	ASY
19 July 2011	WRI	0994-21355	Metal	Green	Black	Yellow	265	356	53.5	80.4	23.3	F	ASY
19 July 2011	WRI	0994-21356	Metal	Green	Black	Light Blue	210	285	45.1	54.4	18.8	U	HY
19 July 2011	WRI	0994-21357	Green	Metal	Black	Green	410	423	73.9	100.3	38.7	M	ASY
19 July 2011	WRI	0994-21358	Light Blue	Metal	Red	Red	420	400	77.7	100	37.6	M	ASY
19 July 2011	WRI	0994-21359	Blue	Metal	Red	Yellow	385	414	74.8	96.5	28.3	M	ASY

^aLocation: WRI= West Raccoon Island.

^bSex: F= Female, M= Male, U=Unknown.

^cAge: ASY= After-second year, HY= Hatch year (Pyle 2008).

APPENDIX B. Banded 2011 and 2012 Skimmers re-sighted on the IDBIR in 2012 –2013.

USGS Band Number	Date Re-sighted	Location	Year Banded	Banding Location	Activity
0994-21330 ^a	9-Aug-2013	WRI ^e	2011	WRI	loafing
0914-50469 ^a	9-Aug-2013	WRI	2012	ERI	loafing
0994-21326 ^b	18-Mar-2012	WRI	2011	WRI	loafing
0994-21352 ^b	17-Feb-2012	WRI	2011	WRI	loafing
0994-21338 ^b	2012	WHISKEY	2011	ERI	loafing
0994-21328	3-Jun-2013	ERI ^f	2011	WRI	loafing
0994-21332	4-Jun-2013	ERI	2011	WRI	nesting
0994-21350	4-Jun-2013	ERI	2011	WRI	nesting
0914-50472	14-Jun-2013	ERI	2011	WRI	nesting
0994-21345	14-Jun-2013	ERI	2011	WRI	nesting
0994-21336	14-Jun-2013	ERI	2011	ERI	nesting
0994-21340	21-Jun-2013	WRI	2011	ERI	nesting
0994-21334	21-Jun-2013	WRI	2011	WRI	nesting
0994-21354	30-Jun-2013	WRI	2011	WRI	loafing
0994-21357	30-Jun-2013	WRI	2011	WRI	loafing
0994-21347	1-Jul-2013	WRI	2011	WRI	nesting
0994-21351	3-Jul-2013	WRI	2011	WRI	loafing
0994-21324	3-Jul-2013	WRI	2011	WRI	loafing
0994-21331	3-Jul-2013	WRI	2011	WRI	loafing
0914-50466 ^c	4-Jun-2013	ERI	2012	ERI	nesting
0914-50466 ^c	27-Jun-2013	WRI	2012	ERI	nesting
0914-50471 ^d	4-Jun-2013	ERI	2012	ERI	nesting
0914-50471 ^d	1-Jul-2013	WRI	2012	ERI	nesting
0914-50468	21-Jun-2013	WRI	2012	ERI	nesting
0914-50467	30-Jun-2013	WRI	2012	ERI	loafing
0914-50470	3-Jul-2013	WRI	2012	ERI	loafing
0914-50466	30-Jun-2013	WRI	2012	WRI	nesting

994-21330^a: re-sight provided by P. Vasseur (*pers. comm.*, USGS)

0994-21326^b: re-sight provided by D. Curtiss (*pers. comm.*, Nicholls State University)

0914-50466^c: Bird re-nested on different islands after first nest failed from flooding impacts

0914-50471^d: Bird re-nested on different islands after first nest failed from flooding impacts.

WRI^e: West Raccoon Island

ERI^f: East Raccoon Island

APPENDIX C. Estimated number of breeding pairs on the IDBIR for each island (Fonetnot et al. 2012). Years reported below had different surveyors and different methods for surveying. Numbers reported prior to 2008 should be considered conservative since skimmers are later nesters than other ground nesting waterbirds, and surveys were aimed for multi-species counts.

Year	Survey Method	Wine	Raccoon ^a	Whiskey	Trinity	TOTAL	Surveyor/ Report Reference
1976	A ^b , G ^c		1,542			1,542	Portnoy (1977)
1983	A	100-500	yes	yes	100–500	1,000	Keller et al. (1984)
1985	A, G	1,000				1,000	Martin and Lester (partial surveys; LDWF-LNHP database)
1986	A, G	1,925				1,925	Martin and Lester (partial surveys; LDWF-LNHP database)
1987	A, G	1,600				1,600	Martin and Lester (partial surveys; LDWF-LNHP database)
1988	A, G	1,800			55	1,855	Martin and Lester (partial surveys; LDWF-LNHP database)
1989	A, G	600		50	25	675	Martin and Lester (partial surveys; LDWF-LNHP database)
1990	A, G	650	450	250		1,350	Martin and Lester (1990)
1993	A	750	750	100		1,600	Vermillion & Carloss (unpub. data; LDWF-LNHP database)
1994	A	500	480	130	300	1,410	Vermillion & Carloss (unpub. data; LDWF-LNHP database)
1995	A	1,100	200			1,300	Vermillion & Carloss (unpub. data; LDWF-LNHP database)
1996	A	1,200	250	300		1,750	Vermillion & Carloss (unpub. data; LDWF-LNHP database)
1997	A	600	150	600		1,350	Vermillion & Carloss (unpub. data; LDWF-LNHP database)
1997	A, G, B ^d	1,640	110	1,850		3,600	Visser & Patterson (unpub.data; LDWF-LNHP database)
1998	A	550	70	350		970	Vermillion & Carloss (unpub. data; LDWF-LNHP database)
1999	A	1,300	570	1,500		3,370	Vermillion & Carloss (unpub. data; LDWF-LNHP database)
2000	G	250				250	Visser & Vermillion (unpub.data; LDWF-LNHP database)
2005	A, G		300			300	Green et al. (2006)
2006	A	150	350			500	Baka et al. (unpub. Data; LDWF-LNHP database)
2008	A	40	110	540		690	Seymour et al. (unpub. Data; LDWF-LNHP database)

2009	G	35	480	780	1,295	Owen (2010)
2010	G	50	250	450	750	Owen (2010)
2011	G	6	1,239		1,245	Furfey (2014)
2012	G	55	1,037		1,092	Furfey (2014)
2013	G	0	572		572	Furfey (2014)

^aRaccoon: Includes data for both East and West Raccoon Islands

^bA: Aerial surveys, includes helicopter and fixed-wing aircraft

^cG: Ground surveys

^dB: Boat surveys

APPENDIX D. Fish species collected from Black Skimmers captured on 30 June 2013 on West Raccoon Island. All Skimmers caught with mist nets on return trips from foraging. Multiple fish collected from one bird were regurgitated stomach contents.

BLSK ID Number	Sex	Fish sp.	Measurement (mm) ^a
0914-50485	M	Atlantic Needlefish	16
0914-50486	F	Atlantic Silverside	5
0914-50486	F	Atlantic Silverside	5
0914-50486	F	Atlantic Silverside	5
0914-50486	F	Atlantic Silverside	5
0914-50486	F	Atlantic Silverside	6
0914-50486	F	Atlantic Silverside	6
0914-50486	F	Atlantic Silverside	5
0914-50486	F	Atlantic Silverside	6
0914-50486	F	Mullet sp.	9
0914-50487 ^b	F	Atlantic Needlefish	11
0914-50487	F	Atlantic Silverside	10
0914-50488	F	Gulf Menhaden	6
0914-50488	F	Gulf Menhaden	6
0914-50488	F	Gulf Menhaden	7
0914-50488	F	Gulf Menhaden	6
0914-50488	F	Gulf Menhaden	5.3
0914-50488	F	Gulf Menhaden	7.5
0914-50488	F	Gulf Menhaden	5
0914-50489	F	Gulf Menhaden	6.5
0914-50490	M	Atlantic Silverside	5
0914-50490	M	Atlantic Silverside	6
0914-50490	M	Atlantic Silverside	6
0914-50490	M	Atlantic Silverside	6
0914-50490	M	Atlantic Silverside	5.8
0914-50490	M	Atlantic Silverside	4
0914-50490	M	Atlantic Silverside	5.3
0914-50490 ^b	M	Atlantic Silverside	1
0914-50492	M	Atlantic Needlefish	13.5

^aMeasurement (mm): Fork length, measured as snout to fork of caudal fin.

^b0914-50487, 0914-50490: Partial samples.

APPENDIX E. Fish species collected with seine nets on the shoreline of East and West Raccoon Islands by Dr. Rich Grippo and Kate Brown on 19 and 20 July 2011.

East Raccoon Island			
		Species	Number Collected
Date	July 19 2011	Striped Killifish	29
Time	20:50	Gulf Menhaden	20
Salinity (ppt) ^a	19	Atlantic Silverside	3
Temperature (°C) ^b	27.9	Grass Shrimp	2
Oxygen (mg/L) ^b	6.71		
Date	July 19 2011	Striped Killifish	173
Time	19:09	Atlantic Silverside	3
Salinity (ppt) ^a	19.5	Sheepshead Minnow	1
Temperature (°C) ^b	34.6		
Oxygen (mg/L) ^b	7.51		
Date	July 19 2011	Atlantic Silverside	127
Time	20:07	Gulf Menhaden	4
Salinity (ppt) ^a	17.5	Southern Kingfish	1
Temperature (°C) ^b	31.3		
Oxygen (mg/L) ^b	6.9		
Date	July 19 2011	Mullet sp.	20
Time	22:40	Atlantic Silverside	19
Salinity (ppt) ^a	–	Striped Killifish	37
Temperature (°C) ^b	–	Gulf Menhaden	8
Oxygen (mg/L) ^b	–	Grass Shrimp	5
		Southern Kingfish	1
		Other (unknown)	1
		Gulf Killifish	10

West Raccoon Island

		Species	Number Collected
Date	July 20 2011	Striped Killifish	66
Time	15:40	Atlantic Silverside	4
Salinity (ppt) ^a	18	White Shrimp	3
Temperature (°C) ^b	34	Mullet sp.	10
Oxygen (mg/L) ^b	8.81	Gulf Killifish	4
Date	July 20 2011	Gulf Menhaden	2
Time	18:31	Gulf Kingfish	1
Salinity (ppt) ^a	19		
Temperature (°C) ^b	34.1		
Oxygen (mg/L) ^b	8.01		

Salinity (ppt)^a: Collected with handheld refractometer.

Temperature (°C)^b, Oxygen (mg/L)^b: Collected with YSI Model 50 Dissolved Oxygen meter.