CHARACTERIZATION OF SEA TURTLE NESTING ON THE UPPER TEXAS COAST

A Thesis

by

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ABSTRACT

Nearly annual record Kemp's ridley sea turtle (*Lepidochelys kempii*) nesting activity on the upper Texas coast (UTC; defined as beaches from Sabine Pass to Matagorda Peninsula), where scientifically verifiable nesting commenced in 2002, has occurred concurrently with recent exponential increases in the nesting population of this critically endangered species. Increased likelihood for anthropogenic interaction with this growing assemblage of UTC nesters mandated documentation of nesting activity on rapidly developing UTC beaches and characterization of in-water movements of mature conspecifics.

Standardized sea turtle nesting patrols implemented on the beaches of Bolivar Peninsula, Galveston Island, and Follets Island to quantify nesting activity, as well as associated beach habitat assessments, identified major deterrents to sea turtle reproductive success and established a scientific baseline necessary for resource managers to facilitate the perpetuation of nesting activity. During 2007-2009, weekday ATV and pedestrian patrols of stated beaches during nesting season (1 April – 15 July) aided the documentation of 15-16 UTC Kemp's ridley nests annually. Nests were predominantly located on patrolled beaches and represented 8-12% of Texas' annual statewide nesting total. Mean emergence success rate for four clutches incubated in-situ was 91.8%.

Eight nesting females intercepted on UTC beaches, as well as a rehabilitated adult male, were satellite tagged. Spatially- and/or temporally-restricted usage of breeding, internesting, migratory, and/or foraging areas in the northern Gulf of Mexico was identified and warrants further examination to facilitate the implementation of conservation initiatives designed to mitigate associated consequential mortality factors. Female internesting period movements were primarily confined to nearshore waters between Galveston and Matagorda Bays, while post-nesting movements in waters <83 m in depth ranged from Texas to the Florida Keys. Male movements near UTC beaches one year post-release were potentially indicative of breeding. Three years of subsequent monitoring indicated this male established long-term seasonal residency on offshore Louisiana foraging grounds.

Nesting and telemetry data indicate the UTC is becoming increasingly important to the Kemp’s ridley population. However, current regulations do not support the sustainment of the UTC nesting cohort. Management recommendations to simultaneously foster UTC nesting and promote the continued recovery of the Kemp’s ridley sea turtle are provided herein.

DEDICATION

For Lillian, who unwittingly relinquished so much to permit me to do this. Now I can make up for lost time.

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This research would not have been possible without the enduring support and guidance of my committee chair, Dr. André M. Landry. It is only because of his mentorship and sustained commitment to my success that so many doors have opened for me over the past 7-½ years. I am also deeply indebted to Dr. Erin Seney for paving the way for me in many respects. Her generosity in sharing her knowledge has been invaluable to the realization of the satellite tagging research presented herein. In addition, I am very grateful for the efforts of my other committee members, Dr. Pamela Plotkin and Dr. Lee Fitzgerald, to support the successful culmination of this study.

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counsel in regards to satellite tracking data analysis; I would not have been able to conduct that portion of my research without their help.

Nesting patrol efforts described herein could not have been accomplished without the extensive time commitments made by graduate and undergraduate students in residence at TAMUG, as well as numerous volunteers from Texas Master Naturalists Chapters and the general public. Steve Alexander, in particular, facilitated the involvement of Master Naturalist volunteers and helped me excavate numerous nests and tag several nesters. Volunteer Sharla Knoll, photographer extraordinaire, always happened to be in the right place at the right time.

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beaches and assisted in deploying sea turtle signage. The Department of Marine Biology at TAMUG provided various in-kind support functions to this study.

I am beholden to a few individuals who have inspired and motivated me throughout this long journey. None of this would have been possible without my husband, who willingly left behind everything he knew to move halfway across the country to enable me to do this. Luckily, we quickly discovered his natural aptitude for, and immense love of, being a stay-at-home dad. Jeff George of Sea Turtle, Inc., thank you for introducing me to sea turtles and rehab; I strive to emulate your efforts every day. Luminary Carole Allen of the Sea Turtle Restoration Project, thank you for fighting for the conservation of all Kemp's ridleys, including those of the upper Texas coast. Finally, a heartfelt thank you to SSQ836, the Kemp's ridley that started it all.

NOMENCLATURE

ASL	Above Sea Level
BOEM	Bureau of Ocean Energy Management
CCL	Curved Carapace Length
CDT	Central Daylight Time
CITES	Convention on International Trade in Endangered Species of Wild Fauna and Flora
CFR	Code of Federal Regulations
ESA	Endangered Species Act
GMT	Greenwich Mean Time
IUCN	World Conservation Union (International Union for the Conservation of Nature)
HEART	Help Endangered Animals - Ridley Turtles
HRT	Home Range Tools
KDE	Kernel Density Estimate
LC	Location Class
MPA	Marine Protected Area
NMFS	National Marine Fisheries Service
NOAA	National Oceanic and Atmospheric Administration
NOAA STF	NOAA Fisheries Sea Turtle Facility
NPS	National Park Service
PAIS	Padre Island National Seashore

PIT	Passive Integrated Transponder
POES	Polar Orbiting Environmental Satellites
PTT	Platform Terminal Transmitter
SCL	Straight Carapace Length
SEMARNAT	Secretariat of Environmental and Natural Resources (in Spanish: *Secretaría de Medio Ambiente y Recursos Naturales*)
SST	Sea Surface Temperature
STAT	Satellite Tracking and Analysis Tool
TAMUG	Texas A&M University at Galveston
TED	Turtle Excluder Device
TEWG	Turtle Expert Working Group
TGLO	Texas General Land Office
TPWD	Texas Parks and Wildlife Department
USFWS	United States Fish and Wildlife Service
UTC	Upper Texas Coast

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CHAPTER I

INTRODUCTION: SYNOPSIS OF THE KEMP'S RIDLEY SEA TURTLE (*LEPIDOCHELYS KEMPII*)

KEMP'S RIDLEY: SPECIES CHARACTERIZATION

First described by Samuel Garman in 1880 as *Thalassochelys kempii* [Carr 1952, U.S. Fish and Wildlife Service (USFWS) & National Marine Fisheries Service (NMFS) 1992], the Kemp's ridley (*Lepidochelys kempii*) is one of seven extant sea turtle species and one of two in the genus *Lepidochelys*. Mitochondrial DNA analysis suggests reproductive isolation and subsequent morphological differentiation (Pritchard 1989) of the Kemp's ridley and its congener, the olive ridley sea turtle (*Lepidochelys olivacea*), likely occurred with the closure of the Isthmus of Panama approximately 2.5-3.5 million years ago (Bowen et al. 1998).

The endangered Kemp's ridley sea turtle has been federally protected under the U.S. Endangered Species Conservation Act and, subsequently, the Endangered Species Act (ESA; 50 US Code of Federal Regulations 17.11) since December 2, 1970. It is currently considered the most endangered marine turtle species in the world (Bowen et al. 1998, Márquez et al. 2005). Classified as 'critically endangered' by the World Conservation Union (IUCN 2011), international commercial trade in this species is prohibited by protections afforded under Appendix I of the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES 2012).

HISTORICAL POPULATION STATUS

Although anecdotal evidence suggests the Kemp's ridley was once the Gulf of Mexico's most abundant species (USFWS & NMFS 1992, Eckert et al. 1994, Landry et al. 2005), little is known about its historical nesting range or population level (Burchfield 2005). What is known is that an estimated 40,000 females nested at Rancho Nuevo, Tamaulipas, Mexico (23.2°N, 97.5°W; Hildebrand 1963), the ridley's primary nesting beach, on a single day in 1947 (Burchfield 2005). Despite federal protection afforded these nesting grounds in 1966, documented ridley nesting activity at Rancho Nuevo declined to 702 nests for the entire 3.5-month nesting season by 1985 (USFWS & NMFS 1992, Arroyo et al. 2003, Burchfield 2005). This decrease in nesting activity, likely precipitated by the concurrent anthropogenic pressures of comprehensive annual egg harvests (Hildebrand 1963) and incidental capture of juvenile and adult ridleys in U.S. and Mexican trawl fisheries (Woody 1989, Magnuson et al. 1990, Frazier et al. 2007), translated into a 99% reduction in breeding stock and eventual population collapse (Márquez et al. 2005).

Historical data regarding marine turtle reproduction on Texas' beaches are scarce (Hildebrand 1963). An article (Doughty 1984) detailing the 19th century Texas green sea turtle (*Chelonia mydas*) fishery describes unidentified "clusters of mammoth turtles" seen on a Galveston beach just prior to sunset during late April or early May 1851. This diurnal nesting assemblage and seasonal nesting period are more suggestive of ridleys than that of green or loggerhead turtles (*Caretta caretta*) that typically nest nocturnally and in earnest beginning in June (Burchfield 2005). Potential ridley nesting activity is also noted by Hildebrand (1963), who provides an anecdotal account of “two small turtles nesting on the beach, on a hot and strongly windy day, approximately in May 1938” on Padre Island. Texas’ first scientifically documented Kemp’s ridley nest was laid on Padre Island National Seashore (PAIS) in 1948 (Werler 1951, Carr 1967, Arroyo et al. 2003).

BI-NATIONAL HEADSTART PROGRAM SYNOPSIS

Prolonged diminution in the number of Kemp’s ridley females utilizing Rancho Nuevo’s beaches and concerns regarding the conceivable extinction of the species prompted the U.S. and Mexican governments to implement the bi-national headstart experiment in 1978 (USFWS & NMFS 1992, Arroyo et al. 2003). One aspect of this experiment involved using nest products obtained from Mexico to establish a secondary nesting colony at PAIS by means of innovative imprinting techniques (Woody 1990; Fontaine & Shaver 2005; NMFS, USFWS & SEMARNAT 2011). Two distinct groups of head-started Kemp’s ridleys were captive reared for approximately 9-11 months at the NMFS Galveston Laboratory before their release into Gulf of Mexico waters. Annually from 1978 through 1988, approximately 2000 eggs laid at Rancho Nuevo were collected in polyethylene bags to prevent contact with native substrate, placed in polystyrene foam boxes containing moist sand sourced from PAIS, and subsequently transported to PAIS for incubation (Burchfield & Foley 1989). The resulting hatchlings were exposed to the beach at PAIS and permitted to enter the surf before collection and transportation to the

NMFS Galveston Laboratory for rearing (Woody 1990). Each year from 1989 through the termination of the headstart experiment in 1992, approximately 2000 Rancho Nuevo-imprinted hatchlings were transported directly to the NMFS Galveston Laboratory captive rearing facility (Byles 1993). Ultimately, 22,596 Kemp's ridleys headstarted by the Galveston facility during the 15-year experiment were tagged and released at various locations within the Gulf of Mexico (Eckert et al. 1994). Lastly, the NMFS Galveston Laboratory annually captive reared 200 Rancho Nuevo ridley hatchlings for turtle excluder device (TED) certification trials from 1993 through 2000. However, these turtles were not part of the headstart experiment (Shaver & Wibbels 2007).

CURRENT POPULATION STATUS

Exponential increases in the reproductively viable segment of the Kemp's ridley population of approximately 15% per year have been documented since the mid-1980's (Fig. 1.1; Heppell et al. 2005; Márquez et al. 2005; NMFS, USFWS & SEMARNAT 2011). While analyses of the bi-national headstart program reveal numerous valuable scientific contributions, the experiment is not currently recognized as benefitting population levels (Fontaine & Shaver 2005; Shaver & Wibbels 2007; NMFS, USFWS & SEMARNAT 2011). Instead, management operations to improve survival at all life stages, including protection of nesting habitats, nest products, and commercial shrimp trawl fishery TED regulations and enforcement, have likely exerted the most substantial positive influence on the Kemp's ridley population recovery (Turtle Expert Working Group (TEWG) 2000; NMFS, USFWS & SEMARNAT 2011). Federal regulations exist

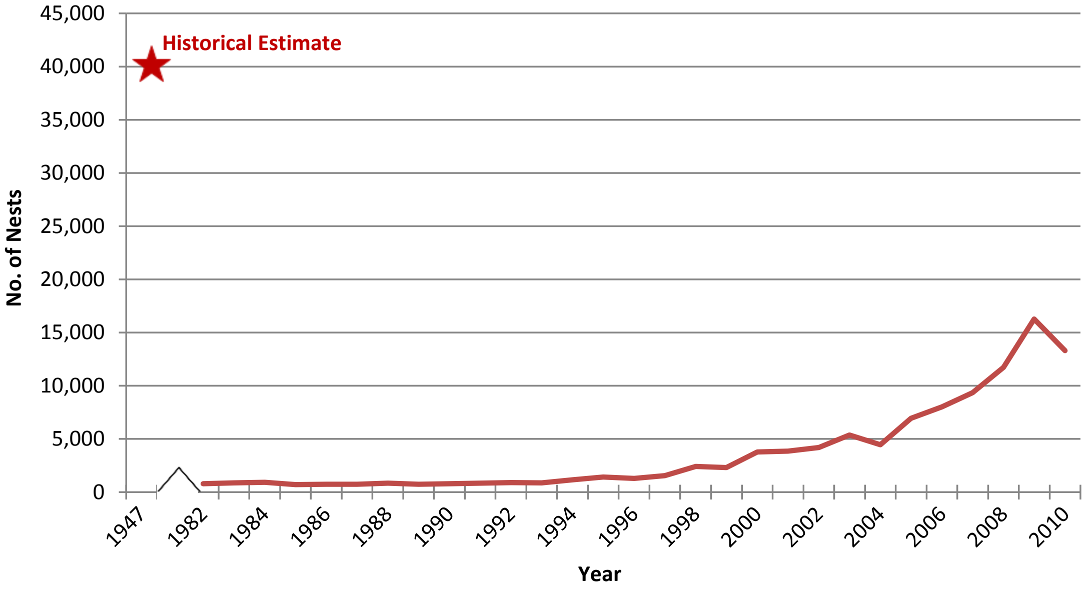


Figure 1.1. Kemp's ridley nests documented at Rancho Nuevo, Mexico, 1947-2010 (compiled from: Peña et al. 2005; Witzell et al. 2005a; Burchfield 2009; NMFS, USFWS and SEMARNAT 2011; L.J. Peña, pers. comm.).

to conserve beach nesting habitats and protect nesting activity at Rancho Nuevo and PAIS, and seasonal trawling prohibitions are enforced for nearshore waters (Márquez et al. 1989; TEWG 2000; NMFS, USFWS & SEMARNAT 2011).

Kemp's ridley nest numbers reached their highest recorded level since 1947 in 2009, when over 21,000 nests were documented on the beaches of Tamaulipas and Veracruz, Mexico (Burchfield 2009). With population models predicting sustained growth rates in nesting of 12-19% per year for the near future, it is expected that the ESA downlisting criterion of 10,000 nesting females utilizing the three primary nesting beaches in Mexico (Rancho Nuevo, Tepehuajes, and Playa Dos) within a season could be achieved at any time (NMFS, USFWS & SEMARNAT 2011).

Recent increases in nesting activity along the entire Texas coast (Fig. 1.2) are an auspicious indicator of a recovering population, although it is unclear if the species is reoccupying historic nesting sites or expanding its nesting range. The 911 Kemp's ridley nests documented in Texas between 2002-2010 (NMFS, USFWS & SEMARNAT 2011) exceed by an order of magnitude the 81 nests recorded during the preceding 53 years (1948-2001; Shaver & Caillouet 1998, Shaver 2005b). However, implementation of patrols necessary to document the ephemeral tracks indicative of ridley nesting activity (Pritchard 1989) has occurred sporadically, with limited surveys first enacted at PAIS in 1986. Sea turtle nesting surveys were expanded to certain lower Texas coast beaches beginning in 1999, while formal nesting investigations of the upper Texas coast were not

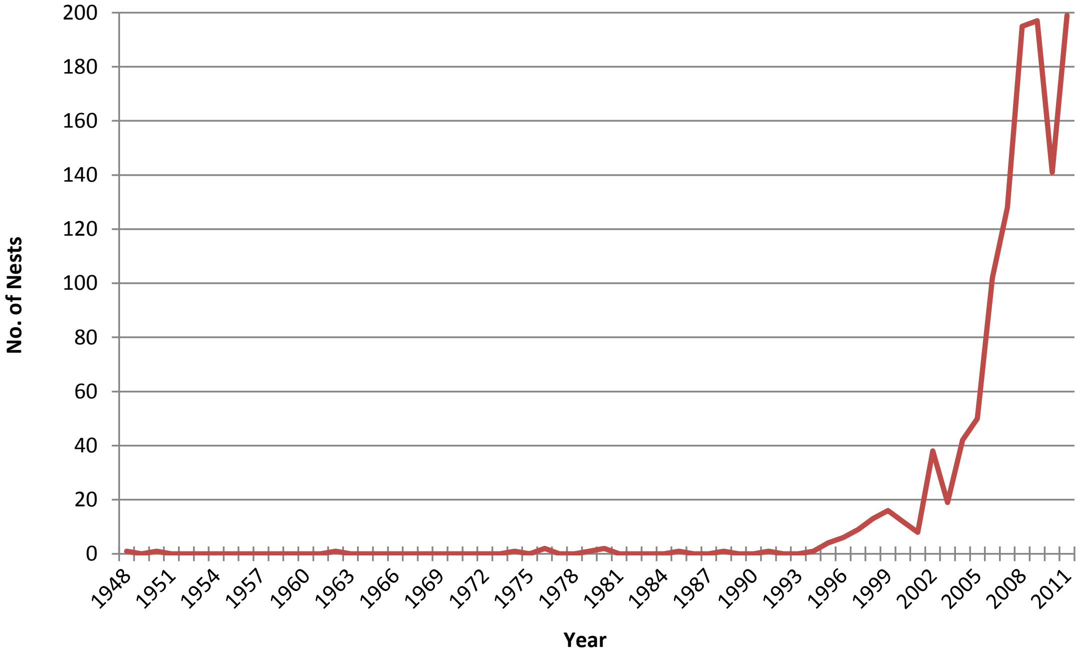


Figure 1.2. Kemp's ridley nests documented in Texas, USA, 1948-2011 (compiled from: Shaver and Caillouet 1998; Shaver 2000, 2001, 2002a, 2004, 2005a, 2006a, 2006b, 2007, 2008, 2009, 2010, 2011, 2012).

implemented until 2007. Currently, nesting patrols incorporating varying degrees of effort occur along the entire Texas coastline throughout the ridley nesting season (Shaver 2012).

LIFE HISTORY & DEMOGRAPHICS

Maturation of the Kemp's ridley is estimated to occur at 10-17 years of age, with adults typically 25-54 kg in weight and 55-78 cm in straight carapace length (SCL; Márquez 1994, Chaloupka & Zug 1997, Zug et al. 1997, Heppell et al. 2005, Snover et al. 2007). The universal gray-black pigmentation of hatchlings undergoes substantial alteration during maturation (Márquez 1994). Young post-pelagic juveniles possess the yellow-white plastron retained by adults, and the carapace lightens to an olive gray color by adulthood (NMFS, USFWS & SEMARNAT 2011). Morphologically distinct characteristics allowing differentiation of adult *L. kempii* from other sea turtle species include comparatively short forelimbs, a dorsoventrally flattened and profoundly ossified carapace of a width approximately equal to its length, a nuchal scute that contacts the first of 5 pairs of costal scutes, and the presence of 4 pairs of pored inframarginal scutes spanning the carapace-plastron bridge (Márquez 1994, Pritchard 2007a). The physiological purpose of the Rathke's gland housed in the inframarginal pores (Márquez 1994) remains unconfirmed; however, the prevailing hypothesis suggests the glands emit pheromones that contribute to the formation of nesting beach arribadas (Pritchard 2007a).

Reproductively mature males are phenotypically distinguishable from females. To aid in copulation, males possess a prehensile tail that extends beyond the carapace margin, a robust curved claw on each front flipper (Márquez 1994), and a well vascularized, dekeratinized plastron (Owens 1997). Currently, relatively little is known about the seasonal, foraging, and reproductive movements of adult male ridleys (Shaver et al. 2005, Morreale et al. 2007). Satellite telemetry data obtained from eleven mature males by Shaver et al. (2005) suggested primarily year-round residency in nearshore waters in the vicinity of the Rancho Nuevo nesting beach. However, this study's small sample size, limited tracking durations (maximum 233 days), and evidence of one male's directed movements to waters adjacent to Galveston, Texas, do not dismiss the potential for reproductively mature males to display significantly more migratory behavior than currently documented.

Substantially more knowledge exists regarding the movements of females satellite-tracked after nesting on western Gulf of Mexico beaches. Thirty-six tag deployments on 28 females during 1997-2006 by Shaver & Rubio (2008) indicated Texas' nesters sustained directed movements paralleling the coastline to neritic foraging grounds in northern or eastern Gulf of Mexico waters, with heavier concentrations noted between southern Texas and the Florida panhandle. Use of nearshore habitat adjacent to the PAIS nesting beach appeared to be primarily limited to the April – July nesting season. Tracks from 11 females satellite tagged by Byles (1989) after depositing clutches at Rancho Nuevo indicated plasticity in post-nesting season movements (north and south) and the availability of neritic foraging grounds between Rancho Nuevo and Cabo Catoche, the northeastern point of the Yucatan Peninsula. While Rancho Nuevo nesters have been documented utilizing nearshore foraging habitats spanning from Florida to the Yucatan Peninsula (Shaver et al. 2013), Texas' nesters do not appear to establish post-nesting residency in Mexican waters, although brief southward migrations to Tamaulipas' coastal waters have been documented (Seney & Landry 2008, 2011; Shaver & Rubio 2008; Shaver et al. 2013).

The April through July Kemp's ridley nesting season is preceded by a March breeding period in which females exhibit polyandry (Rostal 1991, Rostal et al. 1998, Kichler et al. 1999). As with *L. olivacea*, *L. kempii* may display either solitary or arribada nesting behavior (Hildebrand 1963, Márquez 1994). Unique in regards to their diurnal nesting preference and egg deposition efficiency (the entire nesting process may be concluded in 35-50 minutes; Márquez 1994, Witzell et al. 2005b), female Kemp's ridleys typically nest biennially, although annual re-migrations have been documented (TEWG 1998, Shaver & Rubio 2008). Mean internesting interval separating each of the approximately 3 clutches per season averages 21 days (Márquez 1994, Rostal 1991, Rostal 2005). Clutches, each containing approximately 100 eggs (Rostal 2005), incubate for 45-55 days before nocturnal hatchling emergence (Witzell et al. 2005b). Kemp's ridleys exhibit temperature-dependent sex determination with a pivotal temperature between 28.6-30.4^{o}C (Shaver et al. 1988, Shaver 2005b, Eich 2009). A heterogeneous assemblage of male:female sex ratios occurs in nests subjected to either naturally varying or artificially constant temperatures averaging approximately 27 to 32^{o}C during the middle third of incubation, with warmer temperatures resulting in an increased frequency of female hatchlings (Shaver et al. 1988, Eich 2009).

RELEVANT RECOVERY PLAN STIPULATIONS

Upper Texas Coast Sea Turtle Nesting Dynamics

Commencement of documented nesting by the Kemp’s ridley on the upper Texas coast (herein defined as beaches from Sabine Pass to Matagorda Peninsula; Fig. 1.3) occurred in 2002 (Seney 2008). Continued recovery of the Kemp’s ridley population will likely augment sea turtle nesting activity on UTC beaches, including those of Galveston Island, Bolivar Peninsula, and Follets Island. Increased likelihood for interaction between this growing assemblage of nesters and rapid development of the UTC mandates an analysis of sea turtle nesting activity prerequisite to the formation of conservation-oriented beach habitat management policies. This nesting investigation will facilitate attainment of the Kemp’s Ridley Recovery Plan needs of “implementing and strengthening coastal zone management plans” and ensuring “long-term protection of important nesting beaches in Texas.”

Upper Texas Coast Nesting Habitat Assessment

The primarily undeveloped (Shaver 2008) and federally protected beaches of Rancho Nuevo and PAIS, which currently support the preponderance of Kemp’s ridley nesting activity in Mexico and Texas, respectively, are composed mainly of fine grain sands

Figure 1.3. Location of upper Texas coast nesting beaches in relation to significant Kemp's ridley rookeries in the U.S. and Mexico.

(Carls et al. 1995) and contain extensive unconstrained dune ecosystems stabilized by native coastal vegetation (McAtee & Drawe 1981, Márquez 1994). As such, data regarding the short- and long-term ramifications of common habitat alterations currently inflicted upon increasingly populated UTC beaches (coastal armoring, nourishment, mechanical beach raking, residential and commercial development, etc.) in relation to the Kemp's ridleys' ability to reproduce are nearly nonexistent. Resultant factors associated with these anthropogenic environmental perturbations may adversely affect sea turtle nesting success by negatively impacting female nest site selection, egg incubation, or hatchling seafinding behavior (McFarlane 1963; Horrocks & Scott 1991; Márquez 1994; Crain et al. 1995; Salmon et al. 1995; Rumbold et al. 2001; Bertolotti & Salmon 2005; Tuxbury & Salmon 2005; Chen et al. 2007; Brock et al. 2008; NMFS, USFWS & SEMARNAT 2011). As such, a detailed assessment of this region's beaches is needed to identify and potentially rectify associated deterrents to sea turtle reproductive success.

In-Water Movements of Adult Kemp's Ridleys

Currently, a paucity of data exists regarding in-water movements and nest site fidelity for the small but increasing number of Kemp's ridleys utilizing UTC nesting habitats. Seney & Landry (2008, 2011) reported movement patterns similar to those documented by Shaver & Rubio (2008) for six females monitored after nesting on the UTC: internesting periods were characterized by restricted nearshore movements coincident with fidelity to UTC nesting beaches, whereafter post-nesting females migrated along the 20 m isobath and established foraging sites offshore central Louisiana in waters 10-30 m deep. However, data sourced from only six UTC nesters may be insufficient in developing management policies supporting the continuance of nesting activity in this region. Additional satellite telemetry research on UTC nesters is needed not only to examine nest site fidelity (both within and between seasons), but also in support of a recovery task in the Kemp's Ridley Recovery Plan that mandates the protection and management of conspecifics in the marine environment, in part via the determination of migratory pathways between and among foraging grounds and nesting beaches (NMFS, USFWS & SEMARNAT 2011).

RESEARCH OBJECTIVES

The recent expansion of the Kemp's ridley's nesting range onto the UTC, combined with nearly annual increases in the number of females nesting on constituent beaches, create a unique opportunity to generate information assessing the importance of this region as sea turtle nesting habitat. Information such as this is needed by the Texas General Land Office (TGLO) and other state and federal agencies charged with managing use of Texas' coastal zone by the beach-going public and sea turtle species protected under the ESA. To this end, the following research objectives were identified:

1. To characterize sea turtle nesting activity on the upper Texas coast through 2009.
2. To identify nester fidelity to upper Texas coast habitats (both within and between seasons), internesting interval, and post-nesting movement.

CHAPTER II

SEA TURTLE NESTING DYNAMICS ON THE UPPER TEXAS COAST

INTRODUCTION

Concerns prominent in the 1970s and 1980s surrounding the conceivable extinction of the Kemp's ridley sea turtle (*Lepidochelys kempii*; Carr 1977, Wibbels 1984, Andersen 1987) have been superseded by prospects regarding the potential downlisting of this endangered species under the U.S. Endangered Species Act (NMFS, USFWS & SEMARNAT 2011). More than two decades of sustained exponential increases in reproductive output on the Kemp's ridley's primary nesting grounds in Mexico, particularly Rancho Nuevo, are optimistically indicative of a recovering population (NMFS, USFWS & SEMARNAT 2011). Concurrent with this recovery, nearly annual record Kemp's ridley nest numbers have been documented on both the upper Texas coast (UTC; herein defined as beaches from Sabine Pass to Matagorda Peninsula; Fig. 2.1) and the entire Texas coast since 2002.

Kemp's ridley sea turtle nests were first reported on Texas' beaches in 1948 (Werler 1951, Carr 1967). Confirmed ridley reproductive activity remained highly sporadic through 1994 (Shaver & Caillouet 1998) despite the institution of Texas' first (albeit limited) sea turtle nest detection patrols at Padre Island National Seashore (PAIS) in 1986 (Shaver 2005b). Consequential to a record four ridley nests deposited on constituent beaches in 1995, increasingly comprehensive sea turtle nesting patrol efforts

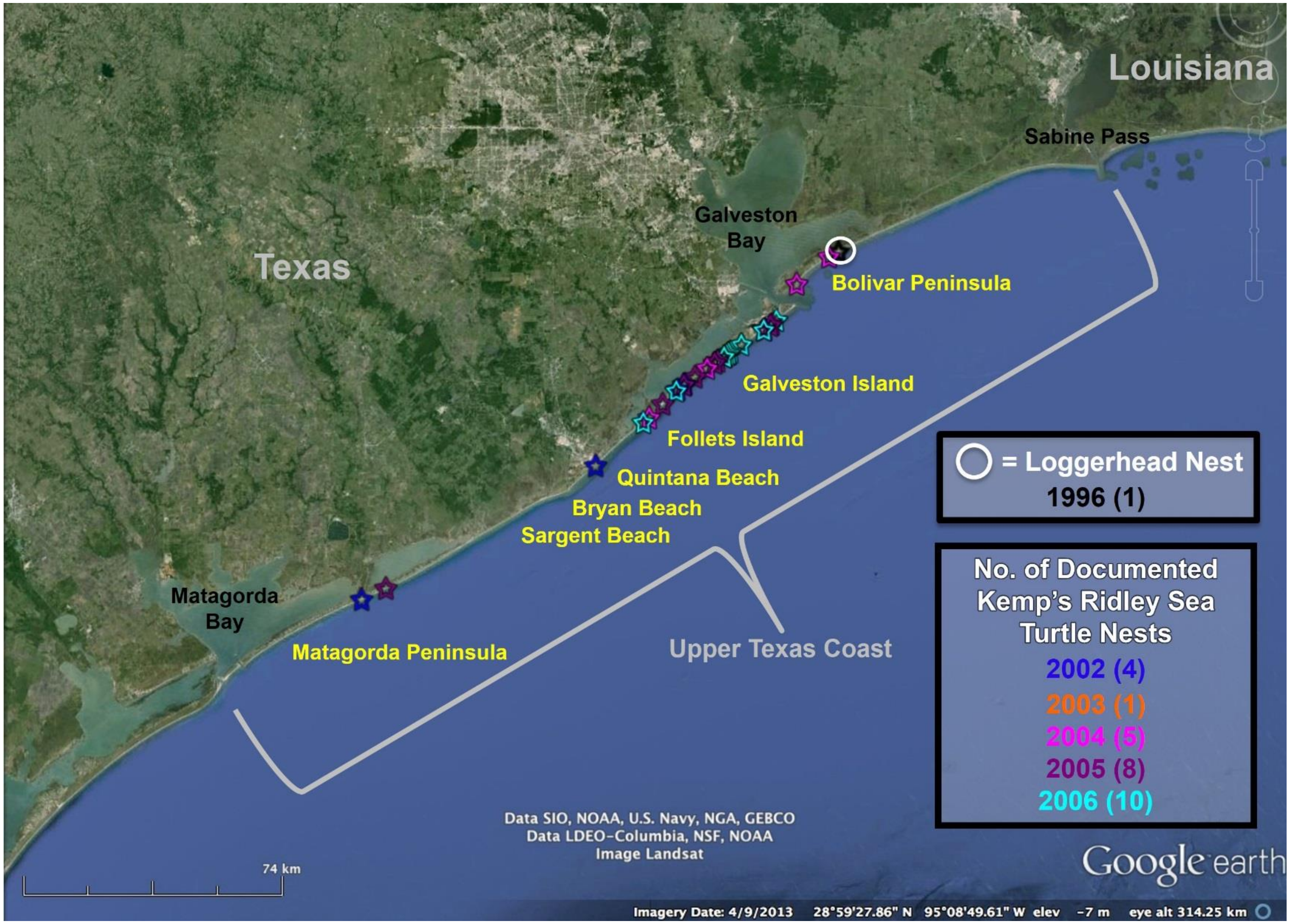


Figure 2.1. Delineation of upper Texas coast beaches and associated historical sea turtle nesting activity through 2006.

were undertaken at PAIS (Shaver 2005b). Supplementary nest detection efforts were instituted on additional south Texas beaches beginning in 1999, including Boca Chica Beach (1999; Shaver 2000), South Padre Island (2000; Shaver 2001), Matagorda Island (2003; Shaver 2005a), and Mustang Island (2004; Shaver 2006a). By 2006, systematic nesting and/or stranding patrols were occurring at least intermittently on the majority of Texas Gulf Coast beaches, and annual Kemp's ridley nesting on associated habitats had reached a previously unsurpassed 102 nests (Shaver 2007).

Historical UTC Sea Turtle Nesting

Scientifically verifiable Kemp's ridley nesting first occurred on Brazoria, Galveston, and Matagorda County beaches in 2002 (Shaver 2004). Prior to 2007, sea turtle nesting activity data for the UTC were generated by National Oceanic and Atmospheric Administration Sea Turtle Facility (NOAA STF) personnel responding to sporadic reports of nesting events from the beach-going public. In 2004, HEART (Help Endangered Animals-Ridley Turtles) established a statewide, toll-free hotline (1-866-TURTLE-5) to facilitate reporting of terrestrial sightings of sea turtles or their nesting tracks on Texas beaches. However, it is likely that records of UTC nesting through 2006 are conservative estimates of this zone's marine turtle reproductive activity, as formalized nesting patrols (hereafter also referred to as surveys or monitoring) were nonexistent, and constituent beaches did not receive adequate public recognition as sea turtle nesting grounds (Seney & Landry 2008).

With the exception of one loggerhead sea turtle (*Caretta caretta*) nest deposited on Bolivar Peninsula in 1996 (B. Higgins pers. comm.), all other 28 sea turtle nests documented on the UTC through 2006 were laid by Kemp's ridleys. Twenty-one ridley nests were laid on urbanized Galveston Island, the most densely populated UTC locale. Nests found elsewhere included 2 on Bolivar Peninsula in 2004, as well as single nests on Follets Island in both 2004 and 2006, Quintana Beach in 2002, and Matagorda Peninsula in both 2002 and 2005.

All historical UTC nesting activity occurred between 5 April and 14 July, coincident with Kemps' ridley nesting periodicity elsewhere in Texas and at Rancho Nuevo (this date range disregards the aforementioned Bolivar Peninsula loggerhead nest laid 27 July 1996). These data suggest diurnally-restricted egg laying by Kemp's ridleys in this region; 7 of the 15 females directly observed by permitted responders were engaged in nesting activity between 0800-1100 hours, although at least one turtle was detected within each hourly interval from 0700-1759 except 1400-1459. A total of 2782 eggs comprising all 28 Kemp's ridley nests laid along the UTC through 2006 was transported to the sea turtle egg incubation facility at PAIS where an overall 74.9% emergence success rate resulted in the release of 2084 UTC hatchlings from PAIS beaches (D. Shaver pers. comm.).

A minimum of twelve distinct Kemp's ridley females have engaged in nesting activity on the UTC through 2006; insufficient data exist to permit identification of three individuals observed nesting between 9 and 10 June 2002. All 12 identifiable females were neophyte nesters with no prior nesting history in Texas or Mexico (D. Shaver pers. comm.). In addition, 9 of these 12 (as well as 1 of 3 indiscernible nesters in 2002) were associated with the joint U.S. and Mexico Kemp's ridley headstart experiment (USFWS & NMFS 1992, Shaver & Rubio 2008). As hatchlings, these nine females were imprinted at Rancho Nuevo between 1989-1992 and transferred to the NOAA STF, where they were captive reared ("headstarted") for approximately one year before release into Gulf waters off Galveston Island (Shaver 2005b, B. Higgins pers. comm.). Two of the nine headstarted turtles were each documented nesting twice on Galveston Island while one engaged in a non-nesting emergence (false crawl) on Bolivar Peninsula. The remaining three neophyte nesters were wild conspecifics with no known affiliation to the UTC.

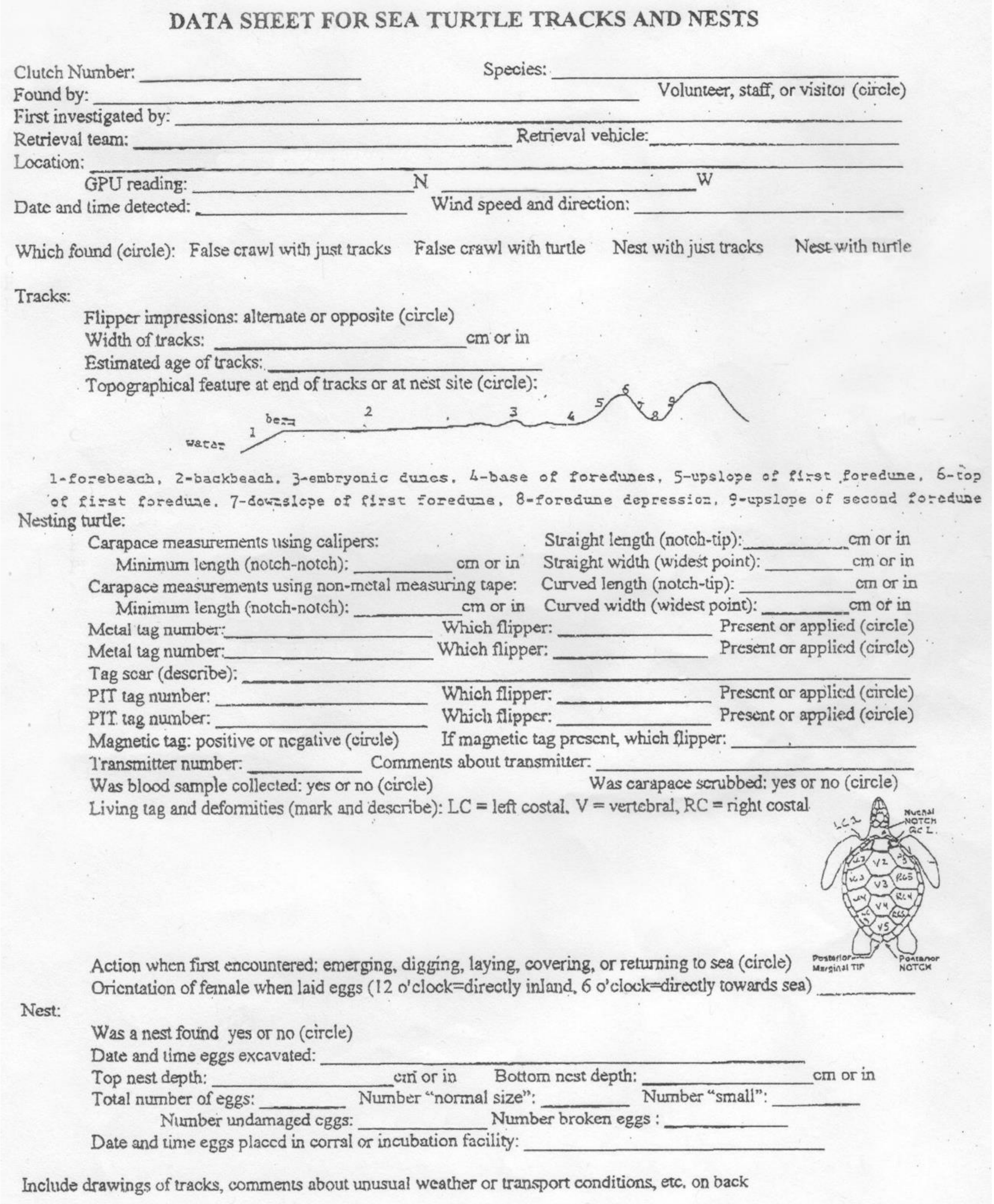
Research Objectives

The ramifications of a recovering Kemp's ridley population on UTC nesting productivity, particularly in light of the proliferation in nesting activity at PAIS since 2003 (Shaver 2012), are unknown. However, historical data suggest continued sustainment of, and annual increases in, UTC marine turtle reproductive activity. Strategic implementation of standardized nesting surveys on UTC beaches is required to accurately assess this region's potential as critical sea turtle nesting habitat. The creation and scrutiny of UTC sea turtle nesting activity projections are prerequisite to beach management policy formation and will occur via thorough examination of nesting activity through 2009. Research objectives addressed in this chapter include:

1. Identification of spatiotemporal nesting patterns on UTC beaches.
2. Characterization of the UTC nesting assemblage including morphometrics, within-season reproductive potential (existence of vitellogenic follicles, atretic follicles, or oviductal eggs), and fidelity to UTC beaches.
3. Comparison of reproductive behaviors and success exhibited by captive reared females versus that of wild conspecifics.
4. Quantification of clutch parameters.
5. Determination of environmental correlates of nesting.
6. Ascertainment of the UTC's current contribution to Texas' total Kemp's ridley reproductive output.

METHODS

Sea turtle nesting activity in Texas is comprehensively chronicled on the "Texas Data Sheet for Sea Turtle Tracks and Nests" (Figs. 2.2-2.3) developed by Dr. Donna Shaver (Chief, Division of Sea Turtle Science and Recovery, Padre Island National Seashore, Corpus Christi, Texas). Characterization of sea turtle nesting on the UTC from 2007 through 2009 included a query of Texas' standardized sea turtle nesting data sheets. Nesting data compiled for the UTC between 2007-2009 were collated with historical information (1996-2006) and analyzed in comparison with nesting trends at both Rancho



DATA SHEET FOR SEA TURTLE TRACKS AND NESTS

Clutch Number: ____________________ Species: ______________________________

Found by: ____ Volunteer, staff, or visitor (circle)

First investigated by: ____

Retrieval team: ________________________________ Retrieval vehicle: ____________________

Location: ____

GPU reading: ____________________N ____________________W

Date and time detected: ____________________ Wind speed and direction: ____________________

Which found (circle): False crawl with just tracks False crawl with turtle Nest with just tracks Nest with turtle

Tracks:

Flipper impressions: alternate or opposite (circle)

Width of tracks: ______________________cm or in

Estimated age of tracks: ______________________

Topographical feature at end of tracks or at nest site (circle):

1-forebeach, 2-backbeach, 3-embryonic dunes, 4-base of foredunes, 5-upslope of first foredune, 6-top of first foredune, 7-downslope of first foredune, 8-foredune depression, 9-upslope of second foredune

Nesting turtle:

Carapace measurements using calipers: Straight length (notch-tip): __________cm or in

Minimum length (notch-notch): __________ cm or in Straight width (widest point): __________cm or in

Carapace measurements using non-metal measuring tape: Curved length (notch-tip): __________cm or in

Minimum length (notch-notch): __________cm or in Curved width (widest point): __________cm or in

Metal tag number: ____________________ Which flipper: ______________ Present or applied (circle)

Metal tag number: ____________________ Which flipper: ______________ Present or applied (circle)

Tag scar (describe): ____

PIT tag number: ____________________ Which flipper: ______________ Present or applied (circle)

PIT tag number: ____________________ Which flipper: ______________ Present or applied (circle)

Magnetic tag: positive or negative (circle) If magnetic tag present, which flipper: ______________

Transmitter number: __________ Comments about transmitter: ______________________________

Was blood sample collected: yes or no (circle) Was carapace scrubbed: yes or no (circle)

Living tag and deformities (mark and describe): LC = left costal, V = vertebral, RC = right costal

Action when first encountered: emerging, digging, laying, covering, or returning to sea (circle)

Orientation of female when laid eggs (12 o'clock=directly inland, 6 o'clock=directly towards sea) __________

Nest:

Was a nest found yes or no (circle)

Date and time eggs excavated: ____

Top nest depth: ____________________cm or in Bottom nest depth: ____________________cm or in

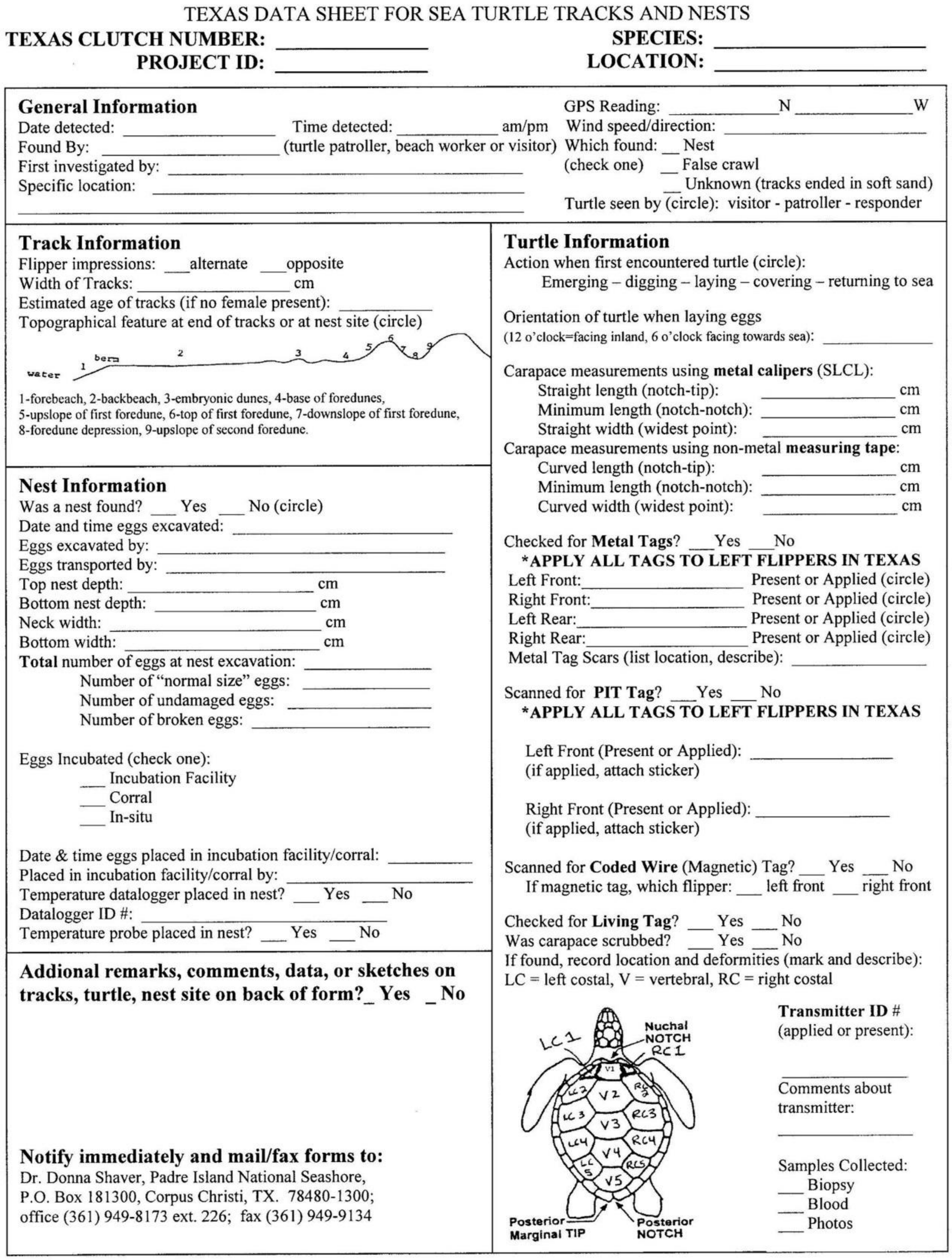
Total number of eggs: ________ Number "normal size": ________ Number "small": ________

Number undamaged eggs: ____________ Number broken eggs : ____________

Date and time eggs placed in corral or incubation facility: ______________________________

Include drawings of tracks, comments about unusual weather or transport conditions, etc. on back

Figure 2.2. Data sheet on which observations of sea turtles, sea turtle tracks, and/or nests laid along the upper Texas coast were recorded during 2002-2006.



TEXAS DATA SHEET FOR SEA TURTLE TRACKS AND NESTS

TEXAS CLUTCH NUMBER: ______________ **SPECIES:** ____________________

PROJECT ID: ______________ **LOCATION:** ____________________

General Information

Date detected: _________________ Time detected: ___________ am/pm

Found By: ___________________ (turtle patroller, beach worker or visitor)

First investigated by: ____

Specific location: ____

____

GPS Reading: ____________N ____________W

Wind speed/direction: ______________________

Which found: __ Nest

(check one) __ False crawl

__ Unknown (tracks ended in soft sand)

Turtle seen by (circle): visitor - patroller - responder

Track Information

Flipper impressions: ___alternate ___opposite

Width of Tracks: _________________ cm

Estimated age of tracks (if no female present): __________

Topographical feature at end of tracks or at nest site (circle)

1-forebeach, 2-backbeach, 3-embryonic dunes, 4-base of foredunes, 5-upslope of first foredune, 6-top of first foredune, 7-downslope of first foredune, 8-foredune depression, 9-upslope of second foredune.

Nest Information

Was a nest found? ___ Yes ___ No (circle)

Date and time eggs excavated: ________________________

Eggs excavated by: ________________________________

Eggs transported by: ______________________________

Top nest depth: ______________________ cm

Bottom nest depth: __________________ cm

Neck width: _________________________ cm

Bottom width: _______________________ cm

Total number of eggs at nest excavation: _____________

Number of "normal size" eggs: _____________

Number of undamaged eggs: _____________

Number of broken eggs: _____________

Eggs Incubated (check one):

___ Incubation Facility

___ Corral

___ In-situ

Date & time eggs placed in incubation facility/corral: _________

Placed in incubation facility/corral by: ___________________

Temperature datalogger placed in nest? ___ Yes ___ No

Datalogger ID #: ___________________________

Temperature probe placed in nest? ___ Yes ___ No

Addional remarks, comments, data, or sketches on tracks, turtle, nest site on back of form?_ Yes _ No

Notify immediately and mail/fax forms to:

Dr. Donna Shaver, Padre Island National Seashore,
P.O. Box 181300, Corpus Christi, TX. 78480-1300;
office (361) 949-8173 ext. 226; fax (361) 949-9134

Turtle Information

Action when first encountered turtle (circle):

Emerging – digging – laying – covering – returning to sea

Orientation of turtle when laying eggs

(12 o'clock=facing inland, 6 o'clock facing towards sea): ____________

Carapace measurements using **metal calipers** (SLCL):

Straight length (notch-tip): ______________ cm

Minimum length (notch-notch): ______________ cm

Straight width (widest point): ______________ cm

Carapace measurements using non-metal **measuring tape**:

Curved length (notch-tip): ______________ cm

Minimum length (notch-notch): ______________ cm

Curved width (widest point): ______________ cm

Checked for **Metal Tags**? ___Yes ___No

***APPLY ALL TAGS TO LEFT FLIPPERS IN TEXAS**

Left Front:________________ Present or Applied (circle)

Right Front:________________ Present or Applied (circle)

Left Rear:________________ Present or Applied (circle)

Right Rear:________________ Present or Applied (circle)

Metal Tag Scars (list location, describe): ______________

Scanned for **PIT Tag**? ___Yes ___ No

***APPLY ALL TAGS TO LEFT FLIPPERS IN TEXAS**

Left Front (Present or Applied): ______________
(if applied, attach sticker)

Right Front (Present or Applied): ______________
(if applied, attach sticker)

Scanned for **Coded Wire** (Magnetic) Tag? ___ Yes ___ No

If magnetic tag, which flipper: ___ left front ___ right front

Checked for **Living Tag**? ___ Yes ___ No

Was carapace scrubbed? ___ Yes ___ No

If found, record location and deformities (mark and describe):

LC = left costal, V = vertebral, RC = right costal

Transmitter ID #
(applied or present):

____

Comments about transmitter:

____

Samples Collected:

___ Biopsy

___ Blood

___ Photos

Figure 2.3. Data sheet on which observations of sea turtles, sea turtle tracks, and/or nests laid along the upper Texas coast were recorded during 2007-2009. *(Data sheets utilized in 2007 requested identical information using slightly altered language in certain sections.)*

Nuevo and PAIS to create a comprehensive baseline assessment of Kemp's ridley nesting in this area. However, protocols used to generate historical nesting information differed significantly from that implemented in the form of standardized nesting patrols and increased beachfront signage in limited areas of the UTC during 2007-2009.

Nesting Patrols

Quantitative characterization of sea turtle nesting on the UTC, including spatial and temporal attributes of nests laid; nester stock (wild vs. captive reared), morphometrics, site fidelity, and internesting interval; as well as clutch size and hatching success; required the implementation of systematic surveys to detect nesting activity. Accordingly, standardized nesting patrols were instituted on nearly all Galveston Island beaches in 2007, with patrol coverage expanded to select beaches on Bolivar Peninsula in 2008 and Follets Island in 2009 (Fig. 2.1).

To staff these patrols, an evolving team of approximately 30 student interns and volunteers sourced from Texas A&M University at Galveston (TAMUG), Master Naturalist chapters in the Houston-Galveston area, and local communities were recruited, trained, and deployed on Galveston Island (2007-2009), Bolivar Peninsula (2008-2009), and Follets Island (2009) beaches. Patrollers outfitted in conspicuous, bright green t-shirts proclaiming "Sea Turtle Patrol" concurrently surveyed designated sections of beach for sea turtle tracks while educating beachgoers about sea turtles and the role of beach habitat in nesting activity, thus increasing the potential for public reporting of nesting activity.

Weekday patrols were conducted from 1 April through 15 July in 2007 and 2008 to encompass the Kemp's ridley nesting season (USFWS & NMFS 1992, Márquez 1994). In 2009, weekday surveys occurred between 15 April and 15 July. Patrols were scheduled to incorporate the 0800-1100 timeframe to maximize potential interception of Kemp's ridley females, which are primarily diurnal nesters (Márquez 1994). Staffing and financial constraints mandated that each patrol section (Table 2.1, Figs. 2.4-2.7) be surveyed by one individual once each weekday; these limitations maintained a continued dependence upon public reporting of nesting events, particularly those occurring during non-patrol hours and on weekend days.

Galveston Island

Galveston Island was partitioned into two distinct patrol zones, West Beach (Fig. 2.4) and Seawall (Fig. 2.5), naturally divided by a 6.5 km section of shoreline situated between 8 Mile Road and 61st Street. This centrally located shoreline, which was predominantly devoid of sandy beach habitat and composed of riprap bordering a seawall, failed to provide a suitable environment for nesting sea turtles and thus was not formally surveyed. West Beach was comprised of 28.29 km of contiguous shoreline adjacent to residential development extending west of 8 Mile Road to San Luis Pass (Fig. 2.4). On Galveston's commercially developed east end, the 12.11 km Seawall Zone

Table 2.1. Attributes of upper Texas coast sea turtle nesting patrol sections surveyed from 2007-2009.

Location	**Section**	**Patrol Method**	**Section Length[1] (km)**	**Time Start**	**Time End**	**Total Time (hrs)**
Galveston Island	61st Street [2]	Foot	4.22	0800	1100	3.0
Galveston Island	Flagship [2]	Foot	4.09	0800	1100	3.0
Galveston Island	East Beach [2]	Foot	3.80	0800	1100	3.0
Galveston Island	West Beach [2]	ATV	28.29	0800 [3]	1230 [3, 4]	4.5
Bolivar Peninsula	Bolivar [5]	ATV	38.96	0700	1300 [4]	6.0
Follets Island	Follets Island [6]	ATV	22.26	0700	1100 [4]	4.0

[1] Section length indicates one-way distance; however, all patrols were conducted as round-trip circuits.

[2] Patrols occurred during 2007-2009.

[3] In 2009, patrols were conducted from 0700-1130.

[4] Actual patrol end times varied due to beach and weather conditions.

[5] Patrols occurred during 2008-2009.

[6] Patrols occurred in 2009 only.

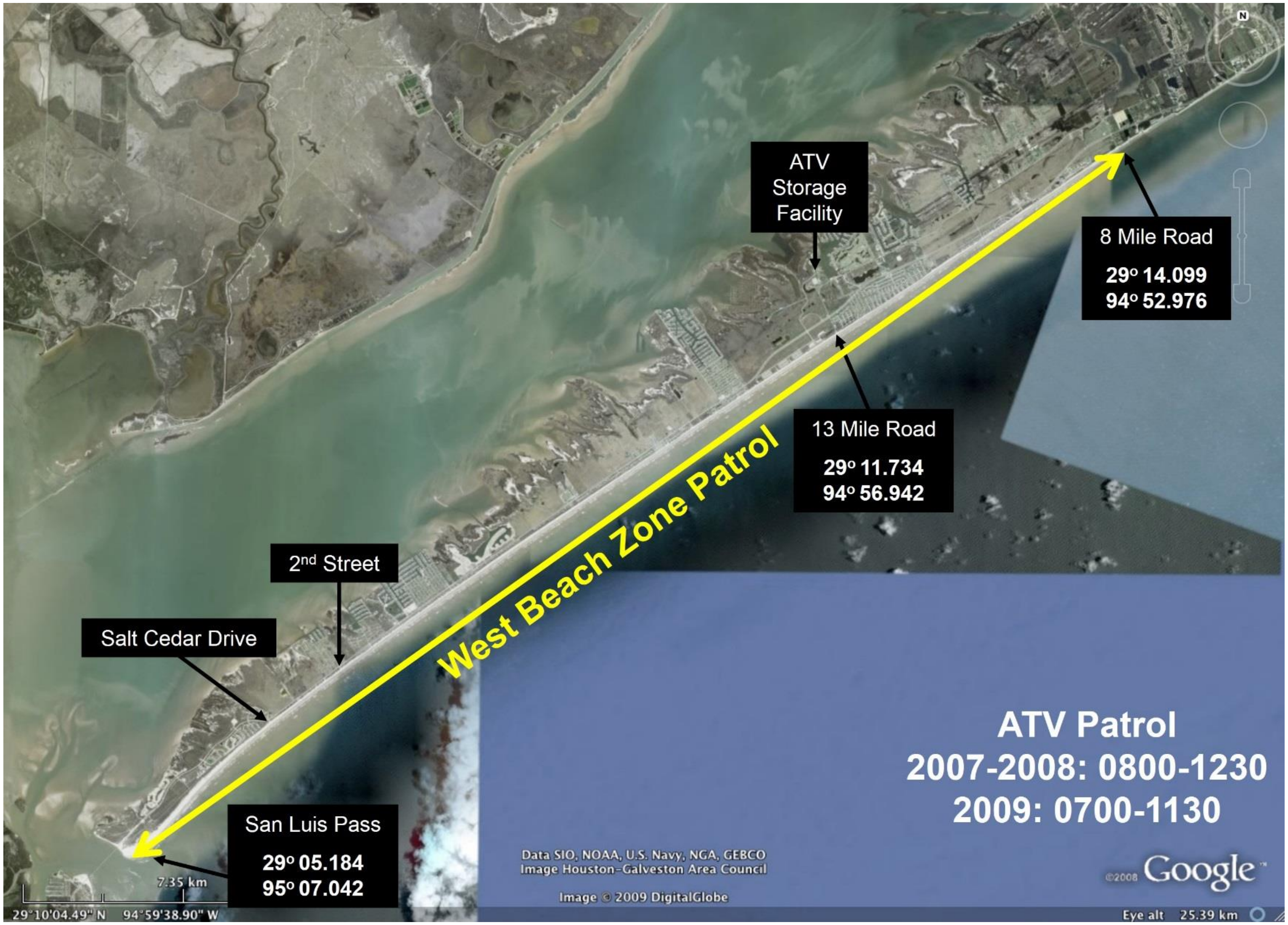


Figure 2.4. Delineation of west Galveston Island beaches patrolled for nesting sea turtles via ATV during 2007-2009.

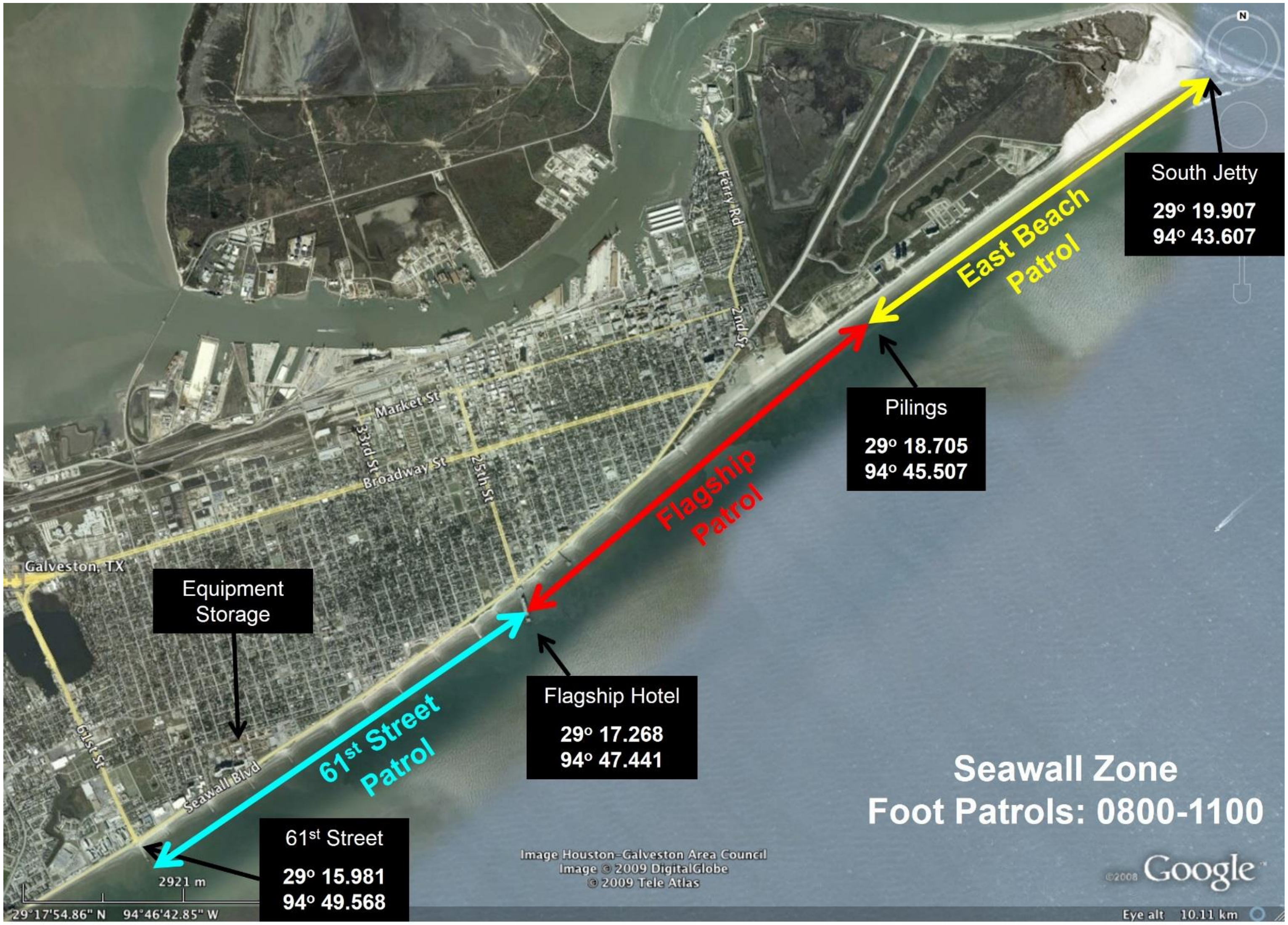


Figure 2.5. Delineation of east Galveston Island beaches patrolled on foot for nesting sea turtles during 2007-2009.

Figure 2.6. Delineation of Bolivar Peninsula beaches patrolled for nesting sea turtles via ATV during 2008-2009.

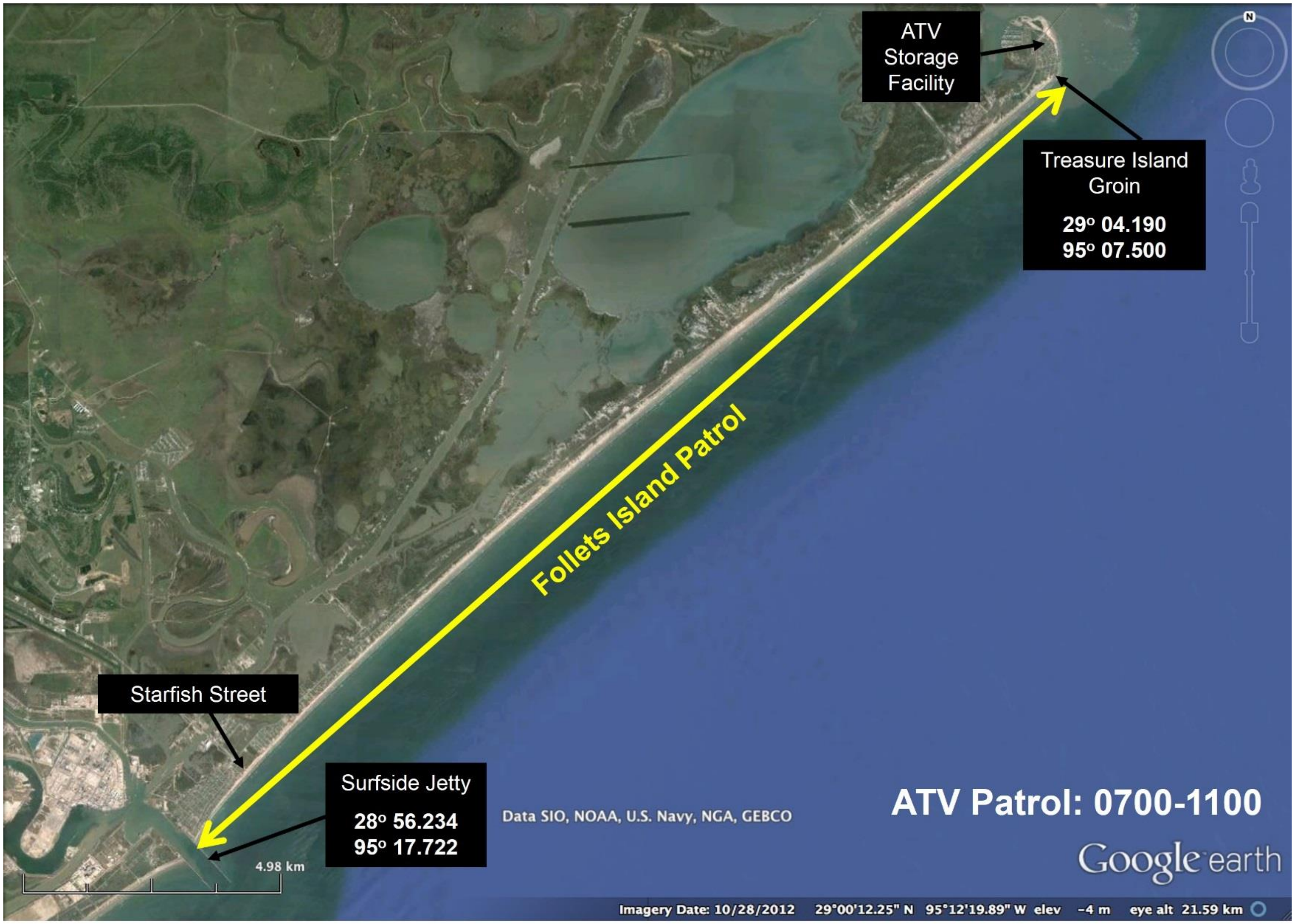


Figure 2.7. Delineation of Follets Island beaches patrolled for nesting sea turtles via ATV during 2009.

was largely characterized by heavily utilized beaches constrained by a 5.2 m high seawall and associated revetments and groins. This zone was subdivided into three patrol sections: 61st Street, Flagship, and East Beach (Fig. 2.5). The 61st Street patrol encompassed 4.22 km of beach between 61st Street and the Flagship Hotel located at 25th Street. The Flagship Hotel patrol covered 4.09 km of beach situated between the Flagship Hotel and pilings positioned 0.5 km west of the Palisade Palms Condominiums. The northward deviation of the seawall inland that began near 12th Street diminished its influence on the eastern 2.4 km of this section's beaches, particularly east of Stewart Beach. Consequently, the East Beach patrol incorporated 3.80 km of primarily undeveloped residential beachfront not noticeably constrained by this seawall that extended from the pilings 0.5 km west of the Palisade Palms Condominiums to Galveston Island's eastern boundary at the South Jetty. Vehicular traffic was comprehensively prohibited on Galveston Island beaches with the exception of two locations in the West Beach Zone: 1) from 2nd Street west approximately 2.1 km to Salt Cedar Drive, and 2) the westernmost 2.2 km of beachfront adjacent to San Luis Pass.

Bolivar Peninsula

Nesting patrols of Bolivar Peninsula (Fig. 2.6), located to the northeast of Galveston Island, commenced in 2008 to survey the westernmost 38.96 km of primarily residentially developed beach habitat accessible by vehicle. These patrols extended from the eastern boundary of the Bolivar Flats Shorebird Sanctuary, located on the southwestern tip of the Peninsula, east to the beach immediately adjacent to the intersection of Highways 87 and 124, just south of High Island. Beaches comprising this section permitted public vehicular travel and were contiguous with the exception of Rollover Pass, a man-made waterway 60 m in width.

Follets Island

Formal surveys were initiated in 2009 on 22.26 km of uninterrupted coastline on Follets Island (Fig. 2.7), located directly southwest of Galveston Island adjacent to San Luis Pass. These primarily undeveloped beaches were constrained by coastal County Road 257 (Bluewater Highway) that bisected Follets Island lengthwise. Moderate residential and/or commercial development, although interspersed throughout the island, was concentrated at the southwestern terminus in the Village of Surfside Beach. Nesting patrols to monitor this contiguous shoreline extended from the fortified groin situated below the southern termination of Jolly Roger Drive in the Treasure Island subdivision southwest to Surfside Jetty. Vehicular beach access was permitted throughout the island with the sole exception of the westernmost 1.6 km of beach habitat located between Starfish Street and the Surfside Jetty, contiguous with Surfside Beach.

Patrol Method

Two distinct patrol methods, ATV (all-terrain vehicle) and foot, were utilized to survey designated beaches of Galveston Island, Bolivar Peninsula, and Follets Island for evidence of sea turtle nesting activity. Existing sea turtle nesting patrols in Texas and Mexico were primarily conducted via motorized vehicles such as ATV's or UTV's (utility terrain vehicle; C.L. Hughes pers. obs.) as these transport modes enabled individual patrollers to survey a greater distance per unit of time than walking patrols. As such, ATV patrols were instituted on Galveston Island's West Beach Zone and on the entirety of the patrolled sections of Bolivar Peninsula and Follets Island. Regulations prohibited the use of motorized vehicles on Galveston Island with limited exceptions; however, permission to operate a single daily ATV patrol along Galveston's West Beach Zone was obtained from city officials.

ATV's on UTC beaches were operated at or slightly above the high tide line at speeds not exceeding 24 km h^{-1} to maximize the patroller's ability to visually observe signs of nesting activity. On Galveston Island's West Beach Zone, a single ATV patroller conducted one round-trip circuit (56.58 km) between San Luis Pass and 8 Mile Road from 0800 to approximately 1230 each weekday during 2007 and 2008, and from 0700 to approximately 1130 each weekday in 2009. As the ATV and associated patrol equipment (Table 2.2) were stored at the Galveston Island State Park maintenance facility, this patrol began at the Park's easternmost beach boundary adjacent to 13 Mile Road, initially proceeded west to San Luis Pass, returned east to 8 Mile Road, and concluded at the Park starting point. On Bolivar Peninsula, a single ATV patroller conducted weekday monitoring of constituent beaches from 0700 to approximately 1300 (roundtrip distance: 77.92 km). Patrollers initially drove west from the Rettilon Road access point to the pilings delineating the eastern boundary of the Bolivar Flats Shorebird Sanctuary, traveled east along the beach to the intersection of Highways 87

Table 2.2. List of equipment required for ATV patrols of upper Texas coast beaches, 2007-2009.

Volunteer Provides:
Cell Phone

Patrol Backpack:
Action List
Brush (to clean turtle's carapace)
Cable Ties
Disposable Camera
Disposable Rain Gear
Dry Erase Board & Pen (for photographs)
Educational Handouts
Extra Ziploc Bags (3-5)
First Aid Kit
Fix-a-Flat
Hand Sanitizer
Insect Repellant
Large Towel
Latex Gloves
Meat Tenderizer (for jellyfish stings)
Nest Marker (black rope)
Nesting Data Sheets (5)
Notepad, Sharpie, Pens, & Pencils
Permits & Authorization Letter
Soft Measuring Tape
Sunscreen

Items Required for Bolivar Peninsula ATV Patrol Only:
GPS in Ziploc Bag
GPS Instruction Booklet
Extra AA Batteries (2+)

Mandatory Item Provided at Storage Facilities:
Helmet

Optional Items Provided at Storage Facilities:
Lunch Cooler
Snacks
Water

and 124 at High Island, and returned west to exit the beach at Rettilon Road. Beach habitats comprising the Follets Island patrol zone were also surveyed once each weekday via ATV from approximately 0700 to 1030 (roundtrip distance: 44.52 km). Patrols, which originated and terminated on the beach adjacent to the Treasure Island subdivision's reinforced groin, initially moved southwest to the Surfside Jetty before returning northeast.

On Galveston's Seawall Zone, substantial public use and anthropogenic alterations, including groins and rip-rap associated with the seawall, presented significant obstacles to ATV passage and thus mandated the implementation of pedestrian patrols. The institution of three foot patrols on Galveston Island's Seawall Zone enabled individuals to conduct round-trip surveys of associated beaches at a moderate walking pace of approximately 3.2 km h^{-1} from 0800-1100 each weekday. Prior to arriving at designated patrol section starting points by 0800, foot patrollers obtained conspicuously labeled sea turtle patrol backpacks containing essential equipment (Table 2.3) from a storage trailer situated in the student parking lot of the TAMUG Fort Crockett campus located at 5007 Avenue U. Both the 61st Street patrol (roundtrip distance: 8.44 km), which began and ended at 61st Street, and the Flagship patrol (roundtrip distance: 8.18 km), which commenced and concluded at the Flagship Hotel, initially proceeded east to previously designated midpoints. However, beach access restrictions required that the East Beach patrol (roundtrip distance: 7.60 km) initially proceed west from the South Jetty to the pilings delineating the midpoint jointly utilized by the Flagship and East Beach patrols.

Table 2.3. List of equipment required for foot patrols of upper Texas coast beaches, 2007-2009.

Volunteer Provides:
Cell Phone

Patrol Backpack:
Action List
Brush (to clean turtle's carapace)
Disposable Camera
Disposable Rain Gear
Dry Erase Board & Pen (for photographs)
Educational Handouts
First Aid Kit
Hand Sanitizer
Latex Gloves
Meat Tenderizer (for jellyfish stings)
Nest Marker (black rope)
Nesting Data Sheets (2)
Notepad, Sharpie, Pens, & Pencils
Permits & Authorization Letters (Galveston & Parks Board)
Soft Measuring Tape (to measure turtle tracks)
Ziploc Bags (3-5)

Optional Items Provided at Turtle Trailer:
Insect Repellant
Snacks
Sunscreen
Water

While patrollers were expected to walk at or immediately above the high tide line on the beach, tidal fluctuations and small areas composed of rip-rap bordering the seawall on both the 61st Street and Flagship patrol sections occasionally mandated that patrollers briefly travel along the seawall's elevated sidewalk before returning to the beach at the first available opportunity. In addition, patrollers reaching their midpoints before 0930 were required to delay their departure from the midpoint to permit conclusion of their patrol at precisely 1100.

Patrol Protocol

Patrollers tasked with pedestrian and/or ATV patrols participated in multiple training sessions prior to participation in this project to ensure sanctioned tasks were completed safely and in compliance with all pertinent federal, state, and local regulations. Mandated nest detection protocol and provisions ensured the safety of both human participants and nesting sea turtles throughout the duration of this research. Patrollers operated unaccompanied (a minimal number of exceptions were made for pedestrian patrollers only) and carried cell phones to ensure sea turtle sightings and emergencies were efficiently communicated.

Both ATV and foot patrollers were instructed to consistently survey the beach at or just above the high tide line for sea turtle tracks, specifically traces of drag marks bound by bilateral claw impressions characteristic of Kemp's ridleys. ATV patrollers returning over habitat previously monitored that day also observed their outgoing tire tracks for signs of passage by a nester. Patrollers were cognizant of the need to avoid searching for cryptic nesting females or beach refuse, as these visual distractions interfered with the efficacy of patrol efforts (C.L. Hughes pers. obs.). All potential tracks, particularly those oriented perpendicular to the shoreline, required meticulous visual inspection to differentiate between sea turtle tracks and similar marks made by local wildlife or dragged items such as coolers or strollers.

Patrollers who encountered a sea turtle or turtle tracks immediately safeguarded themselves and the animal and/or location and initiated the cooperative nesting response effort by NOAA STF staff and permitted TAMUG personnel; tasks to safeguard a live turtle are outlined on the Action List (Fig. 2.8) included in all patrol backpacks. Patrollers initiated this response by contacting the NOAA STF sea turtle stranding coordinator at 409-771-2872; this is the public contact number provided by the HEART hotline for the Texas coast from the Texas-Louisiana border south to Freeport. After confirming that site evidence warranted investigation, the NOAA STF stranding coordinator contacted TAMUG personnel to identify and activate a permitted responder.

Nest Response

As Kemp's ridleys are highly efficient diurnal nesters that complete the nesting process in as little as 35-50 minutes (Márquez 1994, Witzell et al. 2005b), it was expected that the majority of nesting activity reports would involve sightings of tracks with no female present. Tracks are indicative of two potential nester activities: a non-nesting emergence

WHEN YOU FIND A TURTLE:

Crawling up beach toward dunes:

1. Keep the turtle safe! Direct vehicles away from the turtle.
2. CALL RESPONDERS: **409.771.2872**.
3. Keep bystanders well away from and behind turtle. Inform bystanders who you are. Minimize bystander movement and commotion.

Nesting (laying eggs):

1. Keep the turtle safe!
2. CALL RESPONDERS: **409.771.2872**.
3. Approach turtle from behind only after she has laid several eggs. Dig a small deep hole ~12 inches directly behind turtle's nest. Insert rope nest marker into this hole, and pack sand tightly around it. Lay trailing rope on the sand behind turtle.
4. Examine all flippers for tags. Record 6 digit tag number(s).
5. Take pictures of turtle's tracks, carapace, and flippers.

Returning to the water:

1. Keep the turtle safe! Direct vehicles away from the turtle. Keep turtle's path to water clear of bystanders and vehicles.
2. CALL RESPONDERS: **409.771.2872**.
3. Take photographs of the turtle's carapace.
4. Take action only as directed by responders.

Marine Mammal Strandings:

1.800.9.MAMMAL

Bird Rehabilitation:

Barbara House – Dickinson: 281.337.3683
Margaret Pickell – Friendswood: 281.648.2328

Figure 2.8. Action list detailing patroller response to live nesting sea turtles intercepted on the beach.

or nest deposition. Patroller response for either activity was identical: patrollers preserved and outlined all visible evidence of the turtle's crawl with locally available materials, including driftwood and litter; measured track width; and photographically documented the site.

The federally protected status of sea turtles mandates that only permitted individuals handled these animals and their nest products. Thus, the permitted responder coordinated all activities associated with nest excavation, nester restraint, and transport of females for satellite tagging purposes (see Chapter IV). Responders documented nesting activity through completion of all pertinent fields on the nesting data sheet (Figs. 2.2-2.3) while investigating the site. After measuring track width, the responder attempted to locate a nest near the confluence of the incoming and outgoing tracks where a comparatively insubstantial body pit indicative of nest excavation may or may not have been visible. Nest detection primarily entailed exploration by hand through the compacted sand crust to locate the unconsolidated layers of previously excavated sand covering the nest neck, an area approximately 15 cm in width (C.L. Hughes pers. obs.). Upon locating the nest cavity, the responder donned latex gloves to transfer individual eggs from the nest to a polystyrene foam container lined with moist sand sourced from the nest site. A flexible temperature probe was centrally situated within the clutch to permit external computerized monitoring of incubation temperatures. Eggs were handled in a manner that minimized potential damage to the developing embryo by avoiding rotation and vibration (Limpus et al. 1979); clutches exceeding 100 eggs were split and housed in two polystyrene incubators. Descriptively labeled incubators were secured in PVC transport containers (Fig. 2.9) for vehicular transport to the NOAA STF and, within 48 hours, the PAIS incubation facility. Nester species confirmation and hatch and emergence success rates were obtained from PAIS following hatchling release.

The permitted responder managed the health and safety of retained post-nesting females, particularly maintenance of core body temperature. Females intercepted for tagging were restrained in an environment conducive to the avoidance of hypo- and hyperthermia. Restraint occurred on moist or dry beach sand and/or in a confining plastic transport box containing a 10 cm-thick protective foam cushion situated in an open pickup truck bed for a period not exceeding 2.5 hours before vehicular transport to, and arrival at, the NOAA STF in Galveston. Acceptable methods to detain post-nesting females included the use of handholds on the carapace in the vicinity of the nuchal notch by a responder situated at the turtle's anterior or posterior end; as well as minimization of the turtle's visual perception of the water, best accomplished by orientating the turtle anteriorly toward the dunes. Females were never placed in dorsal recumbency. Although turtles remained dry-docked during restraint, transport, and tagging, wet or dry towels were placed over the carapace to aid in temperature regulation and to minimize dehydration.

Collection of morphometric data; sonography to determine the presence of calcified oviductal eggs or vitellogenic or atretic follicles; and application of flipper, PIT (passive integrated transponder), and satellite tags (see Chapter IV); occurred at the NOAA STF.

Figure 2.9. Polystyrene foam egg incubation container secured in PVC transport carrier with external temperature probe wire visible on right side. (Photo by Sharla Knoll.)

Daytime releases of these intercepted and tagged nesters occurred at their nesting site within 24 hours of initial detection. In 2008, procedures were modified slightly to avoid transportation and detainment of females retaining calcified eggs in the oviduct. Permitted responders previously trained in sea turtle sonographic techniques by Dr. Joe Flanagan, DVM, utilized a portable ultrasound on females returning to the water to verify oviposition had occurred. Turtles engaged in non-nesting emergences (i.e. retaining shelled eggs) were immediately released at their emergence location following procurement of measurements and application of flipper and/or PIT tags.

Environmental Correlates of Nesting

Temporal nesting data sourced from 26 sites where permitted responder(s) directly observed Kemp’s ridleys engaged in nesting behavior on the UTC during 2002-2009 were utilized to compile relevant environmental data for the purpose of identifying correlations between nesting activity and the following: wind velocity, wind direction, tidal cycle, and lunar phase. (One additional direct observation in 2002 was excluded from analysis due to insufficient documentation.) Coastal oceanographic data, including mean sea level (MSL), wind speed and direction, and water temperature, were sourced from NOAA’s Center for Operational Oceanographic Products and Services (CO-OPS) database utilizing the Galveston Bay Entrance, North Jetty Station (ID: 8771341) located at 29°21.4’ N, 94°43.4’ W for all UTC nest sites. This station typically documented meteorological conditions in six-minute intervals through 2008 (no data were available in 2009 due to damage from Hurricane Ike). As such, data utilized in analyses were recorded at the time closest to that when the turtle was first observed by responder(s).

Lunar phase information was obtained from the United States Naval Observatory for all UTC nests documented at oviposition through 2008. Analysis was discontinued for 2009 due to a lack of correlation with UTC nesting activity.

RESULTS

UTC Nesting Dynamics

Two sea turtle species were documented utilizing UTC nesting habitats between 1996 and 2009. A total of 75 Kemp's ridley nests was confirmed on constituent beaches through 2009 (Table 2.4). Thirty-seven of these were laid on Galveston Island; Bolivar Peninsula and Follets Island each tallied 10 nests. Additional nests were deposited on Quintana Beach (4 nests), Bryan Beach (3 nests), Sargent Beach (2 nests) and Matagorda Peninsula (9 nests). Moreover, two loggerhead sea turtle nests were oviposited on Bolivar Peninsula by unique females on 27 July 1996 and 24 June 2008, while non-nesting emergences on Sargent Beach (14 July 2002) and Galveston Island (31 May 2003) were attributed to loggerheads (Shaver 2004).

Record annual Kemp's ridley nesting was documented on the UTC (Table 2.4) in both 2007 (15 nests located between 1 May – 24 June) and 2008 (16 nests documented between 25 April – 27 June). The 2009 nesting season (2 May – 8 June), during which

Table 2.4. Kemp's ridley sea turtle nests documented on upper Texas coast beaches, 2002-2009.

Year	**Bolivar Peninsula** [1]	**Galveston Island** [2]	**Follets Island** [3]	**Quintana Beach**	**Bryan Beach**	**Sargent Beach**	**Matagorda Peninsula**	**Upper Texas Coast Total**
2002		2		1			1	**4**
2003		1						**1**
2004	2	2	1					**5**
2005		7					1	**8**
2006		9	1					**10**
2007	1	7	2		1		4	**15**
2008	6	6	3	1				**16**
2009[4]	1	3	3	2	2	2	3	**16**
Total	**10**	**37**	**10**	**4**	**3**	**2**	**9**	**75**

[1] Formalized sea turtle nesting patrols were instituted on Bolivar Peninsula in 2008.

[2] Formalized sea turtle nesting patrols were instituted on Galveston Island in 2007.

[3] Formalized sea turtle nesting patrols were instituted on Follets Island in 2009.

[4] Northern upper Texas coast beach habitats were severely impacted by Hurricane Ike prior to the 2009 nesting season (Doran et al. 2009).

16 nests were also confirmed, followed the landfall of Category 2 Hurricane Ike (Doran et al. 2009) on Galveston Island 13 September 2008. Associated storm surge levels in Brazoria County, which encompasses Follets Island and Surfside Village, were between 1.5 to 3 m. Maximum storm surge levels (5 m) and onshore wind speeds (175 km h^{-1}) were recorded to the north on Bolivar Peninsula, where 1 to 3 m of water inundated the entire region and extensive destruction of residential beachfront development occurred (Doran et al. 2009). Monitored sea turtle nesting beaches along Follets Island, Galveston Island, and Bolivar Peninsula were profoundly altered via the eradication of dune habitats, extensive loss of sand, and adverse permutations in beach slope and width. Two thousand and nine marked the first year nesting to the south between Quintana Beach and Matagorda Peninsula exceeded that reported northward. The beaches of Bolivar Peninsula, Galveston Island, and Follets Island that collectively accounted for an average of 85.4% of UTC nesting annually through 2008 contained only 44% of nests in 2009.

Galveston Island

Documentation of Kemp's ridley nesting activity (both nests and non-nesting emergences) on Galveston Island met or exceeded previous annual totals in both 2007 and 2008 following the implementation of formalized nesting patrols. While nest counts on Galveston Island declined annually from a peak of 9 in 2006, non-nesting emergences on Island beaches were first reported in 2007 and were documented in both 2008 and 2009. Responders confirmed 7 nests and 2 false crawls in 2007 (a total of 9 nesting activity reports), 6 nests and 4 abandoned nesting attempts in 2008, and 3 nests and 2 non-nesting emergences in 2009 (Table 2.4).

Five (71%) of the seven clutches located during the 2007 nesting season were discovered by the West Beach ATV patrol; tracks were the sole indicator of nesting activity at four of these sites. Beachgoers reporting sea turtles on the beach accounted for the remainder of documented nesting activity, including a hatchling emergence adjacent to the seawall at a previously undocumented nest site that occurred at 0900 on 6 August, post-dating the seasonal surveys. In 2008, patrollers located two non-nesting emergences (20% of documented nesting activity), including one on pedestrian-patrolled East Beach where nesting activity had previously never been reported. Five of the six documented clutches resulted from beachgoers notifying responders of nesting females outside active patrol times; four of these notifications were received before patrols commenced at 0800. In 2009, 80% of nesting activity was identified by the West Beach ATV survey; tracks were again the sole evidence of nesting activity at three of these four sites. The remaining clutch was identified based upon visitor accounts of a nesting turtle near the Pointe West public beach access.

Sea turtle nesting survey efforts on Galveston Island exceeded that on all other sections of the UTC from 2007 through 2009 in terms of both time and distance covered (Appendices A-H). Annual survey commitment on the Island ranged from 793.00-808.00 h to cover a cumulative total of 5271.19–5457.52 km of beach via pedestrian and

ATV patrols (Appendices A, B, E). Galveston's West Beach and Seawall Zones together attained a peak nesting density of 0.22 nests per kilometer in 2006, greater than that at any other UTC locale through 2009.

Bolivar Peninsula

Historic sea turtle nesting on Bolivar Peninsula prior to 2007 amounted to just three nests. A single Kemp's ridley nest laid in 2007 raised the cumulative total to four and marked the beginning of consecutive annual nesting activity from 2007 through 2009 (Table 2.4), although no females were observed by reporters or responders during this period. In 2008, the year nesting patrols commenced (Appendix C), 6 Kemp's ridley nests, 1 loggerhead nest, and 2 non-nesting emergences were confirmed. Eighty-six percent of nesting activity documented before the conclusion of nesting surveys on 15 July resulted from sea turtle track identification by ATV patrollers. Visitor reports of nocturnally emerging hatchlings on 16 and 25 July led to the procurement of two additional nests. In 2009, the first nesting season subsequent to the 13 September 2008 landfall of Hurricane Ike, a single Kemp's ridley nest was documented via the coordinated patrol effort (Appendix F). Peak nesting density, obtained in 2008, reached 0.18 nests per kilometer of beach.

Follets Island

Beachgoer reports of females utilizing nesting grounds adjacent to developed sections of Follets Island accounted for the documentation of two Kemp's ridley nests each in 2007 and 2008 (Table 2.4). In 2008, tracks leading to the third verified clutch, located on an undeveloped stretch of beach, were reported by an off-duty patroller associated with this project. Nesting surveys implemented on Follets Island in 2009 (Appendix G) directly resulted in the confirmation of 3 nests and 1 non-nesting emergence (80% of documented nesting activity), although no turtles were observed. A false crawl was also confirmed as a result of beach residents who witnessed a female emerge on a short segment of unpatrolled beach underneath the San Luis Pass bridge. These non-nesting emergences represent the first such recorded on Follets Island. Peak nesting density, documented in both 2008 and 2009, reached 0.13 nests per kilometer of beach.

Attributes of Kemp's Ridley Nesters

Responders observed 28 instances of Kemp's ridleys engaged in nesting activity on the UTC either directly (n=27) or via video documentation (n=1) during 2002-2009. Emergences of Kemp's ridley females were temporally distributed diurnally, with 46.2% of nesters directly observed by responders between 0800-1059 (n=26 time-stamped records; Fig. 2.10). Eighteen identifiable individuals were derived from 3 distinct stocks: 12 were sourced from the bi-national headstart experiment, 1 female originated from the 1995 year-class associated with NOAA's turtle excluder device research efforts, and 5 ridleys were considered wild with no known affiliation to this region. Headstarted females derived from the 1989 (n=3), 1990 (n=1), 1991 (n=3), and 1992 (n=5) year-classes were between 10 and 19 years of age when engaged in nesting activity. Captive reared females averaged 62.4 cm in straight carapace length (SCL; SD ± 2.0), while wild

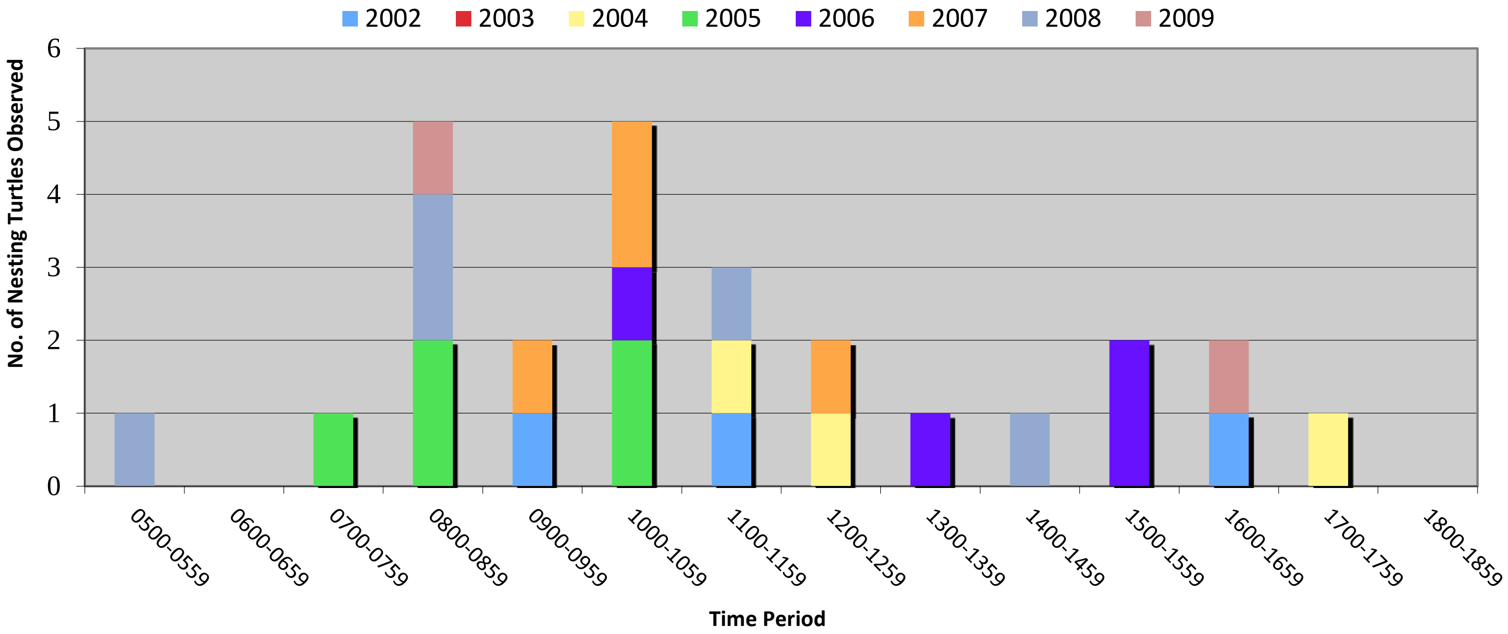


Figure 2.10. Diel distribution of observed Kemp's ridley nesting activity (n=26) on the upper Texas coast, 2002-2009.

conspecifics averaged 64.5 cm SCL (SD ± 2.8). All turtles were considered neophytes with no prior nesting history elsewhere in Texas or in Mexico (D. Shaver pers. comm.).

A query of documented flipper, PIT, living, and/or satellite tags associated with the 18 individuals observed by responders resulted in the confirmation of two wild and four headstarted Kemp's ridleys that demonstrated fidelity to UTC nesting beaches, particularly Galveston Island, either within or between seasons. Five were documented twice on UTC beaches: RRV319 (Benjamina) nested twice in 2005 (35 d internesting interval); RRV371 (Bennie) nested in 2005 and engaged in a non-nesting emergence in 2007; RRV255 (Caillie) laid single nests in 2006 and 2008; RRV258 (Smarttie) nested in 2006 and 2009; and RRV373, a female missing a significant portion of both rear flippers, made two abandoned nesting attempts 15 days apart in 2008. Three nesting records exist for the sixth female, RRV315 (Missy), who deposited two nests 0.70 km apart in 2006 (20 d internesting interval) and one in 2008. With the exception of the 2008 nest laid by RRV255 (Caillie) on Follets Island, all stated philopatric nesting behavior occurred on Galveston Island with distance between documented emergences by individuals averaging 18.36 km (SD ± 16.6, range = 0.70-46.53 km).

Examination of within-season reproductive potential for the 10 individuals intercepted during the 2007, 2008, and 2009 nesting seasons resulted in the confirmation of vitellogenic follicles in eight instances. Sonography was used to identify reproductive status in all but one case in which a wild neophyte nester (YYP019) displaying aberrant behavior on the beach was transported to the NOAA STF after depositing eggs on Bryan Beach 18 May 2009, and developing follicles were confirmed via necropsy after YYP019 perished overnight from an undiagnosed acute illness (J. Flanagan pers. comm.). Calcified oviductal eggs were identified via ultrasound for two turtles: RRV371 (Bennie) on 26 May 2007, and RRV373 on both 12 and 27 June 2008, in which the latter instance revealed what appeared to be atretic follicles (J. Flanagan pers. comm.). Post-ultrasound nesting confirmation was not obtained for either turtle that possessed calcified oviductal eggs.

Clutch Parameters

From 2002-2009, clutch sizes for Kemp's ridleys nesting on UTC beaches ranged from 52 to 123 eggs (mean = 98.4, SD ± 16.3; n=75) while hatchling emergence success ranged from 0 to 100% (mean = 77.8%, SD ± 26.1; n=75). All but four clutches that remained undetected *in situ* were transported to PAIS for incubation and subsequent hatchling release. Estimates regarding clutch size (mean = 81.3, SD ± 14.2; n=4) and emergence success (mean = 91.8%, SD ± 9.0; n=4) for UTC *in situ* nests were established by Dr. Donna Shaver upon receipt of excavated nest contents. Incubation period and nester stock are unknown for *in situ* nests.

Although sample sizes were inadequate for statistical comparison, clutches laid by wild nesters tended to contain more eggs (mean = 104.2, SD ± 12.4; n=5) and yielded improved rates of emergence (mean = 87.6%, SD ± 8.4; n=5) than did those by captive reared ridleys (clutch size mean = 98.4, SD ± 12.8; n=17; emergence success mean = 69.0%, SD ± 32.2; n=17). One female from the 1989 year-class known to have deposited three clutches on Galveston Island through 2009, RRV315 (Missy), consistently laid smaller fertile clutches with abnormally poor emergence success rates (5.7%, 23.7%, and 36.2%; D. Shaver pers. comm.). Removing known clutches by this ridley from pooled data resulted in a slight increase in overall clutch size (mean = 99.9, SD ± 13.6; n=14) and improved emergence success (mean = 79.1%, SD ± 24.8; n=14) for captive reared turtles.

Both loggerhead nests laid on Bolivar Peninsula were transported to PAIS for incubation and subsequent hatchling release. Ninety hatchlings (81.8%) emerged from the 1996 clutch of 110 eggs, while the 2008 nest containing 140 eggs produced 135 hatchlings (96.4%).

Environmental Correlates of Nesting

Documented nesting emergences by Kemp's ridley sea turtles on the UTC occurred when sea surface temperatures ranged between 22.0 and 29.5°C and most often under conditions of strong onshore winds from the southeast (Table 2.5). Wind velocities at time of nesting averaged 15.6 kn (range = 7.4-22.6 kn) and exceeded Galveston Island's average monthly wind speeds as recorded by NOAA's National Climatic Data Center (10.5, 10.0, and 9.3 kn during April, May, and June, respectively) 91.7% of the time.

Table 2.5. Environmental data associated with Kemp's ridley sea turtles (n=26) observed nesting on upper Texas coast beaches, 2002-2009. Provided data were uniformly sourced from Station #8771341 at the Galveston Bay entrance, North Jetty, Texas[1].

			Tide			**Wind**			**Water**	
Date	**Time Detected**	**Nesting Phase**	**Time of Measurement**	**Height (MSL[2]; m)**	**Phase**	**Speed (kn)**	**Bearing (º)**	**Compass Direction**	**Temp (ºF)**	**Temp (ºC)**
7 May 2002	1120	NNE[3]	1118	0.22	Rising	18.3	159	SSE	80.8	27.1
9 June 2002	1630	Emerging	1630	0.10	Falling	15.2	147	SSE	85.1	29.5
10 June 2002	0930	Emerging	0930	0.37	Falling	14.2	149	SSE	83.5	28.6
5 April 2004	1100	Covering	1100	0.08	Falling	20.0	96	E	72.0	22.2
17 April 2004	1700	Laying	1700	-0.09	Falling	15.7	128	SE	71.6	22.0
11 May 2004	1215	Returning to Sea	1212	0.40	Rising	18.9	112	ESE	77.7	25.4
16 May 2005	1000	Laying	1000	0.30	Rising	17.9	80	E	77.7	25.4
29 May 2005	0800	Covering	0800	-0.04	Rising	12.4	96	E	79.9	26.6
30 May 2005	0700	Covering	0700	-0.05	Rising	18.5	205	SSW	80.8	27.1
4 June 2005	1000	Returning to Sea	1000	0.24	Falling	16.1	170	S	81.0	27.2
20 June 2005	0830	Digging	0830	0.32	Falling	11.3	58	ENE	82.8	28.2
28 April 2006	1330	Digging	1330	0.28	Rising	22.5	115	ESE	75.9	24.4
6 May 2006	1500	Returning to Sea	1500	0.31	Rising	7.4	214	SW	77.2	25.1
6 May 2006	1500	N/R[4]	1500	0.31	Rising	7.4	214	SW	77.2	25.1
27 May 2006	1030	N/R[4]	1030	0.23	Falling	15.0	131	SE	79.3	26.3
17 May 2007	1000	Returning to Sea	1000	0.32	Falling	15.4	40	NE	77.0	25.0
17 May 2007	1230	Covering	1230	0.31	Rising	11.7	46	NE	79.3	26.3
18 May 2007	0955	Laying	0954	0.49	Falling	20.0	60	ENE	77.5	25.3
26 May 2007	1000	Returning to Sea	1000	0.40	Rising	15.0	108	ESE	78.6	25.9
1 May 2008	1145	Digging	1142	0.32	Rising	18.7	145	SE	73.5	23.1
13 May 2008	1400	Digging	1400	0.37	Falling	16.1	132	SE	76.1	24.5
20 May 2008	0540	Returning to Sea	0542	0.22	Rising	14.4	209	SSW	77.0	25.0
12 June 2008	0830	Digging	0830	0.20	Rising	15.9	155	SSE	83.3	28.5
27 June 2008	0802	Emerging	0800	0.27	Falling	17.3	177	S	84.7	29.3
2 May 2009	0850	Returning to Sea	0848	0.07	Rising	N/A[5]	N/A[5]	N/A[5]	N/A[5]	N/A[5]
18 May 2009	1630	Returning to Sea	1630	-0.03	Falling	N/A[5]	N/A[5]	N/A[5]	N/A[5]	N/A[5]
			Mean	**0.23**		**15.6**	**131.1**		**78.7**	**26.0**
			SD	0.16		3.7	52.4		3.6	2.0
			Range	-0.09 to 0.49		7.4 to 22.6	40 to 214		71.6 to 85.1	22.0 to 29.5

[1] Data provided by NOAA's Center for Operational Oceanographic Products and Services (CO-OPS) database.

[2] Mean sea level.

[3] Non-nesting emergence.

[4] Nesting phase was not documented by responders.

[5] Meteorelogical data were not available from Station #8771341 in 2009.

Nesting activity was equally distributed between rising and falling tidal cycles, although all four females documented at emergence did so during falling tides. However, 84.6% of nesting occurred during periods of increased tidal amplitude; MSL at time of observance averaged 0.23 m (range = -0.09 to 0.49 m). Nesting activity also showed no correlation with primary moon phase. Through 2008, UTC nest deposition dates were nearly equally distributed between spring (n=32) and neap (n=35) tides.

DISCUSSION

Despite debatable historical utilization, the UTC currently represents the northernmost nesting range regularly – and increasingly – exploited by Kemp's ridley turtles. During 2007, 2008, and 2009, ridley nests deposited on all UTC beaches accounted for 12, 8, and 8% of Texas' statewide total, respectively (Shaver 2008, 2009, 2010). Sea turtle nesting patrols sustained at varying degrees of effort on UTC beaches were instrumental in the documentation of a record 22 nests in 2011, including 15 on Galveston Island where ridley clutch deposition over the past decade exceeded that confirmed on the entire Texas coast during the 1990's (Shaver 2012). Notably, near annual increases in reproductive activity by this endangered species on the UTC since 2002, although comparatively small in number, are occurring in parallel with exponential nesting increases at both Rancho Nuevo and PAIS (NMFS, USFWS & SEMARNAT 2011; Shaver 2012).

Nesting Patrols

Patrol effort deployed to identify nesting on the beaches of Bolivar Peninsula, Galveston Island, and Follets Island was effective in detecting sea turtle reproductive activity. Most notably, survey implementation on Bolivar Peninsula in 2008 resulted in the confirmation of six ridley nests, a single year tally double the entire historical total for that location. Various additional positive impacts can be attributed to patrol initiation on all three northern UTC beaches, including but not limited to

i) the education of residents, beachgoers, and beach workers regarding nesting and their role in maintaining habitat suitability and reporting sea turtle sightings,

ii) the protection of nesting females and nest products,

iii) the documentation of nesting activity via tracks when females were not observed,

iv) the execution of associated research initiatives in support of the Kemp's Ridley Recovery Plan (NMFS, USFWS & SEMARNAT 2011; see Chapter IV), and

v) a heightened management focus for agencies governing local protected natural resources and anthropogenic beach uses via collection of standardized data regarding the UTC's role in Kemp's ridley population dynamics.

It is highly plausible that multiple UTC nests remained undetected each year. Factors confounding nest detection include the Kemp's ridleys propensity to nest on windy days conducive to the swift obliteration of their distinctly ephemeral tracks (Pritchard 1989), limited surveying manpower and extensive tracts of undeveloped beachfront on the UTC, and the fact that females are intercepted at less than half of documented nest sites (Shaver 2005b). Despite these impediments, quantitative data procured through standardized patrol efforts described herein serve as the first legitimate barometer of sea turtle nesting activity on beach habitats associated with Bolivar Peninsula, Galveston Island, and Follets Island. This scientific baseline, which serves to establish trends in UTC nester stock and reproductive behaviors enacted on associated UTC habitats, may provide resource managers with information necessary to facilitate the perpetuation of sea turtle nesting activity on constituent beaches through conservation initiatives to benefit nesters, nest products, and beach habitats.

Nester Parameters

The consistent occurrence of wild nesters successfully exploiting UTC nesting habitats corroborates the theory of nesting ground expansion and/or recolonization by this species, and diminishes concerns that reproductive behaviors on constituent beaches are simply an unexpected result of the Kemp's ridley headstart experiment. Although 74.1% of known UTC nesting activity through 2009 can be positively attributed to captive reared females, no significant differences in reproductive behavior or success were identifiable between either wild and headstarted UTC nesters, or between this nesting contingent and those at PAIS and Rancho Nuevo. Captive reared female size; maturation rate; temporal, seasonal, and environmentally-linked reproductive behaviors; and clutch deposition and emergence success rates all fall within normal limits identified for this species (Márquez 1994; NMFS, USFWS & SEMARNAT 2011; Shaver 2012).

However, the predominance of captive reared females within the UTC nesting contingent precipitates questions regarding the imprinting process in hatchlings and subsequent demonstration of nesting beach fidelity by mature females, as well as future expectations regarding sea turtle nesting in this region by both wild and headstarted turtles. Mexico-imprinted Kemp's ridleys from the 1989-1992 yearclasses headstarted at the NOAA STF on Galveston Island were first documented nesting at PAIS (n=1) and on the UTC (n=2) in 2002, coincident with the commencement of annual nesting by this species on UTC beaches (Shaver 2004, 2005b). Generally, turtles hatched and experimentally imprinted in Mexico but reared in Galveston are not lacking philopatric behavior (defined as tending to return to a particular site or area) but instead are demonstrating fidelity to either the UTC, Mustang Island, or PAIS (D. Shaver pers. comm.). It must also be noted that, through 2011, headstarted turtles imprinted to PAIS have never been documented nesting on the UTC despite being reared in Galveston; in contrast, their reproductive activity has been limited to either PAIS or Mexico's nesting beaches (A. Landry pers. comm., D. Shaver pers. comm.).

Through 2009, all wild and headstarted females documented on UTC beaches have remained reproductively faithful to this region (D. Shaver pers. comm.). Tenacity in natal homing (Carr 1975) is best demonstrated by RRV315 (Missy), a biennial nester documented depositing clutches on Galveston Island's West Beach Zone in 2006, 2008, and 2010 (Shaver 2007, 2009; A. Landry pers. comm.). Despite this, extrapolation to aid future management of UTC nesting habitats is confounded by current protocol requiring prompt removal of all reproductive products to the PAIS hatchery, where incubation temperatures are elevated to produce predominantly female hatchlings (Shaver 2010). Following reproductive maturity, will females produced from UTC clutches incubated and released at PAIS display nest site fidelity to UTC beaches, or to those at PAIS? The potential ramifications of the current relocation protocol include the stagnation and/or eventual collapse of the UTC nesting cohort, particularly following the natural demise of the current nesting generation. The prospective loss of recently established UTC nesting beaches at the northernmost extent of the Kemp's ridleys comparatively limited nesting range precludes the realization of numerous latent benefits to multifarious stakeholders (see Chapter VI) and bodes poorly for the expeditious recovery of this endangered sea turtle.

Clutch Parameters

The overall 91.8% emergence success rate attained by the four *in situ* nests incubated sans anthropogenic management on UTC beaches highlights the appropriateness of existing substrates on constituent habitats to support sea turtle reproductive products.

Current concerns surrounding anthropogenically-induced habitat destruction, climate change, and female-biased sex ratios on many sea turtle nesting beaches (Fuentes et al. 2011, Caillouet 2012) could potentially be moderated for Kemp's ridleys with the natural utilization of northern nesting grounds that may permit this species increased protection against certain negative human impacts and production of a relatively greater proportion of male offspring.

Identification and characterization of male-producing nesting beaches is recommended by Mrosovsky & Godfrey (2010) to counteract climate change and its potential "massive feminizing bias" (Mrosovsky 1984) for sea turtle populations. Current latitudinal temperature gradients indicate that the northern beaches of PAIS provide cooler incubation environments than do those at Rancho Nuevo (NMFS, USFWS & SEMARNAT 2011); thus, UTC nesting beaches located north of PAIS may be cooler still. Research to quantify various incubation parameters on the UTC, particularly temperature and the resultant sex ratios of clutches incubated *in situ*, is recommended to confirm this region's potential as male-producing Kemp's ridley nesting habitat.

Environmental Correlates of Nesting

Kemp's ridley nesting on UTC beaches appears strongly correlated with both increased tidal amplitude and vigorous onshore winds from the southeast. Robust winds have long been considered a stimulant for nesting by this species (Márquez 1990, Jiménez-Quiroz et al. 2005), although Pritchard & Márquez (1973) noted nesting at Rancho Nuevo corresponded to strong longshore winds from the north. These environmental conditions, and their resultant synergistic effect, may efficiently obscure tracks, facilitate behavioral thermoregulation, and reduce both energy expenditure and exposure to predators for females in terrestrial habitats (Pritchard & Márquez 1973, Spotila & Standora 1985).

Although nesting by other sea turtle species has been closely associated with tidal and/or lunar cycles (Plotkin 1994, Girondot & Fretey 1996, Lamont & Carthy 2007, Pike 2008), this relationship was not evident for ridleys utilizing UTC habitats. Various factors may be inhibiting the visualization of a relationship between UTC ridley nesting activity and these meteorological parameters, including the small sample size of the current study (n=26) and microclimatic differences between UTC nesting beaches not reflected in data sourced from a single data station offshore Galveston Island. In addition, the simplicity of the stated method precluded a review of the cyclic nature or interrelationship of these environmental parameters, although Jiménez-Quiroz et al. (2005) stated "…it is probable that the periodicity of the variables is more important than their value" for Kemp's ridleys nesting at Rancho Nuevo. However, observed correlations may be useful predictors of nesting activity for surveying purposes.

Management Recommendations

UTC beaches characterized by heavy public use and development require management strategies markedly different from those currently utilized on other ridley nesting beaches, including Rancho Nuevo and PAIS, that benefit from government-mandated protection restricting public access and development. However, the UTC's level of urbanization should not preclude the incorporation of this area into management schemes designed to recover the endangered Kemp's ridley sea turtle. One needs only to examine the dense sea turtle nesting colonies utilizing the beaches of Florida, USA, to determine that successful implementation of beach habitat management policies meeting the needs of human-user groups while minimizing negative impacts to sea turtles is possible. Conservation efforts for the endangered Kemp's ridley, particularly nest protection efforts, should encompass the entire Texas coast (Putman et al. 2010).

The UTC can only realize its potential as a natal beach if current sea turtle nest management protocol is modified to permit local nest incubation and hatchling release. The 15 nests laid on Galveston Island in 2011 are comparable to the 14 nests documented at PAIS in 2003 (Shaver 2005a, 2012). However, UTC nesting likely cannot be sustained if all associated clutches continue to be transferred to PAIS. Excavated clutches undergo two separate vehicular transports to reach PAIS during the critical 6-48 hour post-oviposition timeframe identified by Márquez (1994) as most susceptible to developmental deficiencies and mortality rates reaching 100% due to handling. Repeated manual manipulation of clutches for transport can result in egg inclination, embryo rotation, vibrations, contamination and/or overheating, all of which may negatively impact clutch hatching success. While hatching success rates obtained from Bolivar Peninsula nests subjected to cumulative vehicle transport times typically exceeding 6 hours have been comparable to those from nests deposited and incubated at PAIS

(Shaver 2009), this method involves substantial risk to developing embryos and may be a factor in poor hatch success rates obtained during 2005 and 2006 (Seney 2008). Although additional research beyond that provided in Chapter III is needed regarding incubation conditions on the UTC (an informational void currently exists regarding thermal regime, hydric environment, sand mineral content, gas exchange, etc. on constituent beaches), the 91.8% mean emergence success reported for all four *in situ* clutches suggests that UTC beaches can support sea turtle nest products. Viable options exist for clutches laid in constituent habitats; these alternatives deserve periodic re-evaluation to confirm current management protocol prioritizes species recovery over historical convention.

A nest management strategy whereby nests laid above the high tide line remain *in situ* to incubate and hatch with minimal human interference would significantly reduce relocation efforts. While this strategy is successfully utilized in Florida, where annual nest deposition numbers in the tens of thousands, it is an impractical solution for areas such as the UTC where public education related to sea turtles is lacking and low density nesting by the critically endangered Kemp's ridley warrants protection of every nest. The well-executed relocation of nests and timely monitored release of emerged hatchlings pose significantly fewer threats to nest products than do natural predators and environmental variables (Márquez 1994). When considered in conjunction with existing UTC hazards such as vehicular beach traffic, beach nourishment and grooming activities, compromised dune environments, high levels of beach refuse, and coastal development of homes and associated structures, nest relocation to either PAIS or an upper Texas coast hatchery currently appears necessary to maximize hatchling production and the continued recovery of the Kemp's ridley.

Currently, monitored corrals (hatcheries) secure from predation and poaching are successfully utilized at PAIS (Shaver 2010), on South Padre Island, and at Rancho Nuevo (Gladys Porter Zoo 2005, C. Hughes pers. obs.). Implementation of a corral on Galveston Island for UTC nest products is an alternative that would significantly reduce the risk of embryonic mortality associated with egg handling by permitting expeditious clutch relocation soon after deposition (Eckert et al. 1999). The protected beaches and vegetated dunes of Galveston Island State Park provide one such viable option, as a hatchery ensconced on this comparatively natural beach would be monitored and secured against anthropogenic intrusion by the on-site enforcement entity, the Texas Parks and Wildlife Department. Constraints to implementation do exist (Eckert et al. 1999 details caveats) but likely would not prohibit successful execution of this method. Beneficially, releasing hatchlings imprinted to natal UTC beaches would preclude the loss of an associated nesting cohort and would likely contribute to long-term nesting increases, thus creating exploitable ecotourism and public education opportunities with future expansion potential.

Future Inquiries & Concluding Remarks

Associated impacts of severe flooding and coastal erosion wrought by Hurricane Ike (Doran et al. 2009) on sea turtle nesting density along the northernmost beaches of Bolivar Peninsula, Galveston Island, and Follets Island appear confined to a single year post-storm. Despite the unprecedented predominance of ridley nests on southern UTC habitats between Quintana Beach and Matagorda Peninsula in 2009 following Hurricane Ike, more than 83% of UTC nests were located on Bolivar Peninsula, Galveston Island, and Follets Island in both 2010 and 2011 with no significant alterations in patrol effort at any locale (Shaver 2010, 2011, 2012). This displacement in nesting beach utilization without a reduction in nesting frequency is similar to that noted at Rancho Nuevo following the passage of Hurricane Gilbert in 1988 (Agardy 1990). Is this shift, and its subsequent reversal, indicative of the Kemp's ridleys' ability to prioritize the appropriateness of reproductive habitat over inherent site fidelity and respond via migration to locate suitable shoreline?

Investigative research is recommended to determine the adaptability of nesting Kemp's ridleys to significant natural and anthropogenic alterations of vulnerable beach ecosystems, a valid concern considering geographic nesting range restrictions (Pritchard & Marquez 1973); the likelihood of catastrophic beach degradation associated with hurricanes, the extraction of oil and gas minerals at PAIS (NMFS, USFWS & SEMARNAT 2011) and Gulf of Mexico oil spills like the Ixtoc 1 and Deepwater Horizon; as well as sea level rise correspondent with global warming (Intergovernmental

Panel on Climate Change 2007). Natural expansion of the endangered Kemp’s ridley sea turtle’s severely restricted nesting range, such as is occurring on the UTC, should be promoted by local, state, and federal resource managers not only to mitigate potentially catastrophic localized degradation of nesting habitats but also to promote recovery of this endangered species.

CHAPTER III

AN ASSESSMENT OF GALVESTON ISLAND AND BOLIVAR PENINSULA BEACH HABITATS PRIOR TO HURRICANE IKE: IMPLICATIONS FOR CONSERVATION

INTRODUCTION

Annual nesting on the upper Texas coast (UTC; herein defined as beaches from Sabine Pass to Matagorda Peninsula) by the Critically Endangered Kemp's ridley sea turtle (*Lepidochelys kempii*; IUCN 2011) since 2002 has coincided with recent exponential increases in the reproductively viable segment of the population (Márquez et al. 2005, Shaver 2005b, Seney & Landry 2008). Record nesting activity by the Kemp's ridley has occurred nearly annually since 2004 on both the UTC and the entire Texas coast, with this trend mirroring recent annual increases in the number of nests deposited on the ridley's primary nesting beach at Rancho Nuevo, Tamaulipas, Mexico (NMFS, USFWS & SEMARNAT 2011). Except for 2 loggerhead turtle (*Caretta caretta*) nests deposited on Bolivar Peninsula (1 apiece in 1996 and 2008), all other 59 sea turtle nests historically documented on the UTC prior to Hurricane Ike's landfall 13 September 2008 were laid by Kemp's ridleys.

Continued recovery of the Kemp's ridley population will further augment sea turtle nesting activity on UTC beaches such as those along Galveston Island and Bolivar Peninsula. Increased likelihood for interaction between this growing assemblage of nesters and rapid development of the UTC mandates implementation of management policies meeting the needs of human-user groups while reducing impacts to nesting sea turtles. Open access UTC beaches characterized by heavy public use and development require management strategies that differ markedly from those currently utilized on ridley nesting beaches at Rancho Nuevo and Padre Island National Seashore (PAIS), Texas, that benefit from government-mandated protection limiting public access and development. Information provided herein is intended to serve as guidance for local, state, and federal agencies responsible for addressing the unique sea turtle nesting habitat management challenges that exist on the UTC.

Highly dynamic nesting beach environments, such as those along the UTC, continually erode and accrete in response to wind, waves, currents, storms, and alterations in sea level (Lebuff & Haverfield 1992, Peterson & Bishop 2005). Although sea turtles often exhibit strong nest site fidelity to natal beaches (Meylan et al. 1990, Bjorndal 1995, Shaver 2005b), a multitude of environmental factors may significantly impact the attractiveness of a specific beach to nesters (Santos et al. 2006) and the “seafinding” ability of hatchlings emerging from nests (Salmon et al. 1995, Bertolotti & Salmon 2005). While coverage of all relevant environmental factors and human activities influencing nesting habitat on UTC beaches is beyond the scope of this chapter, those identified as critically important (vegetation coverage, beach slope and width, beach nourishment, artificial lighting) are summarized below.

Vegetation Coverage

The Texas Open Beaches Act § 61.011, by utilizing the existing vegetation line to differentiate between public beach and private property bordering the Texas Gulf coast, underscores the critical importance of dune plant communities in policy making and beach habitat management. UTC species, including sea oats (*Uniola paniculata*), bitter panicum (*Panicum amarum*), seashore dropseed (*Sporobolus virginicus*), and marsh-hay cordgrass (*Spartina patens*), are essential components of healthy dunes that function as plant successional communities to build dunes, bind sediments, and reduce erosion (Márquez 1994, Feagin et al. 2005). However, engineering solutions to coastal erosion (including seawalls and geotextile tubes), beachfront development, and non-native lawn vegetation have created landward barriers to inland dune migration, thereby confining dune plant communities to shrinking zones where characteristic successional patterns are disrupted (Feagin et al. 2005). Failure of embryonic dunes to form Gulf-ward of human-erected barriers disrupts natural seed dispersal mechanisms and isolates plant communities, with both impacts resulting in the loss of critical late-successional vegetation. It is this loss in vegetative cover that escalates beach erosion rates (Feagin et al. 2005).

Vegetative cover is a critical component in sea turtle nest site selection and nesting success. Hawksbill turtle (*Eretmochelys imbricata*) nesting behavior is influenced by vegetative cover, with females displaying a significant preference for vegetated over non-vegetated sites (Horrocks & Scott 1991) and predisposed to nesting along the beach perimeter adjacent to the vegetation line (Santos et al. 2006). Lower sediment compaction rates associated with vegetative cover and the ability of constituent rootlets to loosen substrate positively influence hawksbill nesting success, given the fact that hatchling emergence success is inversely correlated with compaction rate (Horrocks & Scott 1991). This correlation may be a function of increased probability of hatchling suffocation and exhaustion associated with emergence attempts from nests deposited in more compacted substrates (Horrocks & Scott 1991). The vegetation line is also a crucial component in green turtle (*Chelonia mydas*) nest site selection and subsequent reproductive success (Chen et al. 2007). Dune plant communities may function as nest placement indicators to females, as vegetated beaches minimize the risk of nest inundation and provide substrates with compaction values conducive to digging while maintaining nest cavity integrity without collapse (Chen et al. 2007). While insufficient data exist to support a positive correlation between dune vegetation and Kemp's ridley nesting success, Márquez (1994) notes dune stabilization at Rancho Nuevo by an abundance of sea grasses and other coastal plants, as well as preferential nesting by female conspecifics adjacent to or on the foredune.

Conversely, reproductive success may be lower for nests deposited in heavily vegetated areas. Chen et al. (2007) noted that females were deterred from excavating nests in locations where vegetation coverage exceeded 40%, as dense root systems reduced ease of digging. Embryonic mortality can be increased by root mats encompassing or perforating incubating eggs deposited in profusely vegetated areas (Whitmore & Dutton

1985). Hatchlings emerging in dense vegetation are denied visual orientation cues for seafinding, resulting in disorientation (hatchlings crawling in circuitous paths) or misorientation (hatchlings crawling toward light source), particularly on moonless nights (Godfrey & Barreto 1995). Thick dune plant communities can function to slow forward momentum and may entangle or entrap hatchlings, thus increasing predation and desiccation risks (Godfrey & Barreto 1995). Despite these findings, maintenance and enhancement of dune plant communities are essential to maximize overall sea turtle reproductive success. Females require visual cues from, but typically avoid nesting in, heavily vegetated areas while dune plant communities provide hatchlings emerging from nests deposited lower on the beach with critical visual seafinding cues (Bourgeois et al. 2009).

Beach Width & Slope

Alterations in beach width and slope can arise from multiple anthropogenic activities, including shoreline development, beach nourishment, vehicular traffic (Santos et al. 2006, Fish et al. 2008), and installation of erosion control structures (Lebuff & Haverfield 1992, Feagin et al. 2005). Female nest site selection and subsequent reproductive success are partially determined by the inverse correlation between beach width and slope that, in conjunction with tidal amplitude, regulate the potential for inundation-related embryonic mortality and hatchling survival on land (Whitmore & Dutton 1985, Márquez 1994, Garmestani et al. 2000). Nests laid below the high tide line typically experience lower hatching and emergence rates or complete embryonic mortality, as increased salinity associated with seawater wash over of nests can disrupt egg metabolic processes and/or asphyxiate developing embryos (Whitmore & Dutton 1985). Inadequately sloped beaches increase the crawl distance necessary for females to access elevated sites less vulnerable to tidal inundation (Horrocks & Scott 1991, Santos et al. 2006) and the susceptibility of incubating nests to flooding (Márquez 1994). Hatchlings emerging from nests located high on overly wide beaches of reduced slope expend more energy to reach the sea, thus increasing exposure time to land-based predators (Horrocks & Scott 1991, Márquez 1994, Mrosovsky 2006). Narrow eroded or steeply sloped beaches may visually deter nesters and decrease overall nesting frequency (Garmestani et al. 2000, Montague 2008); such is the case for females required to expend increased energy to reach preferred nesting sites on beaches with significant inclines (Santos et al. 2006). Nests deposited on narrow beaches whose width is constrained by development are exposed to negative impacts associated with infrastructure as well as increased risk of nest overlap and seawater saturation (Fish et al. 2008).

Although beach profile preference varies among sea turtle species (Mrosovsky 2006) and remains undetermined for Kemp's ridleys, the moderate profile characteristics of Rancho Nuevo's beach may be considered ideal for ridley females, nests, and nest products. Nests incubating on beaches of moderate slope may benefit from improved substrate drainage and proper humidity levels (Márquez 1994). Moderately sloped beaches that provide a multitude of nest placement options at varying distances above the high tide line are advantageous to nesting success as spatially-distributed nests tend to mitigate negative impacts associated with dynamic beach environments affected by stochastic events (Mrosovsky 2006). In certain years, substantial land-based predator pressure may select for nests laid close to the surf, while nests located high on the beach may produce more hatchlings during seasons with unusually strong storms. Robust estimates of preferred nest locations along the horizontal beach gradient from forebeach to second foredune do not exist for Kemp's ridleys nesting on the UTC. Although ridley nests in Texas have been laid at all positions along the horizontal beach slope, nearly all nests incubated *in situ* and documented at hatching through 2008 have been located high on the beach protected from tides (Shaver 2008, 2009), indicating that sufficiently wide beaches free of tidal inundation are crucial for ridley nesting success in Texas.

Beach Nourishment

Addition of fill material to elevate and extend beaches seaward in developed coastal zones prone to erosion and flooding is a common non-permanent engineering solution (Lebuff & Haverfield 1992, Crain et al. 1995) employed to stabilize shorelines (Peterson & Bishop 2005), protect property, and increase available recreational area (Rumbold et al. 2001). While beach nourishment significantly reduces altered sediment transport and downdrift erosion associated with hardened structures like seawalls and groins (Lebuff & Haverfield 1992, Feagin et al. 2005), it is not ecologically benign (Peterson & Bishop 2005, Montague 2008). Ecological impacts of beach nourishment remain uncertain despite four decades of agency-mandated monitoring (Peterson & Bishop 2005, Montague 2008). Monitoring studies typically lack standardization and scientific rigor, while research conclusions are flawed by inadequate evidence, data analysis or misinterpretation (Peterson & Bishop 2005). Nonetheless, available data indicate sediments obtained from offsite sources, including ship channels and offshore borrow pits, may adversely affect sea turtle nesting success. Such sediments may alter a beach's slope; sand density, color, mineral content, and grain size; shear resistance; and moisture content (Nelson & Dickerson 1988, Benedet et al. 2004, Chen et al. 2007) due to compositional differences in the proportion of carbonate sand, quartz sand, shell, coral, clay, and/or silt (Crain et al. 1995).

Benefits inherent in augmenting available nesting habitat through renourishment efforts (Lebuff & Haverfield 1992, Crain et al. 1995, Montague 2008) may be offset by degradation and disturbance of beach and nearshore environments (Peterson & Bishop 2005), alteration of beach profiles (Brock et al. 2008) and constituent substrates' natural physical and chemical properties, and formation of beaches unsuitable for nesting females and/or clutch incubation (Crain et al. 1995). Effects of physical and chemical substrate permutations on a nester's short- and long-term nest site fidelity are poorly understood (Crain et al. 1995). Related research has documented substantial increases in the frequency of non-nesting emergences correlated with significant reductions in reproductive output from both loggerhead (Rumbold et al. 2001) and green sea turtles (Brock et al. 2008), particularly during the first season post-nourishment. Nourishment-induced changes in female nest site selection and digging behavior may deleteriously affect offspring survival and future reproductive contribution as nest success is, to a certain extent, dependent upon nest cavity configuration and the hydric and thermal environment of the substrate (Crain et al. 1995). Inappropriate incubation temperatures caused by alterations in sand color can negatively affect embryo development, and variations in substrate water potential can limit diffusion of water, nutrients or oxygen across the semi-permeable eggshell (Crain et al. 1995). In addition, sand compaction resulting from nourishment activities or alterations in substrate shear resistance can physically impede or prevent female nest excavation or hatchling emergence (Márquez 1994, Crain et al. 1995, Chen et al. 2007), thus diminishing reproductive success.

Artificial Lighting

Nocturnal illumination of nesting beaches by artificial lighting associated with beachfront development negatively impacts sea turtle nesting habitat (Santos et al. 2006) and reproductive success. Nocturnal nesting activity is depressed on artificially illuminated beaches (Salmon et al. 1995, Bertolotti & Salmon 2005); unnatural lighting can disrupt nest site selection, increase non-nesting emergence ratios, and disorient females (Santos et al. 2006). Nocturnally emerging hatchlings, while able to locate and enter the sea within minutes on dark beaches, often perish due to dehydration, exhaustion or predation as misorientation or disorientation caused by artificial lighting results in seafinding failure (Horrocks & Scott 1991, Bertolotti & Salmon 2005, Tuxbury & Salmon 2005).

Hatchling seafinding behavior is primarily controlled by two visual cues: contrast in luminosity between landward and seaward horizons, and dissimilarity in landward and seaward horizon elevation (Salmon et al. 1995, Bertolotti & Salmon 2005, Tuxbury & Salmon 2005). Vegetated dunes on natural beaches absorb light, aiding hatchlings in orienting toward the naturally brighter reflective ocean surface. Potentially more influential than light intensity cues is orientation of hatchlings toward the lower seaward horizon and away from elevated solid silhouettes, such as those created by dunes or stands of trees. Background illumination, naturally occurring with a full moon, aids hatchlings in differentiating between seaward and landward horizons and enables accurate seafinding regardless of light pollution when adequate horizon cues exist (Bertolotti & Salmon 2005, Tuxbury & Salmon 2005). Hatchlings exposed to discrete light sources typically misorient; disorientation occurs when the landward silhouette is low and/or irregular, as when dunes are impaired or absent or with the occurrence of spaced structures on developed beaches (Salmon et al. 1995).

Research Objectives

Recent increased use of Galveston Island and Bolivar Peninsula beaches by nesting sea turtles accentuates the need for current data detailing impacts of the aforementioned environmental variables and anthropogenic beach activities on nesting habitat quality for management purposes. To this end, the following research objectives were identified:

1. To characterize Galveston Island beaches with regard to sea turtle nesting potential.

2. To characterize Bolivar Peninsula beaches with regard to sea turtle nesting potential.

METHODS

Beach Surveys

Data detailing specific attributes of all Galveston Island beaches patrolled for nesting sea turtles from 2007-2009 (see Chapter II) were collected during three separate surveys in February and March 2008. Beaches from San Luis Pass to 8 Mile Road (herein West End Zone) were surveyed via ATV on 13 February, beaches from 61st Street to 12th Street (herein Seawall Zone) were surveyed on foot 17 February, and beaches from 12th Street to the South Jetty on East Beach (herein East End Zone) were surveyed on foot on 9 March. Bolivar Peninsula beaches patrolled for nesting sea turtles from 2008-2009 (see Chapter II) were comprehensively surveyed via ATV 21 July 2008.

Parameters justifying inspection were chosen on the basis of an extensive literature review of environmental and anthropogenic variables known to impact sea turtle nest site selection and nesting success, and are similar to those quantified by Santos et al. (2006). Visual observations were made regarding beach width and slope; dune height, width, and vegetation coverage; nourishment activity; obstacles to nesting, nest success, and/or hatchling emergence; pedestrian and vehicular traffic; and commercial and residential development. This classification method of visual assessment and categorical qualification of pertinent beach parameters is similar to that employed by de Araujo and da Costa (2008).

Data Compilation & Mapping

Galveston Island and Bolivar Peninsula beaches were partitioned into variable-length sections based upon the occurrence of homogenous characteristics recorded during the aforementioned beach surveys. Relevant locations (section start and end points, vehicle access points, obstacles, etc.) were marked with a Garmin GPS 72, converted to decimal degrees (WGS 84) format, and mapped with Google Earth 5.0. Sections were then categorically qualified as follows:

> **good**, if there were no strong deterrents to nesting;
> **fair**, if a balance of negative and positive habitat characteristics was identified; and
> **poor**, if negative aspects of the habitat were perceived to exert an overriding influence on sea turtle nesting habitat quality.

To avoid bias in habitat quality determinations, all documented historical nesting locations through the 2007 (Galveston Island: n=28) or 2008 (Bolivar Peninsula: n=11) sea turtle nesting seasons, obtained from GPS data or verbiage recorded on the "Texas Data Sheet For Sea Turtle Tracks and Nests" developed by Dr. Donna Shaver (Chief, Division of Sea Turtle Science and Recovery, Padre Island National Seashore, Corpus Christi, Texas), were converted and plotted only after associated beach sections had been formally characterized as either good, fair, or poor. Additionally, data regarding two and three documented non-nesting emergences on Galveston Island and Bolivar Peninsula, respectively, were obtained from the same source and plotted on habitat quality maps for comparison purposes.

RESULTS

Galveston Island

Quality of Sea Turtle Nesting Habitat

West End Zone: Twenty-three distinct sections, ranging in quality from poor to good, were identified along the 28.29-km West End Zone (WEZ) of Galveston Island (Fig. 3.1, Table 3.1). The WEZ was characterized by relatively natural beach habitat situated within a shrinking corridor between the seaward barrier of coastal erosion and a landward barrier of extensive residential development. While the location of the majority of these residential structures behind natural dune habitat presented no clear impediment to nesters, artificial lighting sourced from homes posed a threat to nocturnally emerging hatchlings. Vehicular traffic, including golf carts and all-terrain vehicles, was not allowed on the majority of this segment. However, numerous on- or off-beach vehicle parking areas existed and constituent beaches were heavily utilized by the public, particularly adjacent to beach access points (n=42). Nourishment was a commonly utilized remedy to erosion in this area, although no nourishment projects were apparent or in progress when this zone was surveyed. Overall, moderately wide beaches with well-vegetated, low to moderately high dunes were typical of the WEZ.

Figure 3.1. Delineation of sea turtle nesting habitat quality within the West End Zone of Galveston Island, Texas, per February 2008 survey. Balloon locations delineate section boundaries, while color correlates with quality of nesting habitat immediately to the northeast.

Table 3.1. Sea turtle nesting habitat quality assessment for the West End Zone of Galveston Island, Texas. Associated beaches were surveyed February 2008.

		Section Start		Section End		
Section	**Length (km)**	**Latitude**	**Longitude**	**Latitude**	**Longitude**	**Salient Habitat Characteristics**
🟨 **W1**	1.31	29.08397	95.11488	29.09103	95.10525	- Vegetated dunes removed ~200 m from high tide line on overly wide beach. - Increased vehicular traffic intensifies risk of sand compaction and injury to turtles and nests.
🟩 **W2**	4.02	29.09103	95.10525	29.11635	95.07618	+ Wide beach with low, well-vegetated dunes. + Houses, when present, situated well behind beach.
🟩 **W3**	1.33	29.11635	95.07618	29.12393	95.06560	+ Wide beach with low, well-vegetated dunes. + Houses immediately behind dunes do not present obstacle to nesting. - Sand fences (parallel to water) block nester access to habitat behind base of foredunes along majority of beach.
🟨 **W4**	0.52	29.12393	95.06560	29.12653	95.06120	+ Moderately wide beach with low, well-vegetated dunes. + Houses immediately behind dunes do not present obstacle to nesting. - Three dune crossovers with unusually wide bases extend onto beach, are impediment to nesters and hatchlings.
🟥 **W5**	0.36	29.12653	95.06120	29.12888	95.05855	- Narrow beach may result in tidal inundation of nests. - Beach lacks natural dunes and vegetation, contains piles of raked sargassum. - Houses located directly on beach present major obstacle to nesters.
🟩 **W6**	0.82	29.12888	95.05855	29.13290	95.05152	+ Moderately wide beach characterized primarily by low, well-vegetated dunes (dunes absent occasionally). +/- Houses primarily located directly behind foredunes. Several situated directly on beach. - Sand fences (parallel to water) block nester access to habitat behind base of foredunes along some sections of beach.
🟥 **W7**	0.14	29.13290	95.05152	29.13368	95.05022	- Dunes and vegetation absent. - Six houses situated directly on beach near water. - Sand fences block nester access to dunes behind and between houses.
🟩 **W8**	1.43	29.13368	95.05022	29.14117	95.03833	+ Moderately wide beach with low, well-vegetated dunes. + Houses located behind foredunes. +/- Sand accreting in front of fences (parallel to beach) which block nester access to habitat behind base of foredunes. - One large poorly sited fence (29.13967, -95.04065) presents obstacle to nesters.
🟥 **W9**	0.63	29.14117	95.03833	29.14452	95.03315	+/- Minimal presence of low vegetated dunes between houses. - Majority of houses located directly on beach.
🟩 **W10**	5.31	29.14452	95.03315	29.17178	94.98825	+ Long stretch of moderately wide beach with low, well-vegetated dunes increasing in height to east. + Houses, when present, situated well behind beach. + Sand fences, when present, located in dunes and overgrown by vegetation, present minimal obstacle to nesters.
🟥 **W11**	0.34	29.17178	94.98825	29.17355	94.98537	- Houses located on beach or immediately behind foredunes. - Cut wood pilings (~15 cm high) run parallel to beach for ~50 m, present major obstacle to nester and hatchling movement. - Poorly sited sand fence blocks nester access to dunes along majority of section, no sand accretion in front.
🟩 **W12**	0.87	29.17355	94.98537	29.17800	94.97800	+ Moderately wide beach with low, well-vegetated dunes. + Houses, when present, set well behind dunes.
🟥 **W13**	0.16	29.17800	94.97800	29.17862	94.97682	- No dunes or vegetation present. - Four houses situated directly on beach. - Cut wood pilings (~10 cm high) run parallel to beach for ~10 m, present major obstacle to nester and hatchling movement.

HABITAT QUALITY KEY		
🟩 GOOD	🟨 FAIR	🟥 POOR

Table 3.1. Cont.

	Length	Section Start		Section End		
Section	(km)	Latitude	Longitude	Latitude	Longitude	Salient Habitat Characteristics
🟩 W14	0.85	29.17862	94.97682	29.18298	94.96955	+ Moderately wide beach contains larger, well-vegetated dunes. + Houses, when present, set well behind dunes.
🟩 W15	2.42	29.18298	94.96955	29.19525	94.94895	+ Moderately wide beach contains larger, well-vegetated dunes. +/- Minimal sand accretion in front of sand fences (parallel to beach) which block nester access to dune nesting habitat. + Lack of vehicular traffic reduces risk of sand compaction and injury to turtles and nests.
🟨 W16	0.89	29.19525	94.94895	29.19970	94.94111	- Narrow beach may result in tidal inundation of nests. + Well-vegetated dunes of moderate height present. + Houses, when present, set well behind dunes.
🟥 W17	1.57	29.19970	94.94111	29.20767	94.92785	- Excessively narrow beach lacks dunes and vegetation. - Geotube exposed at >3 locations due to tidal action; slope of geotube is prohibitive to nesters. - Multiple houses located directly behind geotube close to waterline. - This is one of the poorest sections on the island for sea turtle nesting.
🟩 W18	0.92	29.20767	94.92785	29.21233	94.91990	+ Moderately wide beach with low, well-vegetated dunes. + Primarily undeveloped stretch of beach. Houses, when present, located well behind beach.
🟥 W19	1.32	29.21233	94.91990	29.21888	94.90880	- Narrow beach primarily lacking dunes and vegetation. - Houses located on beach present entrapment hazard; nesters and hatchlings able to access space directly under structures. - Multiple locations of cut wood pilings (~5-15 cm high) present major obstacle to nester and hatchling movement.
🟩 W20	0.72	29.21888	94.90880	29.22270	94.90262	+ Moderately wide beach with low, well-vegetated dunes. + Houses, when present, located well behind dunes. - Poor nesting habitat exists in front of geotube located on extremely narrow terminal end of section.
🟨 W21	0.96	29.22270	94.90262	29.22768	94.89452	- Geotube slope prohibitive to nesters regardless of moderate sand accretion and vegetation present. - Two dune crossovers (29.22532, -94.89815) with expansive bases present obstacle to nester and hatchling movement.
🟨 W22	0.72	29.22768	94.89452	29.23135	94.88850	+ Moderately wide beach contains larger, well-vegetated dunes. - Sand fences (diagonal to water, spaced ~2 m apart) present obstacle to movement, limit nester access to dune habitat.
🟩 W23	0.68	29.23135	94.88850	29.23462	94.88323	+ Moderately wide beach with low, well-vegetated dunes. + No development. (One exception - horse rental business located at terminal end of section.) - Tall branching shrub vegetation severely limits turtle movement in dunes on ~120 m stretch just prior to section terminus.
TOTAL	**28.29**					

HABITAT QUALITY KEY		
🟩 **GOOD**	🟨 **FAIR**	🟥 **POOR**

Seven relatively short sections (W5, W7, W9, W11, W13, W17, W19) comprising 16.0% of the WEZ were rated as poor habitat; houses were situated directly on beach habitat near the waterline on all sections except W17 (Fig. 3.1, Tables 3.1 & 3.2). These sections suffered from reduced or an absence of nesting habitat, particularly in front of residential structures where a lack of dunes and vegetation may have lead to visual disorientation of nesters and increased risk of nest flooding. Additionally, section W17, which utilized a geotube to protect homes located immediately behind it from beach erosion, was rated as one of the poorest sections in terms of nesting habitat on Galveston Island (Table 3.1). Multiple locations within section W17 were subject to erosive wave action that exposed bare surfaces of the geotube and rendered it submerged during high tide, thus eliminating beach nesting habitat.

Five sections (W1, W4, W16, W21, W22) representing 15.5% of the WEZ were rated as fair nesting habitat (Fig. 3.1, Tables 3.1 & 3.2). Dunes within section W1 were located several hundred meters from the waterline and, at such a great distance, may have lead to visual disorientation of nesters (Table 3.1). In addition, high vehicular traffic at this popular fishing destination compacted substrate and was likely a visual deterrent to nesting, as well as a potential source of mortality to nesters and hatchlings. Obstacles to nesting or constituting a danger to sea turtles caused three short sections of otherwise good habitat (W4, W21, W22) to be classified as fair (Table 3.1). Section W4 contained three dune crossovers with excessively wide bases constructed in a way that presented an entrapment hazard to nesters and emerging hatchlings; W21 contained two dune

Table 3.2. Correlation between sea turtle nesting activity documented through 2007 and beach habitat quality within Galveston Island's West End Zone.

Section Quality	% of Zone	Total Length (km)	No. of Nests	Nests/km
Good	68.5	19.37	17	0.88
Fair	15.5	4.40	1	0.23
Poor	16.0	4.52	4	0.88
Zone Total	**100.0**	**28.29**	**22**	**0.78**

crossovers whose expansive bases blocked nester movement toward dune habitat; and W22 contained sand fences with minimal to no sand accretion placed at an angle to the waterline, which may have entrapped or disoriented hatchlings and nesting females. Finally, section W16's narrow beach increased the potential for tidal inundation of nests and, thus, was considered only fair habitat (Table 3.1).

Eleven sections constituting 68.5% of the WEZ were rated as good nesting habitat, including the two longest sections (W2 and W10; Fig. 3.1, Tables 3.1 & 3.2). Characteristics of sections classified as good typically included moderately wide beaches with low, well-vegetated dunes with structures, if present, located well behind the dunes. However, three of these sections (W3, W6, W8) contained sand fences parallel to the water's edge that effectively prevented females from accessing nesting habitat behind the base of the foredunes (Table 3.1). In addition, section W15 (Galveston Island State Park) contained sand fences placed diagonally at the base of the foredunes that not only limited nester access to dune habitat but also may have served to disorient or entrap nesters and hatchlings. However, these factors alone did not reduce quality ratings, as certain sections exhibited mitigating factors and historical data for the UTC through 2007 indicated the majority of nesters (80%) did not nest behind the base of the foredunes.

Seawall Zone: The presence of a prominent seawall that effectively eliminated nesting habitat at or behind the base of the foredunes combined with the lack of natural dunes and associated vegetation, routine beach raking, recent nourishment activity (sections S1, S3, S10, S17), and artificial lighting from commercial development, prevented any section (n=20) within the 5.97-km Seawall Zone (SWZ) from being classified as good nesting habitat (Fig. 3.2, Table 3.3). While dunes were absent, occasional mounds of raked *Sargassum* spp. pushed to the foot of the seawall formed minimally vegetated surrogates for natural dunes; all references to dunes along the seawall imply the presence of these raked *Sargassum* spp. piles. The SWZ was a popular tourist destination characterized by high pedestrian traffic and operation of multiple beach furniture rental companies; however, vehicular traffic, other than that associated with early morning delivery of beach furniture, was prohibited.

No beach nourishment activity was apparent on any of the 13 SWZ sections classified as poor, which comprised 49.6% of this zone (Fig. 3.2, Tables 3.3 & 3.4). Nesting habitat had been completely eliminated on four fully armored sections (S2, S4, S6, S19), and was negatively impacted on four partially armored sections (S7, S9, S13, S20; Table 3.3). Partially armored sections consisted of narrow (S7, S9) or moderately wide (S13, S20) beaches heavily interspersed with large granite boulders serving as riprap originally deployed to prevent erosion at the seawall base. This riprap may have visually deterred nesters and/or presented an obstacle to nester and hatchling movement. Four of the five remaining sections classified as poor (S5, S8, S11, S16) consisted of narrow beaches with increased risk of tidal inundation of nests; three of these (S5, S8, S16) were also extremely short in length. Dune-like mounds of scraped *Sargassum* spp. with

Figure 3.2. Delineation of sea turtle nesting habitat quality within the Seawall Zone of Galveston Island, Texas, per February 2008 survey. Balloon locations delineate section boundaries, while color correlates with quality of nesting habitat immediately to the northeast.

Table 3.3. Sea turtle nesting habitat quality assessment for the Seawall Zone of Galveston Island, Texas. Associated beaches were surveyed February 2008.

		Section Start		Section End		
Section	**Length (km)**	**Latitude**	**Longitude**	**Latitude**	**Longitude**	**Salient Habitat Characteristics**
S1	0.29	29.26635	94.82613	29.26773	94.82365	Nourishment: Yes. + Moderately wide beach. - No dunes or vegetation. - 61st St. fishing pier presents potential danger to turtles from increased pedestrian traffic, hook-and-line capture.
S2	0.29	29.26773	94.82365	29.26932	94.82125	- Armored beach: no nesting habitat available.
S3	0.60	29.26932	94.82125	29.27208	94.81603	Nourishment: Yes. + Moderately wide beach. - No dunes, vegetation limited to sparse grasses colonizing nourishment sand.
S4	0.35	29.27208	94.81603	29.27393	94.81310	- Armored beach: no nesting habitat available.
S5	0.08	29.27393	94.81310	29.27425	94.81242	Nourishment: No. - Narrow pocket of beach ~100 m long situated between armored sections, high likelihood nests inundated by tides. + Moderately vegetated dunes ~3 m wide at base of seawall.
S6	0.22	29.27425	94.81242	29.27557	94.81052	- Armored beach: no nesting habitat available.
S7	0.25	29.27557	94.81052	29.27675	94.80835	Nourishment: No. - Extremely narrow beach, nests likely inundated with water. - Sand interspersed with granite boulders presents major obstacle to nester and hatchling movement.
S8	0.13	29.27675	94.80835	29.27333	94.80722	Nourishment: No. - Narrow, short stretch of beach, nests likely inundated with water. - No dunes, few pockets of vegetation on scraped sargassum mounds.
S9	0.16	29.27733	94.80722	29.27820	94.80578	Nourishment: No. - Narrow, short stretch of beach, nests likely inundated with water. - Sand interspersed with granite boulders presents major obstacle to nester and hatchling movement.
S10	0.86	29.27820	94.80578	29.28273	94.79845	Nourishment: Yes. + Moderately wide, minimally sloped beach has increased potential for tidal inundation of nests. - No dunes, vegetation limited to sparse grasses colonizing nourishment sand. - Narrow beach at vehicle entry ramp (29.28118, -94.80100) presents obstacle to nester movement.
S11	0.43	29.28273	94.79845	29.28488	94.79473	Nourishment: No. - Narrow beach, nests likely inundated with water. + Moderately well-vegetated dunes at base of seawall. - Slope of scraped sargassum mounds prohibitive to nesters, irregularity of piles may disorient and trap hatchlings.
S12	0.35	29.28488	94.79473	29.28693	94.79205	Nourishment: No. + Moderately wide beach with vegetated dunes ranging extensively in width, most with prohibitive slopes.
S13	0.17	29.28693	94.79205	29.28780	94.79068	Nourishment: No. + Beach width moderate. - Sand interspersed with granite boulders presents major obstacle to nester and hatchling movement.

HABITAT QUALITY KEY		
GOOD	FAIR	POOR

Table 3.3. Cont.

Section	Length (km)	Section Start		Section End		Salient Habitat Characteristics
		Latitude	Longitude	Latitude	Longitude	
S14	0.07	29.28780	94.79068	29.28823	94.79005	Nourishment: No. - Short section below Flagship Hotel pier likely visual deterrent to nesters.
S15	0.23	29.28823	94.79005	29.28960	94.78833	Nourishment: No. +/- Moderately narrow, short stretch of beach with narrow, well-vegetated dunes.
S16	0.25	29.28960	94.78833	29.29103	94.78652	Nourishment: No. - Narrow, short stretch of beach, nests likely inundated with water. - Minimal dunes and vegetation. - Four piers overlying this section likely visual deterent to nesters.
S17	0.62	29.29103	94.78652	29.29460	94.78170	Nourishment: Yes. + Moderately wide beach. - No dunes, vegetation limited to sparse grasses colonizing nourishment sand.
S18	0.06	29.29460	94.78170	29.29510	94.78130	Nourishment: No. +/- Short section of moderately narrow beach. + Moderately well-vegetated dunes, slope not prohibitive to nesters.
S19	0.50	29.29510	94.78130	29.29830	94.77760	- Armored beach: no nesting habitat available.
S20	0.06	29.29830	94.77760	29.29868	94.77712	+/- Short section of moderately wide beach. - Narrow dunes with minimal vegetation. - Sand interspersed with granite boulders presents major obstacle to nester and hatchling movement.
TOTAL	**5.97**					

HABITAT QUALITY KEY		
GOOD	**FAIR**	**POOR**

Table 3.4. Correlation between sea turtle nesting activity documented through 2007 and beach habitat quality within Galveston Island's Seawall Zone.

Section Quality	**% of Zone**	**Total Length (km)**	**No. of Nests**	**Nests/km**
Good	0.0	0.00	0	0.00
Fair	50.4	3.01	4	1.33
Poor	49.6	2.96	2	0.68
Zone Total	**100.0**	**5.97**	**6**	**1.01**

prohibitively steep slopes were present near the base of the Seawall on S11; the irregularity of these mounds represented an entrapment hazard to hatchlings emerging from any nest laid in the vicinity. Finally, the five commercial piers constructed over portions of two sections (S14, S16) likely presented a visual deterrent to nesters, while artificial lights located on these piers may have increased visual deterrence and posed a hazard to nocturnally emerging hatchlings (Table 3.3).

The remaining seven sections, which constituted 50.4% of the SWZ, contained fair nesting habitat (Fig. 3.2, Tables 3.3 & 3.4). Four moderately wide sections (S1, S3, S10, S17) that were recently nourished exhibited an ensuing berm whose steep slope may have prevented females from accessing most of the beach above the high tide line (Table 3.3). The three sections lacking nourishment (S12, S15, S18) possessed moderately vegetated dunes, although the slope of these dunes was prohibitive to nesters on S12, and beaches of S15 and S18 were moderately narrow.

East End Zone: The East End Zone (EEZ) was composed of 6.14 km of beaches partitioned into eight sections that collectively ranged in habitat quality from poor to good (Fig. 3.3, Table 3.5). This highly variable zone was characterized only by its lack of recent nourishment activity and beach armor. (Note: Section E1, although bordered by the seawall, was included in this zone as beach armoring had little to no effect on nesting habitat east of 12th Street due to the seawall's sharp redirection inland.)

Figure 3.3. Delineation of sea turtle nesting habitat quality within the East End Zone of Galveston Island, Texas, per March 2008 survey. Balloon locations delineate section boundaries, while color correlates with quality of nesting habitat immediately to the northeast.

Table 3.5. Sea turtle nesting habitat quality assessment for the East End Zone of Galveston Island, Texas. Associated beaches were surveyed March 2008.

		Section Start		Section End		
Section	**Length (km)**	**Latitude**	**Longitude**	**Latitude**	**Longitude**	**Salient Habitat Characteristics**
E1	0.23	29.29868	94.77712	29.29985	94.77547	+ Moderately wide beach contains wide, well-vegetated dunes. - Slope and height of dunes likely prohibitive to nesters.
E2	0.25	29.29985	94.77547	29.30147	94.77367	- Excessively wide beach cleared for vehicle parking. - Large, well-vegetated dunes situated behind parking lot difficult and hazardous for nesters to access. - Wood pilings (~30 cm high) extend eastward parallel to water to delineate parking area, present obstacle to movement. - Vehicular traffic in parking area presents danger to nesters and hatchlings. +/- 16 large concrete pilings (29.30082, -94.77433) situated far from waterline present minor obstacle to nester movement.
E3	0.06	29.30147	94.77367	29.30197	94.77333	- Excessively wide beach. + Low, well-vegetated dunes begin at and extend behind tall wood pilings. - Single commercial structure located at rear of wide beach bordered by flat, minimally vegetated foredunes. - Wood pilings (~30 cm high) extend eastward parallel to water to delineate parking area, present obstacle to movement. - Tall wood pilings (~0.9-1.2 m high) located behind smaller pilings present second obstacle to nester and hatchling movement. - Vehicular traffic between pilings presents danger to nesters and hatchlings.
E4	0.08	29.30197	94.77333	29.30245	94.77270	- Beach excessively wide as area behind larger wood pilings cleared for vehicle parking. - Large, well-vegetated dunes located behind parking lot difficult and hazardous for nesters to access. - Wood pilings (~30 cm high) extend eastward parallel to water to delineate parking area, present obstacle to movement. - Tall wood pilings (~0.9-1.2 m high) located behind smaller pilings present second obstacle to nester and hatchling movement. - Vehicular traffic between pilings presents danger to nesters and hatchlings.
E5	0.11	29.30245	94.77270	29.30298	94.77183	- Short stretch of wide beach. + Moderate height, well-vegetated dunes present along majority of section. + Single commercial structure located behind dunes.
E6	0.79	29.30298	94.77183	29.30743	94.76510	- Excessively wide beach heavily utilized by public (Stewart Beach) likely visually disorienting to nesters. - Tall dunes located several hundred meters from waterline likely not seen or utilized by nesters. +/- Single commercial building located well behind waterline lacks dunes and vegetation in vicinity. - High pedestrian traffic increases sand compaction and is visual deterrent to nesters. - Low wood pilings (parallel to water) located far from waterline present minimal obstacle to turtle movement.
E7	3.23	29.30743	94.76510	29.32452	94.73838	+ Long stretch of moderately wide beach contains wide, well-vegetated dunes varying extensively in height. + Minimal commercial and residential development all located well behind dunes. - Excessively wide dune crossover base presents entrapment hazard to nesters and hatchlings (29.31452, -94.75408). - Excessively wide base of dune crossover (29.31787, -94.74902) presents obstacle to nester and hatchling movement.
E8	1.39	29.32452	94.73838	29.33178	94.72678	- Excessively wide beach cleared for vehicle driving and parking poses hazard to nests, nesters, and hatchlings. - Dunes located several hundred meters from waterline likely not seen or utilized by nesters. - Recreational hook-and-line fishing potentially dangerous to nesters. - Variety of configurations of wood pilings delineating vehicle zones present obstacle to nester and hatchling movement.
TOTAL	**6.14 km**					

HABITAT QUALITY KEY		
GOOD	**FAIR**	**POOR**

All five sections (E2, E3, E4, E6, E8) characterized as poor habitat, collectively comprising 41.9% of the EEZ zone (Fig. 3.3, Tables 3.5 & 3.6), had been artificially widened for public use and recreation and contained various configurations of wooden pilings that may have hindered turtle movement. While well-vegetated dunes were present on all sections, these dunes were located behind vehicle parking areas and up to several hundred meters from the tideline (Table 3.5). Nesters crawling onto these sections would likely have become visually disoriented and failed to see and/or utilize dune nesting habitat. In addition, all sections contained rows of wooden pilings placed parallel to the waterline to delineate vehicle access areas. Vehicular traffic is a significant hazard to nesters, nests, and hatchlings, particularly on East Beach (E8) where parking space exists for approximately 7000 vehicles. The two longest sections, Stewart Beach (E6) and East Beach (E8), were popular tourist destinations where significant pedestrian traffic may have deterred nesting.

One section (E5) representing 1.8% of the EEZ qualified as fair nesting habitat (Fig. 3.3, Tables 3.5 & 3.6). While this section contained moderately high, well-vegetated dunes, it was a short, excessively wide stretch located between relatively long sections of poor habitat (Table 3.5).

The majority (56.3%) of the EEZ was comprised of two sections (E1, E7) of good habitat containing moderately wide beaches with well-vegetated dunes (Fig. 3.3, Tables 3.5 & 3.6). Section E7 spanned 3.23 km and, with the exception of two dune crossover

Table 3.6. Correlation between sea turtle nesting activity documented through 2007 and beach habitat quality within Galveston Island's East End Zone.

Section Quality	% of Zone	Total Length (km)	No. of Nests	Nests/km
Good	56.3	3.46	0	0.00
Fair	1.8	0.11	0	0.00
Poor	41.9	2.57	0	0.00
Zone Total	**100.0**	**6.14**	**0**	**0.00**

bases that may have presented an obstacle and/or entrapment hazard to nesters and hatchlings, contained no obvious impediments to nesting sea turtles. However, artificial lights from the limited residential development on this section, particularly those associated with three large condominiums, may have posed a threat to nocturnally emerging hatchlings (Table 3.5).

Historical Nesting Patterns

West End Zone: From 2002-2007, 22 nests and 2 false crawls were documented within the WEZ (Figs. 3.4 & 3.5, Table 3.7), an average of 0.78 nests per kilometer of available habitat (Table 3.2). Four of these nests were documented on beaches of poor quality, resulting in an average of 0.88 nests/km (Table 3.2). Two nests were laid in poor habitat within section W17, a narrow beach lacking dunes and vegetation that was armored by a geotube exposed by wave action at multiple locations (Table 3.7). On 23 May 2006, a ridley nested at the base of this geotube. On 16 May 2003, a nest was deposited 0.16 km east of the previous nest site, although the state of this beach at that time is unclear as data indicate only that the turtle nested at the top of a dune, which may or may not refer to an unexposed geotube. Section W19 contained the two remaining nests located in poor habitat; this narrow beach lacked dunes and vegetation and exhibited multiple residential structures situated directly on the beach. On 6 May 2006, a nester crawled past one of those homes and onto a nearby street; beachgoers relocated her to the beach, where she ultimately completed nesting. On 14 June 2006, one female deposited her nest directly in front of a house on the western edge of this section.

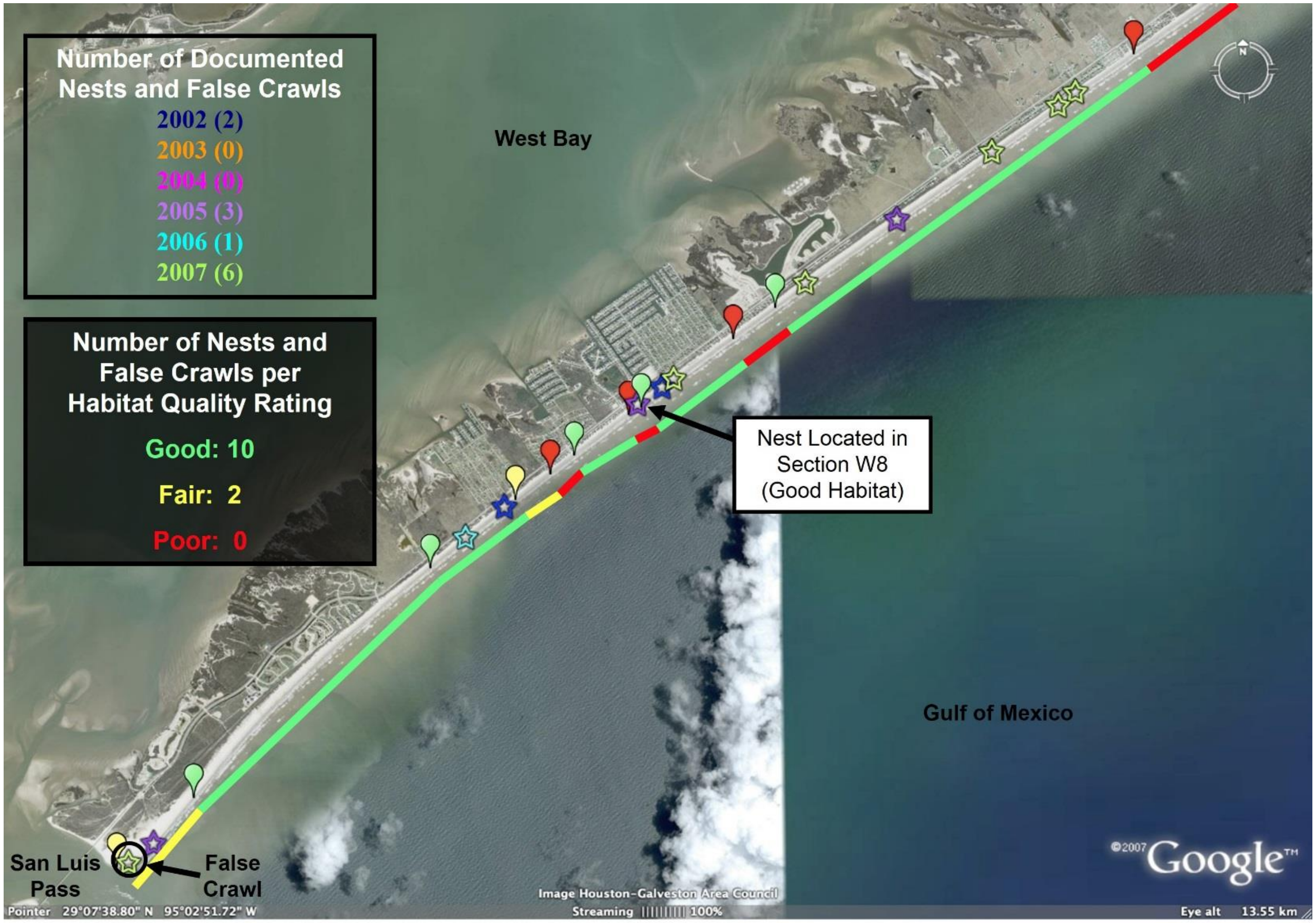


Figure 3.4. Historical nest locations (☆) versus nesting habitat quality within the western half of the West End Zone of Galveston Island, Texas. Balloon locations delineate section boundaries, while color correlates with quality of nesting habitat immediately to the northeast.

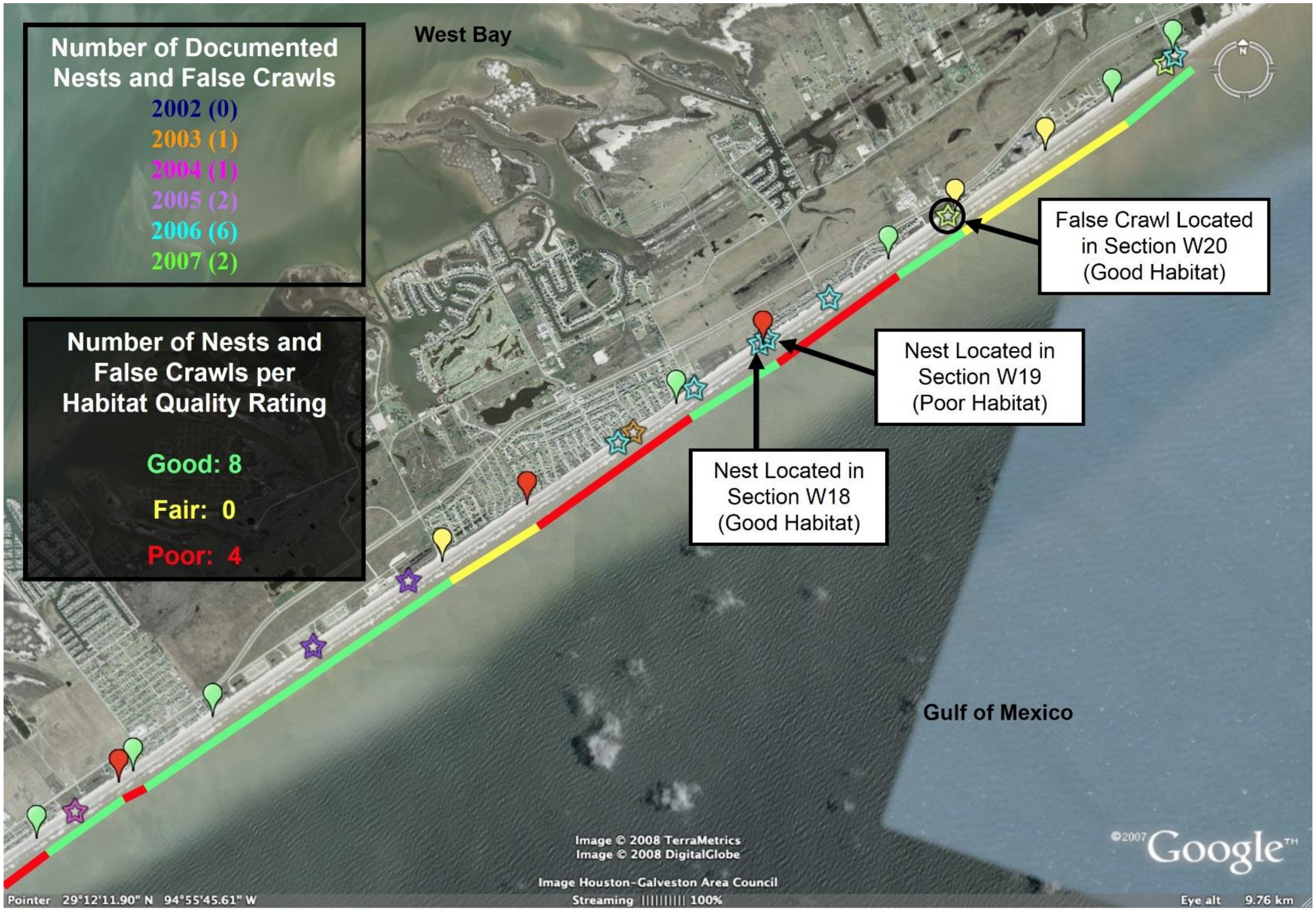


Figure 3.5. Historical nest locations (☆) versus nesting habitat quality within the eastern half of the West End Zone of Galveston Island, Texas. Balloon locations delineate section boundaries, while color correlates with quality of nesting habitat immediately to the northeast.

Table 3.7. Historic Kemp's ridley sea turtle nesting activity in the West End Zone of Galveston Island, Texas, through 2007. -: no data.

		Nest Location					**Nester**		
Date	**Time Detected**	**Latitude[1]**	**Longitude[1]**	**Locality**	**Beach Section**	**Deposition Site**	**Wild or Headstart**	**SCL[2] (cm)**	**Primary Tag**
6/9/02	1630	29.12300	95.06683	Bay Harbor	W3 / Good	Base of Foredunes	1992 Headstart[3]	N/R[4]	N/R[4]
6/10/02	0930	29.13472	95.04583	Sea Isle	W8 / Good	Top of First Foredune	Unknown[5]	-	-
5/16/03	1008	29.20552	94.93158	Pirate's Beach East	W17 / Poor	Top of First Foredune	Unknown[5]	-	-
4/17/04	1700	29.17597	94.98207	Jamaica Beach	W12 / Good	Base of Foredunes	1991 Headstart[3]	62.5	RRV317
5/16/05	1000	29.15393	95.01765	Sandhill Shores - West Indian Beach	W10 / Good	Downslope of First Foredune	1992 Headstart[3]	65.8	SSD127
5/29/05	0800	29.18860	94.96038	Galveston Island State Park	W15 / Good	Base of Foredunes	Wild	62.5	RRV251
5/29/05	1000	29.13392	95.05003	Sea Isle	W8 / Good	Upslope of First Foredune	Unknown[5]	-	-
6/4/05	0630	29.19363	94.95168	Galveston Island State Park	W15 / Good	Base of Foredunes	Unknown[5]	-	-
6/20/05	0830	29.08635	95.11085	San Luis Pass	W1 / Fair	Backbeach	1992 Headstart[3]	65.5	SSD127
5/6/06	1500	29.21595	94.91393	Bermuda Beach	W19 / Poor	Base of Foredunes	1991 Headstart[3]	62.1	RRV255
5/6/06	1500	29.20873	94.92597	Galveston Island Pocket Park #3	W18 / Good	Base of Foredunes	1989 Headstart[3]	61.5	RRV315
5/20/06	0800	29.23485	94.88268	8 Mile Road	W23 / Good	Base of Foredunes	Unknown[5]	-	-
5/23/06	0700	29.20452	94.93290	Pirates Beach	W17 / Poor	Embryonic Dunes	Unknown[5]	-	-
5/26/06	1200	29.21238	94.92007	Bermuda Beach	W18 / Good	Base of Foredunes	1989 Headstart[3]	61.5	RRV315
5/27/06	0900	29.11948	95.07153	Miramar Beach	W3 / Good	Embryonic Dunes	Unknown[5]	-	-
6/14/06	0500	29.21262	94.91943	Bermuda Beach	W19 / Poor	Embryonic Dunes	Unknown[5]	-	-
5/1/07	0845	29.16768	94.99545	Near Beach Access #18	W10 / Good	Base of Foredunes	Unknown[5]	-	-
5/3/07	1045	29.14700	95.02910	Sandhill Shores	W10 / Good	Base of Foredunes	Unknown[5]	-	-
5/17/07	1000	29.13660	95.04558	Sea Isle	W8 / Good	Embryonic Dunes	1991 Headstart[3]	64.0	RRV235
5/17/07[6]	1230	29.08403	95.11390	San Luis Pass	W1 / Fair	Backbeach[7]	1989 Headstart[3]	62.4	RRV237
5/18/07	0955	29.23443	94.88368	8 Mile Road	W23 / Good	Base of Foredunes	1995 Headstart[3]	59.7	SSH496
5/26/07[6]	1000	29.22250	94.90325	Hershey Beach	W20 / Good	Base of Foredunes[7]	1992 Headstart[3]	61.0	RRV371
6/8/07	0945	29.16132	95.00595	Kahala Beach	W10 / Good	Top of First Foredune	Unknown[5]	-	-
6/20/07	1010	29.16627	94.99767	Indian Beach	W10 / Good	Embryonic Dunes	Unknown[5]	-	-

[1] Reference coordinate system WGS 84.

[2] Straight carapace length (notch-tip).

[3] Year class captive reared at the NOAA Sea Turtle Facility on Galveston Island, Texas.

[4] Responder observed turtle but did not collect data.

[5] Nesting female not observed by biologists; species identified based upon nest contents (D. Shaver, pers. comm.).

[6] Non-nesting emergence.

[7] Apex of false crawl.

One nest and one false crawl were located in fair habitat (0.23 nests/km; Table 3.2) within WEZ section W1 near San Luis Pass, where dunes were located several hundred meters from the waterline (Fig. 3.4). On 20 June 2005, a turtle nested approximately 45 m from the waterline on the backbeach; this turtle was previously seen nesting 16 May 2005 on the downslope of the first foredune in section W10 (Table 3.7). On 17 May 2007, a different female was observed nesting on the backbeach approximately 5 m from the waterline, an area that was inundated during high tide. Although beachgoers observed the nesting process, this event was classified as a false crawl as responders were unable to locate the nest.

The remaining 17 nests and 1 false crawl in the WEZ were located in good habitat (0.88 nests/km; Table 3.2).

Seawall Zone: Six nests were located within the SWZ, an overall average of 1.01 nests/km of available habitat (Table 3.4), since nesting was first documented on constituent beaches in 2004 (Fig. 3.6, Table 3.8). Of the two nests in poor habitat (0.68 nests/km; Table 3.4), one was located in embryonic dunes on section S11, a narrow beach where moderately vegetated dunes existed at the base of the Seawall (Table 3.8). The nest laid 28 April 2006 was deposited among large granite boulders near the base of the Seawall on the armored beach of section S19; no nesting habitat was visible when this beach was surveyed in 2008. The remaining four nests were located in fair habitat

Figure 3.6. Historical nest locations (☆) versus nesting habitat quality within the Seawall Zone of Galveston Island, Texas. Balloon locations delineate section boundaries, while color correlates with quality of nesting habitat immediately to the northeast.

Table 3.8. Historic Kemp's ridley sea turtle nesting activity in the Seawall Zone of Galveston Island, Texas, through 2007. -: no data.

		Nest Location					**Nester**		
Date	**Time Detected**	**Latitude**[1]	**Longitude**[1]	**Locality**	**Beach Section**	**Deposition Site**	**Wild or Headstart**	**SCL**[2] **(cm)**	**Primary Tag**
4/5/04	1100	29.27405	94.81637	30th St. & Seawall Blvd.	S11 / Poor	Embryonic Dunes	1989 Headstart[3]	58.5	RRV313
5/30/05	0700	29.28277	94.79860	33rd St. & Seawall Blvd.	S12 / Fair	Upslope of First Foredune	1992 Headstart[3]	63.0	RRV253
6/4/05	1000	29.28583	94.79345	28th St. & Seawall Blvd.	S10 / Fair	Upslope of First Foredune	1992 Headstart[3]	60.0	RRV371
4/28/06	1330	29.29533	94.78107	16th St. & Seawall Blvd.	S19 / Poor	Embryonic Dunes	Wild	67.2	RRV232
5/28/06	0600	29.27132	94.81762	51st St. & Seawall Blvd.	S3 / Fair	Backbeach	Unknown[4]	-	-
8/6/07[5]	0900	29.27090	94.81837	52nd St. & Seawall Blvd.	S3 / Fair	Embryonic Dunes	Unknown[4]	-	-

[1] **Reference coordinate system WGS 84.**

[2] **Straight carapace length (notch-tip).**

[3] **Year class captive reared at the NOAA Sea Turtle Facility on Galveston Island, Texas.**

[4] **Nesting female not observed by biologists; species identified based upon nest contents (D. Shaver, pers. comm.).**

[5] **Nest documented at hatching.**

(1.33 nests/km; Table 3.4) and, with the exception of one laid on the backbeach of section S3 on 28 May 2006, were at or near the base of the Seawall (Table 3.8).

East End Zone: Through 2007, no historical nesting activity had been documented on 6.14 km of beaches of the EEZ (Table 3.6).

Bolivar Peninsula

Quality of Sea Turtle Nesting Habitat

Forty-one distinct sections of beach habitat, ranging in quality from poor to good, were identified along the 38.96-km surveyed zone of Bolivar Peninsula (Figs. 3.7-3.9, Table 3.9). Rollover Pass (section B31), an artificial waterway constructed to connect Galveston Bay with the Gulf of Mexico, was the only section void of nesting habitat. Beaches comprising Bolivar Peninsula were characterized by visible evidence of various anthropogenic activities, particularly those associated with vehicular traffic, beach grooming, beachfront residential development, and increased seasonal usage by tourists and residents, all of which may have visually deterred nesters. Vehicular traffic, a potential source of mortality for nesters and hatchlings, was facilitated by an open beach policy and a multitude of public beach access points distributed throughout the surveyed area (the majority of public roads provided vehicle beach access). Traffic was particularly heavy near access points associated with the extreme eastern and western sections (B1, B2, B42) and Rollover Pass (B31). Beachfront residential developments of varying magnitude occupied all sections with the exception of those on the eastern and

Figure 3.7. Delineation of sea turtle nesting habitat quality on the western segment (sections B1-12) of Bolivar Peninsula, Texas, per July 2008 survey. Balloon locations delineate section boundaries, while color correlates with quality of nesting habitat immediately to the northeast.

Figure 3.8. Delineation of sea turtle nesting habitat quality on the central segment (sections B13-29) of Bolivar Peninsula, Texas, per July 2008 survey. Balloon locations delineate section boundaries, while color correlates with quality of nesting habitat immediately to the northeast.

Figure 3.9. Delineation of sea turtle nesting habitat quality on the eastern segment (sections B30-42) of Bolivar Peninsula, Texas, per July 2008 survey. Balloon locations delineate section boundaries, while color correlates with quality of nesting habitat immediately to the northeast.

Table 3.9. Sea turtle nesting habitat quality assessment for Bolivar Peninsula, Texas. Associated beaches were surveyed July 2008.

		Section Start		Section End		
Section	**Length (km)**	**Latitude**	**Longitude**	**Latitude**	**Longitude**	**Salient Habitat Characteristics**
🟨 B1	1.10	29.37200	94.72763	29.38110	94.72308	+ Low, well-vegetated dunes extend behind beach into bird sanctuary. + No housing development. - Heavy vehicular traffic between Bolivar Flats Bird Sanctuary and Rettilon Road.
🟥 B2	0.30	29.38110	94.72308	29.38368	94.72185	+/- Well-vegetated dunes removed 150-200 m from high tide line on overly wide beach. + No housing development. - Extremely heavy vehicular traffic as is first public beach access point east of ferry landing.
🟩 B3	1.34	29.38368	94.72185	29.39413	94.71520	+ Well-vegetated dunes of moderate height. + No housing development. +/- Large washout (29.38983, -94.71830) may deter nesters who encounter water pooled on beach.
🟩 B4	1.20	29.39413	94.71520	29.40282	94.70808	+ Foredune fronts well-vegetated dune complex of moderate height. + Sparse housing development set well behind dunes begins here and extends east. - Well-constructed dune crossovers present minor obstacle to nesters and hatchlings.
🟩 B5	0.78	29.40282	94.70808	29.40813	94.70282	+ Foredune fronts well-vegetated dune complex of moderate height. + Housing development set adequate distance behind dunes. - Low number of well-constructed dune crossovers present minor obstacle to nesters and hatchlings.
🟨 B6	1.70	29.40813	94.70282	29.41853	94.69015	+/- Vegetated dunes of moderate height lack vegetation on dune face from beach grooming activities. + Sparse housing development set well behind dunes. - Low number of well-constructed dune crossovers present minor obstacle to nesters and hatchlings. +/- Washout (29.41083, -94.69978) may deter nesters who encounter water pooled on beach.
🟩 B7	1.10	29.41853	94.69015	29.42467	94.68130	+/- Vegetated dunes of moderate height lack vegetation on dune face from beach grooming activities. + Housing development set well behind dunes.
🟩 B8	0.40	29.42467	94.68130	29.42682	94.67802	+/- Vegetated dunes of moderate height lack vegetation on dune face from beach grooming activities. + No housing development.
🟨 B9	0.67	29.42682	94.67802	29.43033	94.67233	+/- Vegetated dunes of moderate height lack vegetation on dune face from beach grooming activities. + Housing development set well behind dunes. - Low number of well-constructed dune crossovers present minor obstacle to nesters and hatchlings.
🟩 B10	0.95	29.43033	94.67233	29.43497	94.66423	+ Vegetated dunes of moderate height occasionally lack vegetation on dune face from beach grooming activities. + No housing development. +/- Washout (29.43402, -94.66595) may deter nesters who encounter water pooled on beach.
🟩 B11	0.95	29.43497	94.66423	29.43952	94.65597	+/- Vegetated dunes of moderate height lack vegetation on dune face from beach grooming activities. + Housing development set well behind dunes.
🟨 B12	0.94	29.43952	94.65597	29.44387	94.64765	+/- Low vegetated dunes lack vegetation on dune face from beach grooming activities. +/- Housing development located immediately behind dunes. - Poorly constructed dune crossover near section beginning presents obstacle to nester and hatchlings.
🟩 B13	1.15	29.44387	94.64765	29.44907	94.63742	+ Vegetated dunes of moderate height. + No housing development. +/- Washout (29.44740, -94.64087) may deter nesters who encounter water pooled on beach.
🟩 B14	0.52	29.44907	94.63742	29.45138	94.63273	+/- Vegetated dunes of moderate height lack vegetation on dune face from beach grooming activities. + Housing development set well behind dunes.
🟩 B15	1.04	29.45138	94.63273	29.45587	94.62330	+/- Vegetated dunes of moderate height lack vegetation on dune face from beach grooming activities. +/- Numerous houses located immediately behind dunes.
🟩 B16	1.33	29.45587	94.62330	29.46150	94.61115	+/- Vegetated dunes of moderate height typically lack vegetation on dune face from beach grooming activities. + Housing development set well behind dunes.
🟩 B17	0.12	29.46150	94.61115	29.46202	94.61002	+/- Vegetated dunes of moderate height typically lack vegetation on dune face from beach grooming activities. +/- Row of six houses located immediately behind dunes.

HABITAT QUALITY KEY		
🟩 GOOD	🟨 FAIR	🟥 POOR

Table 3.9. Cont.

Section	Length (km)	Section Start Latitude	Section Start Longitude	Section End Latitude	Section End Longitude	Salient Habitat Characteristics
🟩 B18	0.21	29.46202	94.61002	29.46293	94.60805	+/- Vegetated dunes of moderate height typically lack vegetation on dune face from beach grooming activities. + Housing development set well behind dunes.
🟩 B19	0.32	29.46293	94.60805	29.46420	94.60518	+/- Vegetated, low to moderate height dunes typically lack vegetation on dune face from beach grooming activities. +/- Numerous houses located immediately behind dunes.
🟨 B20	0.07	29.46420	94.60518	29.46442	94.60460	- Sand fence running parallel to water blocks nester access to low, minimally vegetated dunes accreted behind it. +/- Numerous houses located immediately behind dunes.
🟨 B21	0.58	29.46442	94.60460	29.46680	94.59923	+/- Vegetated, low to moderate height dunes lack vegetation on dune face from beach grooming activities. + Numerous houses primarily located well behind dunes. - Multiple well-constructed dune crossovers present minor obstacle to nesters and hatchlings.
🟩 B22	0.88	29.46680	94.59923	29.47035	94.59115	+/- Dunes of low to moderate height intermittently lack vegetation on dune face from beach grooming activities. +/- Numerous houses located immediately behind dunes.
🟩 B23	2.26	29.47035	94.59115	29.47920	94.57012	+ Well-vegetated dunes of low to moderate height display minimal signs of beach raking activities. + Housing development set well behind dunes.
🟩 B24	0.32	29.47920	94.57012	29.48043	94.56707	+ Well-vegetated dunes of low to moderate height have accreted around primarily buried sand fence.
🟩 B25	1.85	29.48043	94.56707	29.48740	94.54980	+/- Dunes of low to moderate height intermittently lack vegetation on dune face from beach grooming activities. + Two houses located well behind dunes.
🟨 B26	0.16	29.48740	94.54980	29.48798	94.54838	+ Well-vegetated dunes of moderate height. +/- Housing development under construction located immediately behind dunes. - Two large dune crossovers present obstacle to nesters and hatchlings.
🟩 B27	0.78	29.48798	94.54838	29.49093	94.54102	+ Well-vegetated dunes of moderate height. + Sparse housing development set well behind dunes.
🟥 B28	3.26	29.49093	94.54102	29.50310	94.51042	- Beach lacks vegetated dunes; exposed geotube eliminates dune nesting habitat. - Beach width narrow. +/- Western portion contains sparse housing development, eastern portion contains houses behind exposed geotube. - Mulitple geotube crossovers with large bases present major obstacle to nesters and hatchlings. - Large (5 m x 12 m) geotube crossover (29.49978, -94.51892) near tideline presents major obstacle to movement.
🟨 B29	0.18	29.50310	94.51042	29.50387	94.50878	- Beach lacks vegetated dunes; exposed geotube eliminates dune nesting habitat. + Beach width adequate due to nourishment activities in May/June 2008. +/- Housing development located immediately behind exposed geotube. - Multiple geotube crossovers present obstacle to nesters and hatchlings.
🟨 B30	0.90	29.50387	94.50878	29.50690	94.50033	- Beach lacks vegetated dunes; geotube primarily covered with vegetated sand eliminates dune nesting habitat. + Beach width adequate due to nourishment activities in May/June 2008. +/- Sparse housing development set well behind dunes; two homes situated immediately behind geotube. - Multiple geotube crossovers present obstacle to nesters and hatchlings.
B31	0.12	29.50690	94.50033	29.50727	94.49862	Rollover Pass - no nesting habitat.
🟥 B32	0.24	29.50727	94.49862	29.50808	94.49673	- Beach lacks vegetated dunes; exposed geotube eliminates dune nesting habitat. - Beach width narrow; beach fully inundated at high tide. + Housing development set adequately behind geotube. - Multiple geotube crossovers present obstacle to nesters and hatchlings. - Heavy vehicular traffic; this is first public access point to beaches east of Rollover Pass.

HABITAT QUALITY KEY		
🟩 GOOD	🟨 FAIR	🟥 POOR

Table 3.9. Cont.

Section	Length (km)	Section Start Latitude	Section Start Longitude	Section End Latitude	Section End Longitude	Salient Habitat Characteristics
🟥 B33	1.71	29.50808	94.49673	29.51438	94.48067	- Beach lacks vegetated dunes; partially to fully exposed geotube eliminates dune nesting habitat. +/- Beach width moderately narrow. +/- Housing development located immediately behind geotube. - Multiple geotube crossovers present obstacle to nesters and hatchlings. - Unoccupied house on beach in front of geotube (29.51033, -94.49110) presents major obstacle to movement.
🟨 B34	0.46	29.51438	94.48067	29.51613	94.47633	- Beach lacks vegetated dunes; geotube covered with vegetated sand eliminates dune nesting habitat. + Beach width moderate. + Housing development set well behind geotube. - Multiple geotube crossovers present obstacle to nesters and hatchlings.
🟥 B35	0.50	29.51613	94.47633	29.51793	94.47152	- Beach lacks vegetated dunes; geotube covered with vegetated sand eliminates dune nesting habitat. - Beach width moderately narrow. +/- Numerous houses located immediately behind geotube. - Multiple geotube crossovers present obstacle to nesters and hatchlings. - Geotube crossover constructed parallel to tideline presents major obstacle to nester and hatchlings.
🟥 B36	0.66	29.51793	94.47152	29.52027	94.46525	- Beach lacks vegetated dunes; primarily exposed geotube eliminates dune nesting habitat. - Beach width narrow; beach fully inundated at high tide. +/- Houses located immediately behind exposed geotube. - Multiple geotube crossovers present obstacle to nesters and hatchlings. - Beach substrate composed primarily of shells.
🟥 B37	0.27	29.52027	94.46525	29.52115	94.46273	- Beach lacks vegetated dunes; geotube covered with vegetated sand eliminates dune nesting habitat. - Beach width moderately narrow. +/- Houses located immediately behind geotube. - Multiple geotube crossovers present obstacle to nesters and hatchlings. - Beach substrate composed primarily of shells.
🟥 B38	0.12	29.52115	94.46273	29.52155	94.46163	- Beach lacks vegetated dunes; exposed geotube eliminates dune nesting habitat. - Beach width moderately narrow. +/- Houses located immediately behind exposed geotube. - Multiple geotube crossovers present obstacle to nesters and hatchlings. - Beach substrate composed primarily of shells.
🟥 B39	0.19	29.52155	94.46163	29.52218	94.45973	- Beach lacks vegetated dunes; geotube covered with vegetated sand eliminates dune nesting habitat. + One house located well behind geotube. - Beach substrate composed primarily of shells.
🟨 B40	4.55	29.52218	94.45973	29.53837	94.41663	+ Well-vegetated dunes of moderate height contain increased plant biodiversity. + Beach width moderate; increased slope minimizes erosion. + No housing development. - Beach substrate composed primarily of shells.
🟨 B41	0.34	29.53837	94.41663	29.53965	94.41343	+ Well-vegetated dunes of moderate height contain increased plant biodiversity. + Beach width moderate; increased slope minimizes erosion. + No housing development. - Beach substrate composed of shell/gravel mixture. - Old fishing pier (~3 m wide) at section beginning presents obstacle to nesters and hatchlings.
🟨 B42	2.44	29.53965	94.41343	29.54832	94.39040	+ Well-vegetated dunes of low to moderate height. +/- Beach width moderately narrow; increased slope minimizes erosion. + No housing development. - Beach substrate primarily shell/gravel mix interspersed with sand grains. - Heavy vehicular traffic as endpoint at intersection of Highways 87 and 124 serves as beach access point.
TOTAL	**38.96**					

HABITAT QUALITY KEY		
🟩 GOOD	🟨 FAIR	🟥 POOR

western endpoints of the surveyed beach (B1-B3, B40-B42). Artificial lighting sourced from these inhabited structures varied in intensity with housing density and proximity to the tide line, but was clearly visible from all beaches and likely posed a threat to nocturnally emerging hatchlings and nesters, particularly loggerheads. Beaches west of Rollover Pass contained an even distribution of approximately 98 refuse disposal stations, typically composed of 2 large circular receptacles mounted on 10.2 cm x 10.2 cm posts immediately adjacent to the dune line; these stations occurred with reduced frequency east of Rollover Pass. While these minor obstacles had a small individual footprint, their density increased the potential to limit nester access to dune nesting habitats.

While moderately wide beaches bordered by partially to fully vegetated dunes of low to moderate height were typical of Bolivar Peninsula, nine sections (B2, B28, B32, B33, B35, B36, B37, B38, B39) comprising 18.7% (7.25 km) of available nesting habitat were qualified as poor (Figs. 3.7-3.9, Tables 3.9 & 3.10). With the exception of sections B2 and B39, nesting habitat on these eroded beaches was severely compromised by geotextile tubes or geotubes (Fig. 3.10, Table 3.9; Feagin et al. 2005) installed to protect residential development from frequent tidal inundation. These geotubes, which eliminated dune nesting habitat, were partially to fully exposed by wave action and thus lacked the sand and vegetative covering characteristic of natural dunes. In addition, wooden dune crossovers designed to facilitate public beach access traversed geotubes bordering these sections (Fig. 3.10, Table 3.9). While crossover design varied

Table 3.10. Correlation between sea turtle nesting activity documented through 2008 and beach habitat quality on Bolivar Peninsula.

Section Quality	% of Zone	Total Length (km)	No. of Nests	Nests/km
Good	45.0	17.50	7	0.40
Fair	36.3	14.09	3	0.21
Poor	18.7	7.25	1	0.14
Zone Total	**100.0**	**38.84** [1]	**11**	**0.28**

[1] **Section B31 lacks nesting habitat and thus is not included in these calculations.**

Figure 3.10. Geotextile tube and associated crossover (in background) on Bolivar Peninsula section B28 (poor quality) under high tide conditions 9 June 2008. (Photo by Christi Hughes.)

considerably, the beachside footprint of many was sizeable, increasing their potential to block nester access to preferred nesting habitat at the base of the geotube (simulated dune line) and magnifying the entrapment hazard for hatchlings.

Section B39 contained an adequately wide beach constrained by a sand-covered, vegetated geotube of reduced height; however, this section (and all sections to the east) contained substrate with a high shell content, a drastic alteration from the small sand particles composing beaches in sections B1-B38. Substrate consisting mainly of large shell shards may deter nesters, interfere with nest excavation (Garmestani et al. 2000), or negatively affect hatching and emergence success of hatchlings through altered incubation properties. Section B2 lacked a geotube (as did all western sections) but contained Rettilon Road, the first public beach access east of the ferry landing. Heavy vehicular traffic and associated sand compaction at this access point, combined with the potential for nester visual disorientation created by the relocation of dunes approximately 135-180 m from the high tide line, negatively affected the quality of this section’s beaches (Table 3.9).

Thirteen sections (B1, B6, B9, B12, B20, B21, B26, B29, B30, B34, B40, B41, B42) incorporating 14.09 km, or 36.3% of the surveyed zone, were classified as fair nesting habitat (Figs. 3.7-3.9, Tables 3.9 & 3.10). Section B1 contained low, well-vegetated dunes bordering the undeveloped Bolivar Flats Shorebird Sanctuary, where heavy vehicular traffic from Rettilon Road (B2) may have endangered turtles traversing this wide beach and inhibited nest excavation through substrate compaction (Table 3.9). Beach raking and scraping activities on four sections (B6, B9, B12, B21) frequently deposited large quantities of sand against the base of dunes, preventing vegetative growth and stabilization of the dune face and drastically reducing or eliminating hatchling emergence potential from *in situ* nests covered by material after nest deposition. Nester access to dune nesting habitat was eliminated on four sections: the sand fence that confined section B20 was situated parallel to the tide line and void of accreted sand beachside, and geotubes spanned the moderate-width beaches of sections B29, B30, and B34 (Table 3.9). Nester and hatchling movement was impeded by dune or geotube crossovers on 7 sections (B6, B9, B12, B21, B26, B29, B34), while 2 substantial structures on section B26 increased the potential for turtle entrapment. The substrate of three sections contained prodigious quantities of shell (B40) or shell/gravel mixture (B41, B42) that may have hindered nest excavation (Garmestani et al. 2000) and/or reduced *in situ* nest hatching success through altered incubation characteristics.

Nineteen sections (B3-B5, B7, B8, B10, B11, B13-B19, B22-B25, B27) containing 17.50 km of beach characterized as good nesting habitat were confined to the western and central portions of the surveyed zone and constituted 45.0% of total available habitat (Figs. 3.7-3.9, Tables 3.9 & 3.10). All lacked engineered erosion control structures and, instead, contained vegetated dunes of low to moderate height. However, beach grooming activities that may have endangered *in situ* nests through deposition of sand at the dune line had prevented vegetation from colonizing and stabilizing dune faces on 12 sections

(B7, B8, B10, B11, B14-B19, B22, B25; Table 3.9). Three sections (B3, B10, B13) intermittently contained washouts that varied in volume and depth with tidal inundation; beaches containing pooled water above the high tide line may deter nesters and increase non-nesting emergence rates. While residential developments were constructed well behind the current dune line on most of these sections, homes located in close proximity to the dunes on four sections (B15, B17, B19, B22) represented a landward barrier prohibiting natural dune migration and contributed artificial light pollution on adjacent beaches.

Historical Nesting Patterns

Historical nesting patterns differentiate Bolivar Peninsula from all other UTC sea turtle nesting habitats. With the documentation of nesting activity by a loggerhead on 27 July 1996 (Table 3.11), Bolivar Peninsula was utilized by nesting sea turtles a minimum of 8 years prior to the recorded use of all other Texas beaches south to and including Matagorda Peninsula. Through 2011, it remained the only UTC site where nesting by a species other than the Kemp's ridley is known to have occurred (see Chapter II). Between 1996-2008, 9 Kemp's ridley nests, 2 loggerhead nests, and 3 false crawls were documented within the 38.84 km surveyed zone (Figs. 3.11-3.13, Table 3.11), resulting in an average of 0.28 nests/km of available habitat (Table 3.10). The majority of this activity (6 Kemp's ridley nests, 1 loggerhead nest, 2 false crawls) was documented in 2008 following the institution of formal nesting patrols (see Chapter II).

Table 3.11. Historic Kemp's ridley sea turtle nesting activity on Bolivar Peninsula, Texas, through 2008. -: no data.

		Nest Location					**Nester**			
Date	**Time Detected**	**Latitude[1]**	**Longitude[1]**	**Locality**	**Beach Section**	**Deposition Site**	**Species**	**Wild or Headstart**	**SCL[2] (cm)**	**Primary Tag**
7/27/96	0300	29.46667[3]	94.59833[3]	3.2 km East of Ramada Beach	B22 / Good	Downslope of First Foredune	Loggerhead	Wild	87.5	none
5/7/02[4]	1120	N/R[5]	N/R[5]	0.3 km East of Bolivar Flats Bird Sanctuary	B1 / Fair	N/R[5]	Kemp's ridley	1990 Headstart[6]	64.7	none
5/11/04	1215	29.45450	94.62652	Crystal Beach	B15 / Good	N/R	Kemp's ridley	1992 Headstart[6]	63.0	RRV311
6/3/04	0900	29.38645	94.72138	0.8 km East of Rettilon Road	B3 / Good	Base of Foredunes	Kemp's ridley	Unknown[7]	-	-
5/24/07	0740	29.52487	94.45302	Gilchrist	B40 / Fair	Embryonic Dunes	Kemp's ridley	Unknown[7]	-	-
4/25/08	1013	29.40742	94.70403	West of Trash Receptacle #18	B5 / Good	Base of Foredunes	Kemp's ridley	Unknown[7]	-	-
5/13/08[4]	1000	29.41068	94.70012	East of Trash Receptacle #21	B6 / Fair	Backbeach[8]	Kemp's ridley[9]	Unknown	-	-
5/14/08	0800	29.39883	94.71208	West of Trash Receptacle #12	B4 / Good	Foredune Depression	Kemp's ridley	Unknown[7]	-	-
5/30/08	0810	29.39587	94.71395	Adjacent to Trash Receptacle #10	B4 / Good	Foredune Depression	Kemp's ridley	Unknown[7]	-	-
5/30/08	0826	29.40865	94.70257	~100 m West of Magnolia Drive	B6 / Fair	Upslope of First Foredune	Kemp's ridley	Unknown[7]	-	-
6/9/08[4]	0930	29.44850	94.63907	~15 m East of Trash Receptacle #56	B13 / Good	Base of Foredunes[8]	Kemp's ridley[9]	Unknown	-	-
6/24/08	1002	29.51157	94.48805	1.0 km East of Rollover Pass	B33 / Poor	Base of Foredunes	Loggerhead	Wild[7]	-	-
7/16/08[10]	2250	29.44185	94.65213	Emerald Beach #1: Surfview Road Beach Access	B12 / Fair	Foredune Depression	Kemp's ridley	Unknown[7]	-	-
7/25/08[10]	0944	29.45877	94.61750	West of Trash Receptacle #69	B16 / Good	Base of Foredunes	Kemp's ridley	Unknown[7]	-	-

[1] Reference coordinate system WGS 84.
[2] Straight carapace length (notch-tip).
[3] Geographic coordinates estimated based on nest site description.
[4] Non-nesting emergence.
[5] Responder did not document coordinates or crawl data.
[6] Year class captive reared at the NOAA Sea Turtle Facility on Galveston Island, Texas.
[7] Nesting female not observed by biologists; species identified based upon nest contents (D. Shaver, pers. comm.).
[8] Apex of false crawl.
[9] Nesting female not observed by biologists; species identity based on crawl width.
[10] Nest documented at hatching.

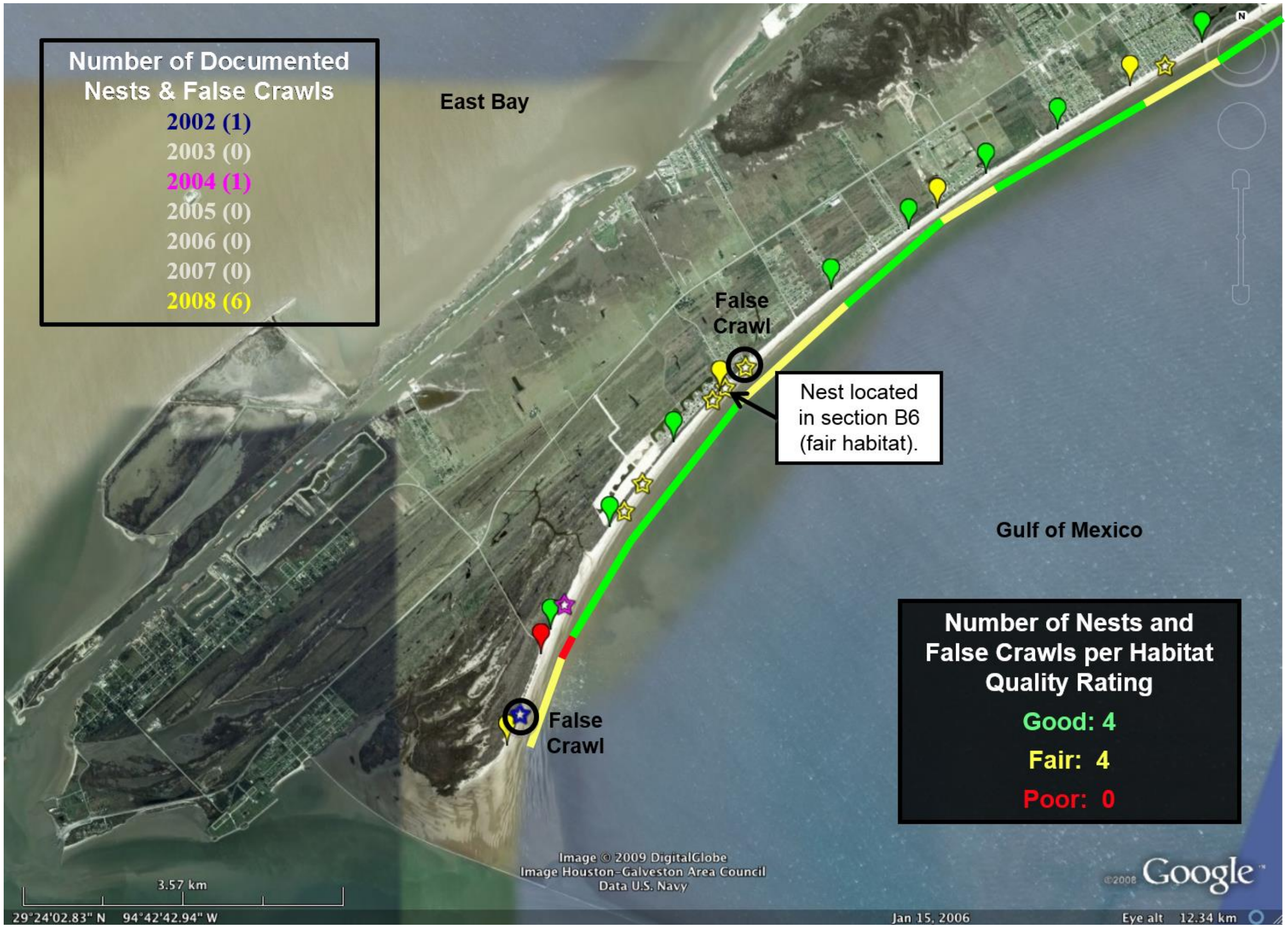


Figure 3.11. Historical nest locations (☆) versus nesting habitat quality within the western segment (sections B1-12) of Bolivar Peninsula, Texas. Balloon locations delineate section boundaries, while color correlates with quality of nesting habitat immediately to the northeast.

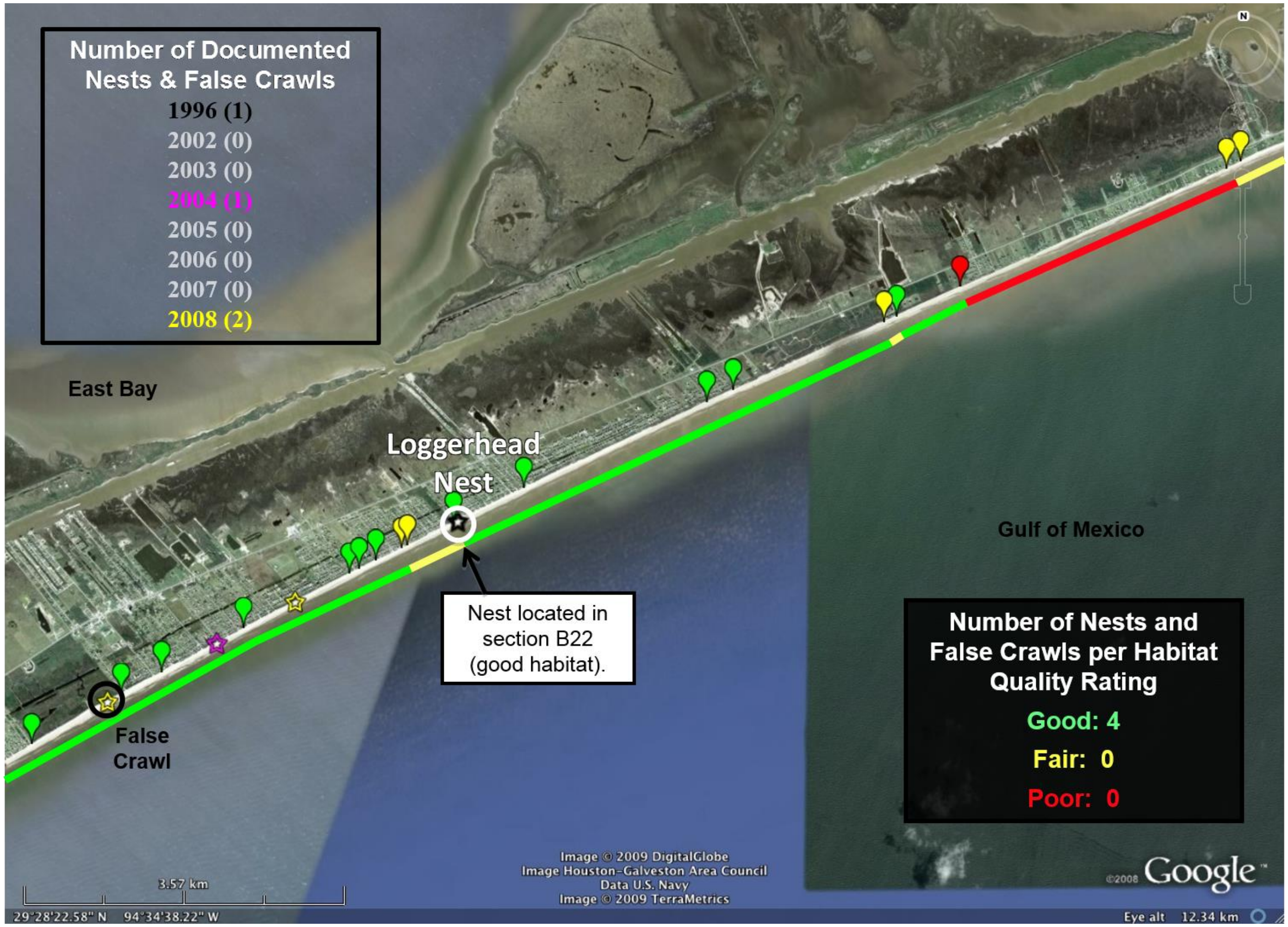


Figure 3.12. Historical nest locations (☆) versus nesting habitat quality within the central segment (sections B13-29) of Bolivar Peninsula, Texas. Balloon locations delineate section boundaries, while color correlates with quality of nesting habitat immediately to the northeast.

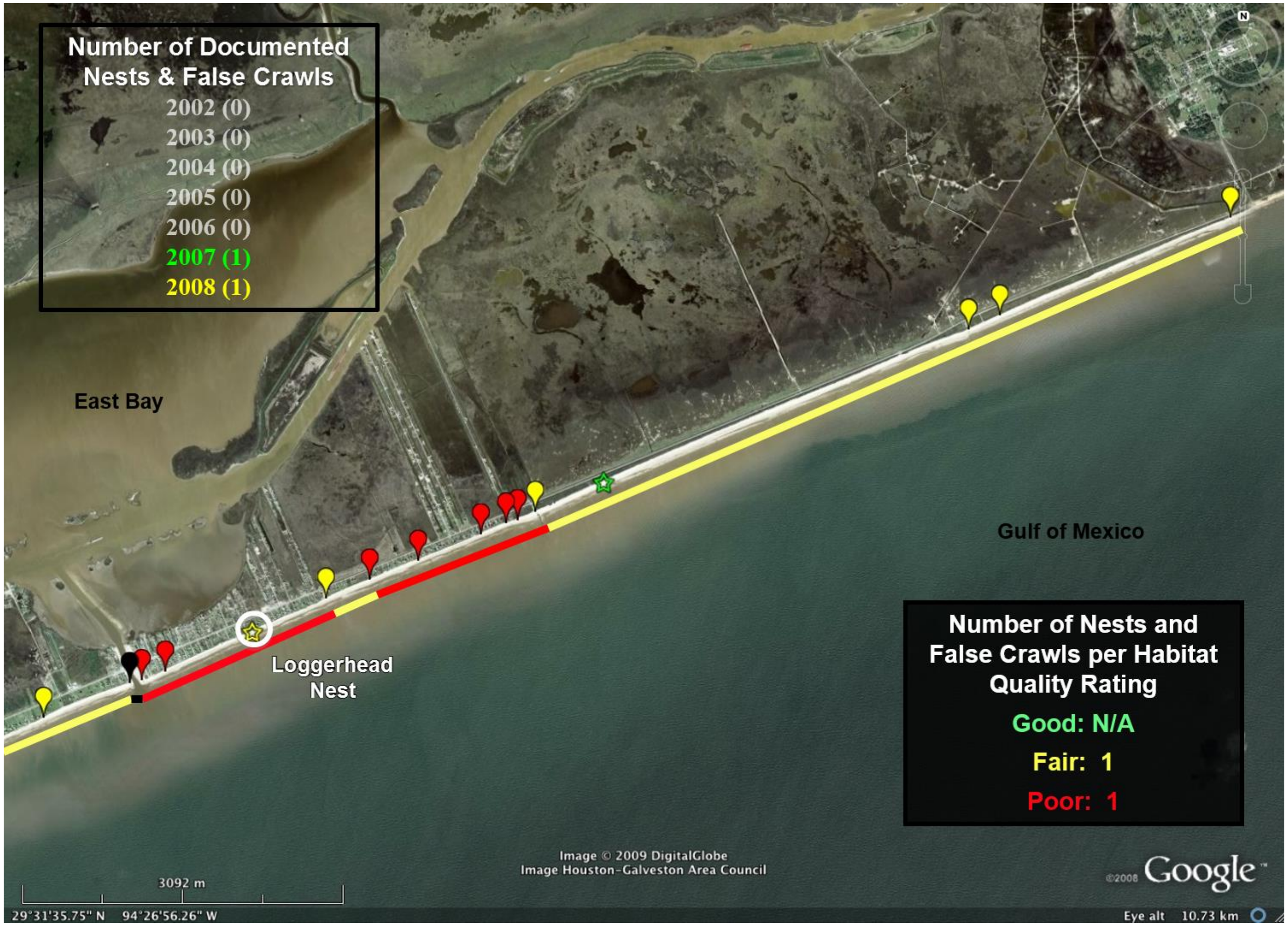


Figure 3.13. Historical nest locations (☆) versus nesting habitat quality within the eastern segment (sections B30-42) of Bolivar Peninsula, Texas. Balloon locations delineate section boundaries, while color correlates with quality of nesting habitat immediately to the northeast.

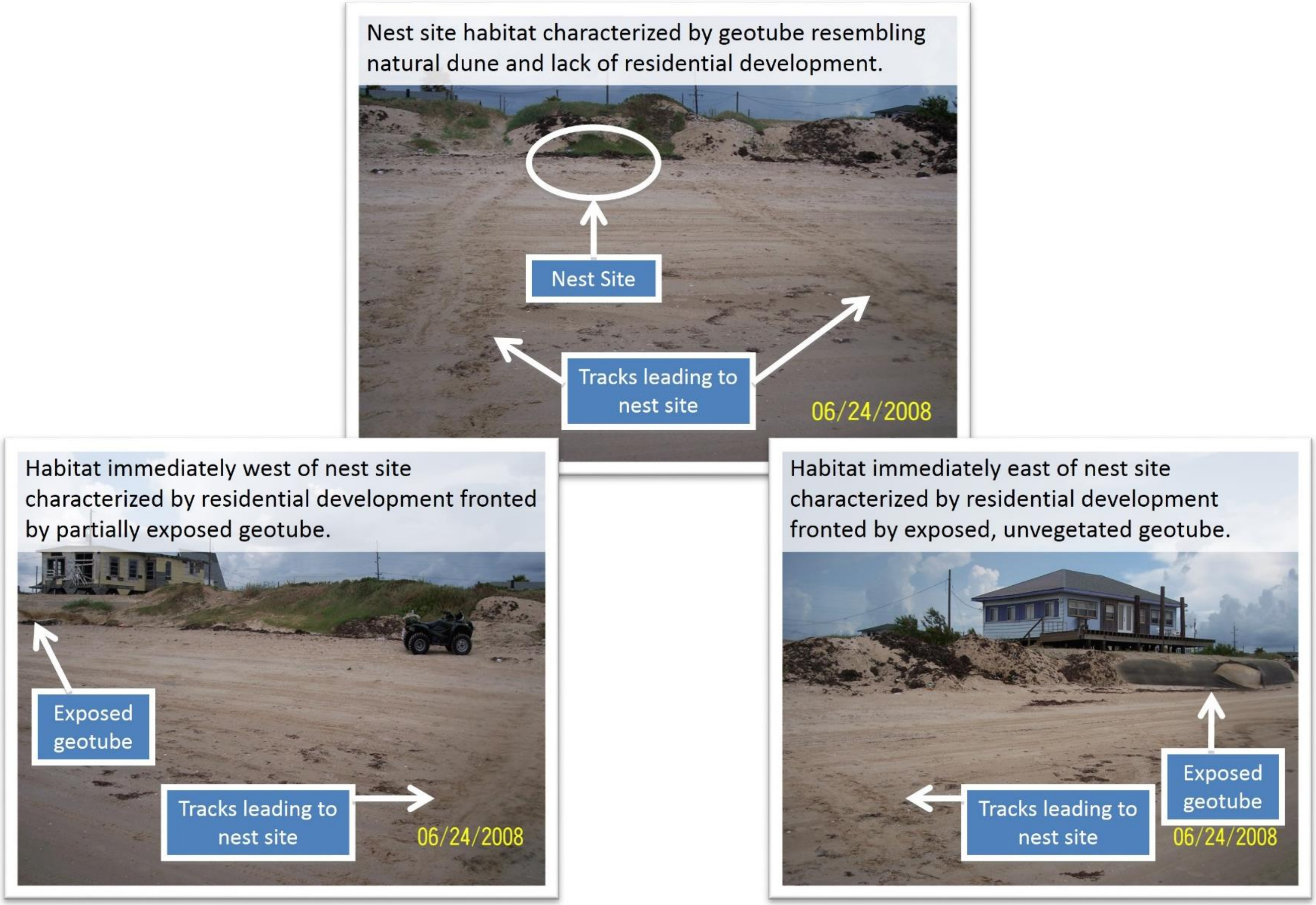
A loggerhead nest deposited within section B33 on 24 June 2008 constituted the sole nest located in habitat herein qualified as poor (Fig. 3.13, Table 3.11); no Kemp's ridley nests were documented in poor habitat (Tables 3.11 & 3.12). While section B33 was characterized by residential development protected from tidal inundation by an exposed geotube, the visual attributes of the specific nest site differed significantly from those of the general zone (Fig. 3.14, Table 3.11). The nest site, centrally located between poorer quality portions of beach, lacked the visual deterrent of residential construction and contained a fully covered segment of geotube that more closely resembled a natural dune.

Nesting activity by Kemp's ridleys along habitat qualified as fair (0.21 nests/km) was less than that documented on beaches classified as good (0.34 nests/km; Table 3.12). In addition, two of three documented non-nesting emergences occurred in fair habitats (Table 3.11). On 7 May 2002, a nester encountering a large branch near dunes in section B1 returned to the Gulf without laying eggs. On 13 May 2008, a female encountering pooled water above the tide line on section B6 also failed to deposit eggs (Fig. 3.15); data suggest this female successfully nested on section B4 (good habitat) the following day. A nest discovered while hatching on 16 July 2008 in fair habitat on section B12 was laid in the foredune depression less than 2 m east of a paved beach access road leading into a well-developed residential area (Table 3.11). However, it is not clear if the female traversed the dunes or travelled approximately 7 m along the sandy access road before

Table 3.12. Correlation between Kemp's ridley sea turtle nesting activity documented through 2008 and beach habitat quality on Bolivar Peninsula.

Section Quality	% of Zone	Total Length (km)	No. of Nests	Nests/km
Good	45.0	17.50	6	0.34
Fair	36.3	14.09	3	0.21
Poor	18.7	7.25	0	0.00
Zone Total	**100.0**	**38.84** [1]	**9**	**0.23**

[1] **Section B31 lacks nesting habitat and thus is not included in these calculations.**



Nest site habitat characterized by geotube resembling natural dune and lack of residential development.

Habitat immediately west of nest site characterized by residential development fronted by partially exposed geotube.

Habitat immediately east of nest site characterized by residential development fronted by exposed, unvegetated geotube.

Figure 3.14. Nest site selected by loggerhead turtle (*Caretta caretta*) in section B33 (poor habitat) on Bolivar Peninsula 24 June 2008. (Photos by Mark Bane.)

Figure 3.15. Site of Kemp's ridley sea turtle (*Lepidochelys kempii*) non-nesting emergence potentially caused by water pooled above high tide line in section B6 (fair habitat) on Bolivar Peninsula 13 May 2008. (Photo by Christi Hughes.)

turning east to access an unvegetated dune nest site. Individual nests were located in fair habitat of sections B6 (30 May 2008) and B40 (24 May 2007).

The remaining 6 Kemp's ridley nests, 1 loggerhead nest, and 1 false crawl were located in habitat classified as good (0.40 nests/km; Tables 3.10 & 3.11).

DISCUSSION

Qualification of Galveston Island and Bolivar Peninsula beach habitats presented herein represent only a snapshot in time of a dynamic environment susceptible to drastic alterations from both natural and anthropogenic sources. As such, recommendations presented in reference to specific sections should be considered generalizations adaptable to comparable situations, particularly in light of acute transmutations wrought by Hurricane Ike on constituent habitats in September 2008 [a comprehensive analysis of associated coastal alteration is provided by Doran et al. (2009)]. Additionally, while the generation of data specific to nesting beach habitats (particularly recently identified beaches on the UTC) is of paramount importance to long-term sea turtle conservation practices, managers must realize that the life history strategy and late maturation of these marine reptiles mean it may take decades for the effects of management decisions to be apparent.

Management of Threats to Sea Turtle Nesting Habitat

Beach Erosion & Nourishment

Huang's (1997) findings that current shoreline loss rates accelerated by anthropogenic influences on coastal erosion, including subsidence and predicted sea level rise, will leave beach habitats confined by a landward barrier of residential development vulnerable to associated ecological ramifications and infrastructure increasingly susceptible to damage from environmental hazards are applicable to UTC nesting habitats, particularly those associated with Galveston Island and Bolivar Peninsula. Although data are deficient for Bolivar Peninsula, Galveston Island has historically attained relative projected rates of sea level rise; a continuation of this trend will accelerate erosion rates that already exceed several meters per year (Feagin et al. 2005). Because natural plant and dune migration processes are prevented by hardened structures, remedies such as beach nourishment are required to maintain beaches functionally useful for both humans and sea turtles.

Minimizing detrimental biological impacts of nourishment on nesting sea turtles and nest products will require implementing a scientifically rigorous assessment process on the UTC that utilizes standardized methodology to analyze cumulative effects of nourishment activities. While previous research indicates sea turtle non-nesting emergence frequency is significantly increased on beaches during the first nesting season post-nourishment and subsequently decreases as natural processes restore beach slope equilibrium (Rumbold et al. 2001, Brock et al. 2008), data regarding false crawls in relation to nourishment are non-existent for Kemp’s ridley nesting beaches, including those on the UTC. Biological, physical, and chemical characteristics of a nourished beach are largely determined by sand source and application technique; ideally, fill material should simulate natural sediments (Crain et al. 1995, Montague 2008). Sea turtle nesting success is correlated with nest microhabitat quality; it is critical that pertinent sediment parameters be analyzed before, during, and after application of fill material, as post-nourishment restoration of natural sediment attributes may be impossible (Peterson & Bishop 2005).

Although an informational void exists regarding preferred beach width parameters for ridleys nesting on the UTC, nests at Rancho Nuevo are typically laid 10-35 m from the tide line (Márquez 1994). As ridleys preferentially nest between the base and top of the first dune (Márquez 1994), this may approximate the ideal crawl distance necessary to access dune habitat and serve as a rough estimate for beach extension distance on the UTC. The provision of adequate beach width (i.e., one that enables spatially diverse nest excavation options beyond the mean high tide line) is critical for undetected nests; all 14 nests successfully incubated *in situ* and detected while hatching on the Texas coast through 2007 (Shaver 2008), as well as 2 *in situ* nests successfully incubated on Bolivar Peninsula in 2008 (C. Hughes pers. obs.), were laid high on the beach in areas typically free of seawater washover.

When possible, nourishment activities should only occur outside of nesting season to avoid inherent detrimental impacts associated with increased activity, artificial lighting, construction equipment, and inadvertent burial of *in situ* nests. Projects occurring on the UTC between 1 April and approximately 15 August will require monitors to minimize possible negative interactions with nesters and hatchlings. Dissipation of steep scarps will occur naturally as beach profiles normalize (Crain et al. 1995). Nonetheless, scarps functioning as obstacles to nesters accessing more landward beach habitats, such as those documented on four recently nourished sections (S1, S3, S10, S17) of Galveston Island in 2008, should be removed manually.

Nourishment is an appropriate, albeit temporary, solution to erosion of multiple poor sections on Galveston Island (W5, W7, W9, W11, W13, W17, W19, S5, S7-9, S11, S16; Figs. 3.1 & 3.2, Tables 3.1 & 3.3) and Bolivar Peninsula (B28, B32, B33, B35-38; Figs. 3.8 & 3.9, Table 3.9) typified by narrow beaches with enhanced potential for tidal inundation of nests. It was effectively employed as a provisional solution in May and June 2008 for Bolivar Peninsula section B29 that, while characteristically similar to the aforementioned sections, is currently qualified as fair since it provides females with nest placement locations at varying distances above the high tide line.

Dune Habitat & Vegetation Coverage

Beach ecosystems managed to retain their natural morphology provide numerous multifaceted, crucial benefits to adjacent coastal communities and multiple user groups, including beachgoers and sea turtles. For UTC economies reliant on tourism dollars, beach aesthetics improved by dunes and native plant communities are critical in attracting visitors to coastal regions. The presence of vegetation is essential for land management purposes associated with the Texas Open Beaches Act § 61.011, as the vegetation line delineates boundaries separating public and private coastal property. In addition, dunes function as natural buffers against storm systems and, thus, may financially benefit communities by protecting home and business owners from negative impacts associated with storm-induced wave action.

Vegetated dunes provide a favorable environment conducive to sea turtle nesting and overall reproductive success. Visual composition of the nesting beach environment, specifically that produced by dunes, vegetation, and beach width and slope, is a critical component of sea turtle nest site selection. Females detecting unsuitable terrestrial environment conditions during their initial habitat assessment performed immediately before emergence onto the beach (Pike 2008) may fail to emerge and instead proceed to an alternative nesting location. Vegetation minimizes substrate compaction levels, and the elevated, darker silhouette created by vegetation and/or dunes (in contrast to the lower, brighter seaward horizon) is a critical component of hatchling seafinding success (Salmon et al. 1995, Bertolotti & Salmon 2005, Bourgeois et al. 2009). Robust estimates of preferred nest locations along the horizontal beach gradient between the forebeach and second foredune do not exist for Kemp's ridleys nesting on the UTC, and nesting locations landward of the base of the foredunes are often inaccessible due to man-made barriers such as the seawall, sand fences, and residential structures. However, only 2 of 39 total nest sites documented herein were laid seaward of the embryonic dunes, thus signifying the potential importance of dune habitat in nest site selection for sea turtles on the UTC.

Beach raking and scraping activities, which intensify during the co-occurrence of nesting and tourist seasons, have prevented the perpetuation of dune face vegetation on various sections of Bolivar Peninsula classified as fair or good (B6-B12, B14-B19, B21-B23, B25; Figs. 3.7 & 3.8, Table 3.9). The practice of depositing scraped sand on the dune face should be reevaluated in comparison to alternatives that support dune vegetation persistence while concurrently benefitting sea turtles, as the former endangers undetected *in situ* nests. Excess sand covering *in situ* nests may negatively alter incubation temperatures, and hatchlings may be incapable of digging through surplus substrate before succumbing to exhaustion or suffocation.

Current rates of beach erosion on the UTC will likely be exacerbated in the near future by anthropogenic factors, including sea level rise and continued loss of native dune vegetation due in part to increasing coastal development (Feagin et al. 2005). Accelerated beach erosion will increase habitat managers' dependence on temporary and costly mitigation measures, such as beach nourishment, to maintain beach widths enabling dune habitat persistence. Cost-effective, long-term beach habitat management strategies must incorporate the maintenance and/or regeneration of natural sand dunes and associated plant communities (Feagin et al. 2005, Ficetola 2007, de Araujo & da Costa 2008, Montague 2008, Bourgeois et al. 2009, Mazaris et al. 2009), as dune vegetation minimizes erosion, binds sediments, and enhances dune formation (Márquez 1994, Feagin et al. 2005), thus reducing dependence on expensive erosion control measures. Dune restoration also significantly improves sea turtle reproductive success, particularly on developed beaches compromised by artificial lighting, by intensifying hatchling seafinding cues associated with disparities in landward and seaward horizon elevation (Salmon et al. 1995, Bertolotti & Salmon 2005, Tuxbury & Salmon 2005).

Restoration of natural dune systems (and adjacent beach width adequate to maintain them) is recommended for a multitude of sections on Galveston Island (W5, W7, W9, W11, W13, W17, W19, W21; Fig. 3.1, Table 3.1) and Bolivar Peninsula (B28, B32, B33, B35-B39; Figs. 3.8 & 3.9, Table 3.9), particularly narrow beaches bordered by a geotube. Habitat restoration should incorporate dune building with replanting multiple species of native vegetation, particularly perennial, late successional species capable of binding sediments. Maintenance of beach width and cohesive dune ecosystems on multiple Galveston Island (W1-4, W6, W8, W10, W12, W14-16, W18, W20-23, E1, E5, E7; Figs. 3.1 & 3.3, Tables 3.1 & 3.5) and Bolivar Peninsula (B1, B3-B5, B13, B24, B26, B27, B40-B42; Figs. 3.7-3.9, Table 3.9) sections characterized as good or fair should also be prioritized, as these comparatively healthy natural systems assist in reducing beach erosion and serve as a seed source for associated habitats.

Residential & Commercial Development

Beach environments, particularly those utilized by nesting sea turtles, should be protected from unplanned, uncontrolled development (Ficetola 2007, de Araujo & da Costa 2008). Implementation of setback regulations prohibiting development within a defined distance from shore would aid in maintaining natural beach morphology and vegetation and substrate characteristics (Mazaris et al. 2009) critical to sea turtle reproductive success. Setback regulations preserving the natural ecology of beaches susceptible to weather-related disturbances like hurricanes allow them to function as migratory buffers, thus minimizing damage to residential and commercial structures (Fish et al. 2008). Opposition to setback regulations could be minimized with implementation schemes applicable only to future development. Benefits accrued from restricting development of beach habitat include increased tourism revenue for local communities (sea turtle-related tourism is successfully exploited globally on nesting beaches), reduced short- and long-term financial costs associated with hurricane damage, and improved quality of beach environments.

Artificial lighting from residential and commercial development is currently the least likely factor to negatively impact UTC nesting beaches. However, expected increases in sea turtle nesting and continued beachfront development will amplify the detrimental effects of lighting on sea turtle reproductive success if light pollution is not eliminated or controlled. Implementation of lighting ordinances encompassing the Kemp’s ridley nest hatching season (approximately 15 May – 15 August) would aid survival and seafinding of hatchlings emerging from *in situ* nests by reducing mortality associated with lighting-induced misorientation and disorientation. While lighting is unlikely to affect diurnally nesting Kemp's ridleys, previous research has shown the majority of this species' nest emergences occurs between 0200 and 0400 (J. Peña pers. comm.), thus justifying the need for lighting ordinances on ridley nesting beaches. As nocturnal nesting activity on developed beaches is inversely correlated with lighting (Salmon et al. 1995), lighting restrictions may facilitate an increase in nesting activity by loggerhead females while reducing the potential for nester disorientation, particularly on Bolivar Peninsula. Specifics of lighting ordinances should include extinguishing all non-critical lights; reducing wattage and/or altering luminaire type [i.e. Witherington (1992) demonstrated that low pressure sodium vapor bulbs had no significant effect on nesting when compared to that from mercury vapor bulbs; LED's warrant examination]; and filtering, lowering, and/or shielding light sources to reduce beachside visibility of lights. Integrating lighting ordinances with dune and beach habitat restoration would greatly reduce associated negative impacts as normal hatchling orientation can occur on light-polluted beaches when horizon elevation cues are enhanced (Bertolotti & Salmon 2005, Tuxbury & Salmon 2005).

On Bolivar Peninsula, where beachfront habitat wasn't as heavily developed as that on Galveston Island, 5 of 6 Kemp's ridley nests laid in 2008 were located in sections where residential development was situated well behind vegetated dunes of moderate height (B4, B5, B6, B16; Figs. 3.11 & 3.12, Table 3.11); 3 of these nests were in sparsely developed areas with minimum potential for visual deterrence of nesters. In addition, the loggerhead nest documented in 2008 was situated in habitat lacking manmade structures within the visual frame of reference utilized by females during nest site selection (Salmon et al. 1995, Fig. 3.14). Although additional research is required to determine the influence beachfront development has on nest site selection, particularly that by Kemp's ridleys utilizing UTC beaches, results reported herein indicate turtles may preferentially nest on undeveloped or minimally developed beaches containing vegetated dunes and lacking permanent erosion control structures.

Obstacles to Nesting

Visual contamination of beach habitats by solid waste from terrestrial and oceanic sources, particularly plastics (Fig. 3.16), is of widespread and growing global concern due to its negative effects on tourism and wildlife, including sea turtles (de Araujo & da Costa 2008). Ensuring an aesthetic state of Texas' beaches should be of significant concern to upper coast economies dependent upon income generated by tourism. Beach litter may visually deter nesting females or serve as an obstacle to nest site selection and/or digging (Santos et al. 2006), subsequently increasing the incidence of non-nesting emergences (Montague 2008). Refuse creates a significant obstacle to a hatchling's forward movement, potentially increasing time necessary to access the sea and thus reducing survivorship by increasing predator exposure (Montague 2008). UTC beaches, associated wildlife, and corresponding local economies would benefit significantly from remediation of refuse-strewn beach habitats; supplementations to current beach cleanup

Figure 3.16. Typical Bolivar Peninsula beach habitat (section unknown) littered with refuse following post-holiday tourism activity 7 July 2008. (Photo by Christi Hughes.)

efforts include bolstering and enforcement of beach litter policies and public education efforts aimed at source reduction.

Anthropogenic structures constructed on beach habitats may also pose an obstacle to sea turtle reproductive success (Márquez 1994, Santos et al. 2006). A multitude of beach sections on Galveston Island (W4, W21; Fig. 3.1, Table 3.1) and Bolivar Peninsula (B4-B6, B9, B12, B21, B26, B28, B29, B32-B37; Figs. 3.7-3.9, Table 3.9) contain dune or geotube crossovers enabling public beach access while preventing damage to sensitive dune habitats. While the majority of these structures are designed to minimize their footprint on beach habitat, a significant number are constructed in a manner that maximizes the potential to obstruct nester and hatchling movement (Fig. 3.10). Entrapment by crossovers is a potential source of mortality (due to hyperthermia during daylight hours) for nesters and hatchlings. Emerging hatchlings may also fail at seafinding due to disorientation or misorientation sourced from the visually altered landscape created by crossovers. While conflicts between nesting or hatchling turtles and dune crossovers have not been documented, beach habitats should be managed to reduce the potential for negative interactions between these federally protected animals and beachside constructions. These concerns mandate that construction of new dune crossovers occur only as needed and employ designs minimizing impacts to sea turtles.

Finally, policies permitting vehicular traffic on beach habitats, particularly those utilized by nesting sea turtles, are of great concern (Santos et al. 2006). While vehicular traffic is prohibited on the majority of Galveston Island's beaches (Chapter II specifies vehicle access policy), it remains unrestricted on all surveyed sections of Bolivar Peninsula and is encouraged through the provision of numerous beach access points. Through 2008, Texas' beach driving policies have resulted in the documented deaths of three nesting females, including a loggerhead struck and killed after nesting on Bolivar Peninsula (section B22) in 1996 (Shaver 2009, B. Higgins pers. comm.). Vehicles also served as a source of mortality for multiple hatchlings emerging from both *in situ* nests detected while hatching on Bolivar Peninsula (sections B12 and B16) in 2008 (C. Hughes pers. obs.). The beach-going public's lack of knowledge regarding use of UTC beaches as nesting habitat is of growing concern. Failure to inform this constituency may lead to an increase in vehicular-related deaths to sea turtles, given the likelihood that the ongoing recovery exhibited by the Kemp's ridley will precipitate increased nesting activity on the UTC. Habitat managers and policy makers should periodically evaluate the efficacy of instituting spatial and/or temporal driving limitations on Bolivar Peninsula beaches to protect sea turtles. In addition, workers operating machinery on all UTC beaches during nesting season (beach rakers, nourishment crews, etc.) should receive training in sea turtle identification and nesting response.

Management of Sea Turtle Nest Products

An informational void exists regarding the ability of UTC beaches to provide suitable incubation conditions (thermal regime, hydric environment, sand mineral content, gas exchange, etc.) for sea turtle nests. However, hatching success rates estimated for all 3 *in* *situ* nests detected while hatching on the UTC through 2008, including 1 on Galveston Island (2007) and 2 on Bolivar Peninsula (2008), were between 80.6-94.3% (D. Shaver, pers. comm.), suggesting that nests can be successfully incubated in constituent habitats.

Nearly all detected nests deposited on the Texas coast (with the exception of those on South Padre Island and Boca Chica Beach) are transported by vehicle to an incubation facility operated by the National Park Service at PAIS following excavation by trained, permitted responders. However, multiple management options for sea turtle nest products located on the UTC exist and should be periodically re-evaluated to ensure implementation and/or continuance of the most viable and appropriate course of action to maximize sea turtle reproductive success while minimizing time and monetary costs.

Nest relocation practices utilized on the UTC since the 1996 inception of nesting involve excavation and placement of eggs into Styrofoam incubation boxes lined with sand obtained at or near the nest site. These eggs undergo two separate transfers by vehicle to reach PAIS for subsequent incubation and hatchling release during the critical 6-48 hour post-oviposition timeframe identified by Márquez (1994) in which inappropriate egg handling can result in complete clutch failure. Lethal developmental deficiencies and mortality rates reaching 100% can occur during nest relocation or transport which results in egg inclination and embryo rotation, vibrations, contamination and/or overheating (Márquez 1994). While hatching success rates obtained from Bolivar Peninsula nests subjected to cumulative vehicle transport times typically exceeding six hours have been comparable to those from nests deposited and incubated at PAIS, this method involves substantial risk to developing embryos.

State and federal resource managers must carefully consider the long-term effects of continued relocation of sea turtle nest products from the UTC to PAIS, as this practice may endanger the role of constituent beaches as important natal nesting habitat and thus negate associated socioeconomic and ecological benefits. While the imprinting process that enables natal philopatry by nesters is not fully understood (Meylan et al. 1990, Márquez 1994, Crain et al. 1995, Shaver 2002b), hatchlings incubated and released at PAIS will likely return to PAIS, and not their natal beach, to nest, thus reducing the potential for increased nesting fidelity to the UTC. In addition, further increases in number of nests laid on UTC beaches, combined with expected growth in nesting activity at PAIS, may soon render transfer of clutches to PAIS time- and cost-prohibitive.

Relocation of UTC nests to a centrally located corral secured against egg poaching and natural predation, such as a facility located within Galveston Island State Park and safeguarded by the Texas Parks & Wildlife Department (TPWD), should be assessed as an alternative to transferring clutches to PAIS. This protocol is utilized effectively at PAIS (Shaver 2010), in South Texas (South Padre Island and Boca Chica Beach; C. Hughes pers. obs.), and on the ridley's primary nesting beach at Rancho Nuevo (NMFS, USFWS & SEMARNAT 2011). Risk of embryonic mortality associated with egg handling is minimized in clutches relocated to a hatchery within 2 hours of deposition (Eckert et al. 1999). Furthermore, hatching success rates from sea turtle nests relocated promptly can be comparable to nests incubated *in situ* (Mrosovsky 2006). Increased hatching and emergence success rates may be obtained with use of improved transport boxes, as occurred with the experimental container used to convey Kemp's ridley eggs described by Vazquez-Sauceda et al. (2008). As such, local relocation poses considerably less risk to nest products than does long-distance translocation to PAIS. More importantly, release of hatchlings imprinted to natal UTC beaches will preclude the loss of an associated nesting cohort and will likely contribute to long-term nesting increases, thus creating exploitable ecotourism and public education opportunities with future expansion potential.

Conclusions

Habitat quality along the UTC, including that on Galveston Island and Bolivar Peninsula, significantly impacts the economic health of constituent communities dependent upon tourism revenue and the potential to establish a self-sustaining cohort of nesting sea turtles. State and federal agencies responsible for implementing management policies must carefully consider interdependent socioeconomic and environmental concerns in developing strategies for the long-term governance of UTC beach habitats. While public use of UTC beach environments is very diverse, restoration and maintenance of constituent habitats successfully serving a multitude of user groups does not preclude the simultaneous provision of beaches able to support sea turtle reproductive success.

The evolution of sea turtle management practices on the UTC will require additional research in relation to the following questions, which are adapted from those originally posed by Santos et al. (2006). First, what actions can be taken to maintain existing high quality nesting habitat in undeveloped areas, and what can be done to improve compromised nesting habitat, particularly in areas with extensive coastal development? Second, if current nest product management procedures are altered to allow eggs laid on the UTC to remain for subsequent incubation and release, what criteria will be used to identify surrogate incubation habitat? Finally, how much and what kinds of terrestrial habitat disturbances can sea turtles, particularly Kemp's ridleys, tolerate?

While current nesting totals indicate that the population of the critically endangered Kemp's ridley turtle, Texas' dominant nester, remains significantly reduced from historic abundance levels, the recovery of this species is ongoing (NMFS, USFWS & SEMARNAT 2011). Continued examination of the role of the UTC in providing nesting habitat to increasing numbers of conspecifics is critical, and must be coupled with successful beach habitat conservation and management plans minimizing conflicts between nesters and other beach user-groups while promoting ecotourism benefiting sea turtles and local economies.

CHAPTER IV

INTERNESTING AND FORAGING HABITATS AND ASSOCIATED MIGRATORY CORRIDORS UTILIZED BY KEMP'S RIDLEY SEA TURTLES INTERCEPTED ON UPPER TEXAS COAST NESTING BEACHES

INTRODUCTION

Decades of conservation measures employed on historically significant Kemp's ridley sea turtle (*Lepidochelys kempii*) nesting beaches, particularly those at Rancho Nuevo, Tamaulipas, Mexico, have contributed to exponential increases (approximately 15% annually) in the propagative female population of since the mid-1980's demographic bottleneck (Heppell et al. 2005; Márquez et al. 2005; NMFS, USFWS & SEMARNAT 2011). Regulations protecting nesters and nest products, in conjunction with significant reductions in at-sea mortality via enforcement of turtle excluder device (TED) utilization by U.S. and Mexican shrimp trawlers, are primarily credited for optimistic indicators of recovery for this Critically Endangered sea turtle (IUCN 2011). However, current population assessments are primarily based on temporally robust nesting beach data sets that lack essential in-water demographic information critical to proactive management schemes ensuring the ridley's continued recovery (NRC 2010).

Protection and management of in-water life stages is a Priority 1 Recovery Task in the 2011 revision of the Kemp's Ridley Recovery Plan, yet data describing spatially and temporally discrete neritic habitats currently utilized by mature ridleys in the Gulf of

Mexico are insufficient (NMFS, USFWS & SEMARNAT 2011). Life stage comparisons suggest increasing survivorship of breeding adults in long-lived species, including the Kemp's ridley, has a significant positive impact on population growth rate (Heppell et al. 1999, Gerber & Heppell 2004). Therefore, further reductions in adult mortality, particularly that associated with negative human impacts and achieved through geographically distinct and seasonally appropriate management strategies, may aid recovery efforts. Successful implementation and evaluation of habitat conservation tools, such as spatially delineated marine protected areas (MPA; NMFS, USFWS & SEMARNAT 2011), will require substantive information to identify seasonal usage of breeding, inter-nesting, and foraging habitats and behaviors, as well as associated connective migratory corridors.

Reproductively mature female ridleys primarily inhabit neritic Gulf of Mexico waters less than 37 m in depth spanning from the northern tip of the Yucatan Peninsula to southern Florida (Byles 1989; Morreale et al. 2007; Shaver & Rubio 2008; NMFS, USFWS & SEMARNAT 2011). Nesters utilizing Mexico's beaches engage in directed northern or southern post-nesting migrations throughout the majority of this range (Byles 1989, Renaud et al. 1996, Shaver et al. 2013), while Texas' nesters primarily establish residency in northern and eastern Gulf of Mexico foraging habitats (Seney & Landry 2008, 2011; Shaver & Rubio 2008; Shaver et al. 2013). However, seasonal movements between foraging grounds, nesting beach remigration, and courtship and breeding habitats remain poorly defined (NMFS, USFWS & SEMARNAT 2011) as satellite tracking durations have typically spanned less than one year.

A paucity of data exists for the small but increasing number of Kemp's ridleys recurrently utilizing upper Texas coast (UTC) nesting habitats. Telemetry research conducted by Seney & Landry (2008, 2011) on six UTC nesters suggests inter-nesting residency off Galveston Island in waters <10 m in depth, followed by directed post-nesting movements along the 20 m isobath to neritic foraging grounds offshore central Louisiana. Additional satellite telemetry research on UTC nesters is warranted to examine intra- and inter-annual nest site and foraging area fidelity, as well as to permit a more robust quantification of movements in the marine environment. The investigation herein also addresses a Kemp's Ridley Recovery Plan task mandating the protection and management of marine habitats utilized by conspecifics, in part via the identification of "important marine foraging, breeding, and inter-nesting habitats" and the determination of migratory pathways between and among foraging grounds and nesting beaches.

METHODS

All sea turtles intercepted while engaged in nesting activity on the UTC during 2007-2009 were examined for existing tags and assessed for potential in-season fecundity and suitability for satellite tagging (Chapter II details obtainment of nester morphometrics and nesting data). Existing external metal flipper and living tags, as well as internal passive integrated transponder (PIT) and coded wire tags, permitted differentiation between headstarted and wild turtles. Metal flipper and/or PIT tags were deployed on females lacking such identifiers to aid in future nesting activity documentation. Ultrasonography (via the inguinal region) of females at their nest site enabled confirmation of non-nesting emergences via the detection of calcified oviductal eggs, while further ultrasound inspection of post-nesting females at the National Oceanic and Atmospheric Administration Sea Turtle Facility (NOAA STF) facilitated identification of vitellogenic or atretic follicles, both of which are indicative of short-term reproductive potential (Rostal et al. 1990, Rostal 2005). One female possessing calcified eggs after engaging in a non-nesting emergence was retained for transmitter attachment in 2007 without incident; however, protocol instituted in 2008 prevented future retention of such nesters. Turtles were never placed in dorsal recumbency.

Satellite Telemetry

Transmitter Attachment

Eight intercepted females were outfitted with a 480 g Sirtrack KiwiSat 101 platform transmitter terminal (PTT) incorporating a Tygon reinforced 4NC antenna and a 2 x C cell battery package. Transmitters were programmed to broadcast messages at a frequency of 401.65 MHz using a 40 second repetition rate and set to operate with a duty cycle of 6 h on:6 h off, thus requiring activation at the beginning of their duty cycle at either 0900 or 2100 GMT (0400 or 1600 CDT). Throughout the 3 to 4 h duration of the PTT attachment process, turtles were dry-docked within a foam-padded transport container or empty fiberglass tank inside an ambient temperature NOAA STF building.

Females retained longer than required for transmitter attachment (i.e. overnight) were held in circular tanks containing locally sourced, ambient temperature seawater until release, which occurred no later than 24 h after initial interception.

PTTs were attached to the first and second vertebral scutes of the nester's carapace with the antenna oriented anteriorly following protocol developed by Seney & Landry (2008; also described in Seney et al. 2010) and similar to other commonly used techniques for hard-shelled sea turtles. This process involved priming the sides and bottom of the PTT (previously coated in aerosol anti-fouling paint) and relevant sections of the turtle's carapace for transmitter attachment with 60-grit sandpaper, followed by an acetone wash. Two coats of Power-Fast two-part standard set epoxy were applied, with sufficient drying time allowed between coats for the outer layer to moderately solidify. Three to four tubes of Sonic-Weld marine epoxy (Mansfield 2006) were distributed over the entire transmitter attachment, smoothed with minimal application of soapy water, and allowed to set for approximately 10 minutes. Finally, two coats of Interlux Micron Extra antifouling paint were brushed onto the entire attachment (excluding PTT saltwater switches and antenna). Releases of telemetered turtles occurred during daylight hours at their nest site or a suitable alternate UTC location.

Data Analysis

Turtle movement data obtained from the transmitters via NOAA's Polar Orbiting Environmental Satellites (POES) were processed and communicated by CLS America to provide location (latitude and longitude derived from the Doppler effect on frequency of received transmissions) and location class (LC) information yielding estimations regarding location accuracy (Table 4.1; Argos 1996). In addition, broadcast messages provided the PTT's unique identifier; transmission date and time; duration of, and number of messages received during, each satellite communication; battery current drain; and saltwater switch moisture level. Accession of archived tagging data via the Satellite Tracking and Analysis Tool (STAT; Coyne & Godley 2005), freely available on SEATURTLE.ORG, enabled obtainment of integrated environmental data for each location including bathymetry, weekly sea surface temperature (SST), and distance to shoreline.

STAT was employed to remove locations of class Z (indicative of a data processing failure; Table 4.1) and those exceeding 1.0 m in elevation. Minimization of autocorrelation in spatial analyses was achieved via the selection of a single "best" daily location (Hawkes et al. 2011, Arendt et al. 2012a) in which only the first occurrence of the highest quality LC during each 24-hour period was retained. Following intensive categorization and filtering of satellite tracking data obtained in the current study, LC 0 was considered either more precise than, or equally reliable as, LC A, despite recent evidence to the contrary (Hays et al. 2001a, Scott 2006, Royer & Lutcavage 2008). Hence, location classes were prioritized upon traditional estimates of accuracy, as supported in recent field studies by Costa et al. (2010): LC 3 > 2 > 1 > 0 > A > B.

Table 4.1. CLS America's Argos location class (LC) accuracy, including potential latitudinal and/or longitudinal deviations from a PTT's[1] true position (Argos 1996).

Location Class	**No. of Messages**	**Estimation of Accuracy (m)**
3	≥4	<150
2	≥4	150 - 350
1	≥4	350 - 1000
0	≥4	>1000
A	3	none
B	2	none
Z[2]	N/A	N/A

[1] **PTT: platform terminal transmitter.**

[2] **Location class information categorized as "Z" indicates a processing failure.**

Data were then subject to simultaneous filters pioneered by Arendt et al. (2011) that omitted locations requiring turning angles of <5° and/or linear swimming speeds exceeding 5 km h^{-1} (Renaud 1995). Failure of the initial best daily location to meet subsequent filtering criteria resulted in either the substitution of corresponding alternate tracking information or complete omission of that day's location from the data set, with this protocol permitting a mean retainment of 99.2% (SD ± 0.5, range = 98.5 – 100%; Table 4.2) of original observation days for the eight monitored turtles.

Retained coordinates were imported into ArcGIS 9.3. Discernibly erroneous geolocations, which averaged 3.8% (SD ± 3.6, range = 0.9 – 12.0%; Table 4.3) of filtered data across eight individuals, were manually omitted. Internesting periods, migratory routes, and foraging areas were deduced based upon directionality and displacement of plotted locations from each turtle's release site, similar to criteria utilized by Hawkes et al. (2011). As no subsequent nesting events were confirmed for any individuals tracked in this study, internesting intervals were deemed terminated when turtles initiated directed movements east or northeast for a minimum of 7 consecutive days to destinations excepting the UTC, criteria similar to that employed by Mansfield et al. (2009). Migratory phases consisted of consecutive directional movements (Griffin et al. 2013), while foraging areas were characterized by restricted, primarily non-directional movements utilized by an individual for a minimum of 12 consecutive days (≥11 geolocations). This temporally- and behaviorally-based termination of migratory behavior (including post-nesting migration) is more robust than

Table 4.2. Modification of "best" daily location information following application of simultaneous speed and turning angle filters[1] on data exported from STAT[2].

Turtle ID	No. of STAT Geolocations	No. of Substitutions[3]	% Rejected Geolocations	No. of Retained Geolocations
74912	407	4	0.5	405
74913	273	1	0.4	272
74914	534	4	0.9	529
74915	349	1	0.9	346
74917	25	0	0.0	25
75421	343	7	1.5	338
83239	439	8	1.1	434
83242	356	9	1.4	351

[1] Filtering method pioneered by Arendt et al. (2011).

[2] STAT: Satellite Tracking and Analysis Tool (Coyne & Godley 2005).

[3] Corresponding alternate tracking information used when initial "best" daily location failed to meet filtering criteria.

Table 4.3. Modification of discernibly erroneous "best" daily location information coincident with importation of filtered data into ArcGIS 9.3.

Turtle ID	No. of Imported Geolocations	% Rejected Geolocations	No. of Retained Geolocations
74912	405	4.4	387
74913	272	3.3	263
74914	529	0.9	524
74915	346	0.9	343
74917	25	12.0	22
75421	338	4.4	323
83239	434	1.4	428
83242	351	3.1	340

that utilized in other sea turtle tracking studies (Zbinden et al. 2008, Marcovaldi et al. 2010).

Subsequent unconfirmed nesting events for tagged ridleys were inferred based upon filtered Argos data as tag duty cycles prevented comprehensive documentation of turtle movements during the internesting period. Duty cycles incorporated to maximize PTT battery life negated the transmission of geolocation information from 1000 to 1559 CST, a time period during which ridleys frequently nest on UTC beaches (see Chapter II). Probable nesting events were deduced based upon plotted location coordinates examined in conjunction with LC, pass duration, salt water switch parameters, and movement behavior (Seney & Landry 2008, Tucker 2010) during the two days preceding and subsequent to such events.

Home Range Tools (HRT; Rodgers et al. 2007) for ArcGIS generated travel paths to, and kernel density estimates (KDE; 50% and 90%) for, each foraging ground with ≥34 daily locations (Millspaugh & Marzluff 2001). Geolocations for foraging grounds utilized during temporally-distinct periods by a post-nesting female were coalesced to generate single cohesive KDE contours. Distortion in KDE contours was minimized by associating location coordinates with the proper Universal Transverse Mercator coordinate system zone (15N, 16N, or 17N) in ArcGIS. Data were subject to the fixed least squares cross-validation smoothing factor and rescaled to unit variance if the ratio of standard deviations exceeded 1.5. For the purposes of estimating core activity areas

(50% probability contour; Hooge et al. 1999) and calculating utilization distributions (90% probability contour; Borger et al. 2006), migration was considered to have ceased when the directional path crossed the established foraging zone boundary (Griffin et al. 2013), resulting in the potential inclusion of up to several days of directional movement inside the foraging ground for KDE estimate generation. Resultant KDE contours were not clipped to exclude limited terrestrial areas contained within specified 50% (n=1) and 90% (n=4; Table 4.4) probability contours for four individuals (74912, 75421, 83239, 83242).

Bureau of Ocean Energy Management (BOEM) Official Protraction Diagram and Leasing Map boundaries, which delineate federal continental shelf Boundary Areas used in exploration and development of Gulf mineral resources such as oil and gas, were incorporated into certain figures exhibiting turtle location data. Boundary Areas were defined to facilitate sea turtle management efforts in the Gulf of Mexico in coordination with resource extraction interests.

RESULTS

Satellite transmitters attached to eight Kemp's ridleys intercepted following nesting activity on UTC beaches between 2007-2009 broadcast location information for an average of 422 days/female (SD ± 194, range = 26 - 710 d; Fig. 4.1, Table 4.5). Seven females were tracked beyond the internesting period; no probable cause was evident for the premature failure of turtle 74917's tag after only 26 days of tracking. Nester stock

Table 4.4. Core use activity areas (50% KDE) and utilization distributions (90% KDE) for Kemp's ridley foraging grounds (n=17) in the Gulf of Mexico with ≥34 locations.

	F1[1]: KDE			F2: KDE			F3: KDE			F4: KDE		
Turtle ID	50% (km^2)	90% (km^2)	No. of Geolocations	50% (km^2)	90% (km^2)	No. of Geolocations	50% (km^2)	90% (km^2)	No. of Geolocations	50% (km^2)	90% (km^2)	No. of Geolocations
74912	285.9	894.6	76	N/A[2]		13	116.6	696.6[3]	251			
74913	N/A[2]		15	1933.8	6181.6	120	465.1	1389.5	75			
74914	183.4	876.6	401	513.8	1471.9	43	N/A[2]		15			
74915	585.8	1803.6	39	2053.6	6115.9	119	153.8	531.9	41	N/A[2]		11
74917[4]	N/A											
75421	52.8[3]	375.8[3]	218									
83239	926.4	3684.5[3]	156	564.8	1927.7	112	298.8	876.1	73	361.2	1272.8	47
83242	674.0	2133.1	55	N/A[2]		15	288.4	1005.4	34	2098.6	8091.3[3]	105

[1] Denotes initial foraging ground used by an individual. Subsequently utilized foraging grounds are designated F2, F3, and F4.

[2] Excluded from calculations due to an insufficient number of geolocations.

[3] Area was not modified to exclude terrestrial components and thus overestimates accessible marine habitat utilized by the individual.

[4] PTT failed prior to commencement of foraging behavior.

Table 4.5. Confirmed and postulated upper Texas coast nesting events[1] for Kemp's ridleys (n=8) satellite tracked between 2007-2009.

						Confirmed Nesting Activity		**Speculated Nesting Activity**		
Turtle ID	**Tag Deployment Date**	**Release Location**	**Tracking Duration (d)**	**Nester Stock**	**SCL[2] (cm)**	**Date**	**Location**	**Date**	**Location**	**Geolocation on Land?**
74912	5/18/2007	Galveston Island	467	Headstart: 1991[3]	64.0	5/17/2007	Galveston Island			
74913	5/18/2007	Galveston Island	376	Headstart: 1989[3]	62.4	5/17/2007	Galveston Island	6/7/2007[4,5]	Galveston Island	Yes
74914	5/26/2007	Galveston Island	710	Headstart: 1992[3]	61.0	6/4/2005[6]	Galveston Island			
						5/26/2007[7]	Galveston Island			
						6/13/2011[8]	Galveston Island			
						6/28/2011[8]	Galveston Island			
74915	5/18/2007	Galveston Island	405	Captive Reared: 1995[3]	59.7	5/18/2007	Galveston Island			
74917	5/1/2008	Galveston Island	26	Headstart: 1992[3]	64.0	5/1/2008	Galveston Island	5/20/2008[4,9]	Matagorda Island	Yes
75421	5/14/2008	Surfside Village	409	Headstart: 1991[3]	62.4	5/6/2006[6]	Galveston Island	6/2/2008[4,10]	Follets Island	Yes
						5/13/2008	Surfside Village			
83239[11]	5/20/2008	Galveston Island	562	Headstart: 1989[3]	62.0	5/6/2006[6]	Galveston Island	6/3/2008[4,12]	Galveston Island	N/A
						5/26/2006[6]	Galveston Island			
						5/20/2008	Galveston Island			
						5/19/2010[8]	Galveston Island			
83242[11]	5/2/2009	Galveston Island	419	Wild	67.6	4/28/2006	Galveston Island			
						5/2/2009	Galveston Island			

[1] Provided information includes data obtained through 2011 only.

[2] SCL: straight carapace length (notch-tip); measurement derived coincident with PTT attachment by this study (2007-2009).

[3] Yearclass headstarted or captive reared at the NOAA Sea Turtle Facility in Galveston, Texas.

[4] Nesting activity unconfirmed but speculated based on comprehensive analysis of telemetry data and individual's internesting behavior.

[5] Telemetry Data: LC 2, Depth +0.9 m, SWS 243, 9 messages received, 351 s pass duration. Location is within 9 km of previous nest site and 2 km of 6/5/2007 geolocation (also on land).

[6] Seney 2008.

[7] Confirmed non-nesting emergence.

[8] A Landry pers. comm.

[9] Telemetry Data: LC 3, Depth +0.9 m, SWS 254, 13 messages received, 697 s pass duration.

[10] Telemetry Data: LC 3, Depth -0.1 m, SWS 247, 10 messages received, 520 s pass duration.

[11] Previously satellite tracked by Seney & Landry (2008).

[12] Attributed based upon beachgoer sighting of satellite-tagged nester; turtle's demonstrated nest site fidelity, track width, and consistently low clutch hatching success; and post-nesting migration date.

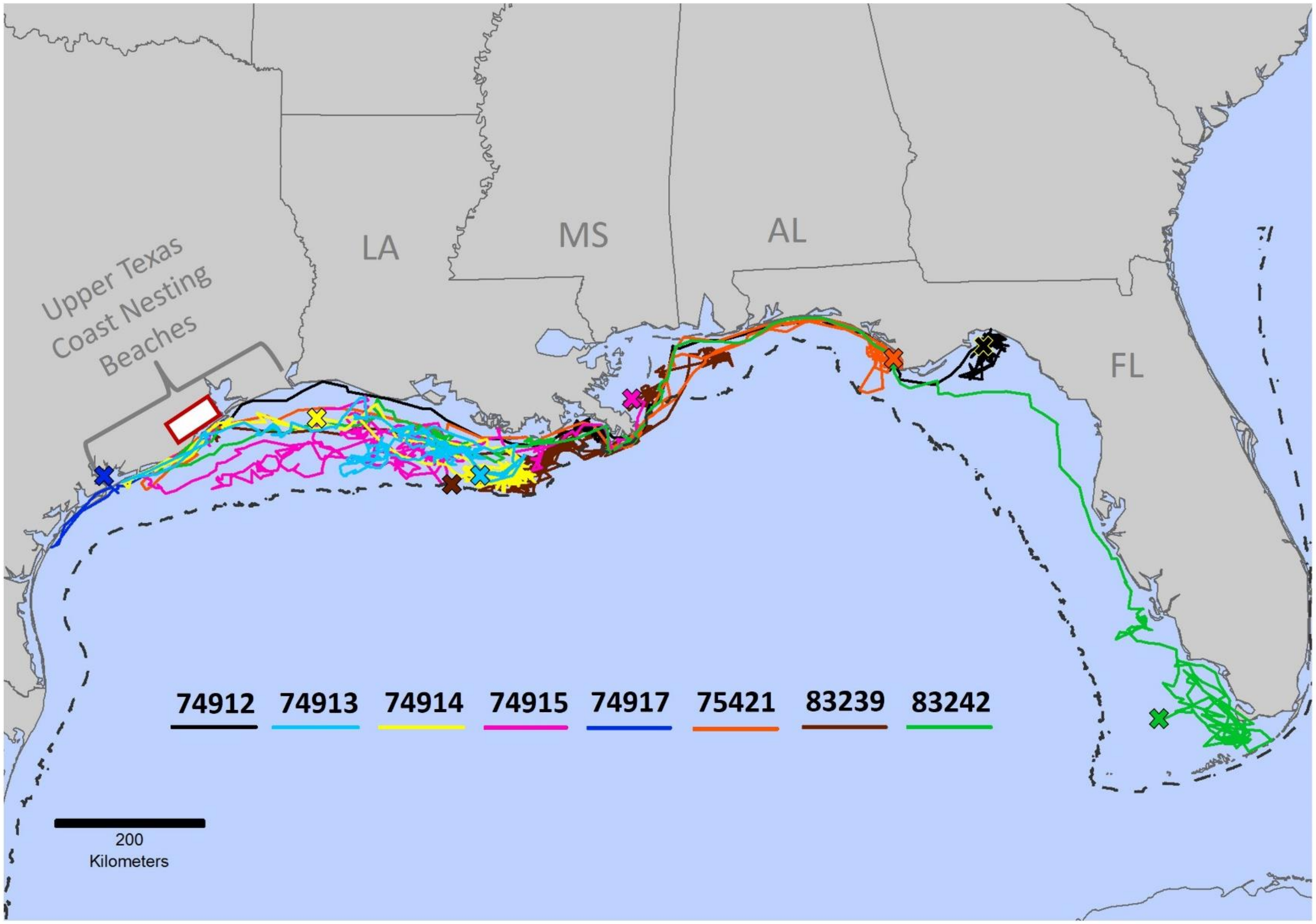


Figure 4.1. Composite movements of female Kemp's ridleys (n=8) tracked from upper Texas coast nesting beaches, 2007-2010. ▭ : Denotes general nesting location; ✕: denotes final PTT transmission location; – – – : denotes 50 m isobath.

(Table 4.5), as well as within-season reproductive potential assessed via ultrasonography, for associated females are further detailed in Chapter II.

Internesting Period

Mean post-tagging internesting period duration was 20 days/female (SD ± 9.3, range = 0 - 29 d; Table 4.6). One female (74912) that possessed developing follicles (J. Flanagan pers. comm.) but was not included in subsequent analyses of the internesting period engaged in a post-nesting migration immediately following tag attachment and release on 18 May 2007 (Fig. 4.2a). Throughout the internesting period, females remained in waters averaging 26.3º C SST (SD ± 1.4, range = 23.0 - 29.8°C), 6.1 m in depth (SD ± 6.7, range = 1.0 to -25.6 m), and 6.4 km from the nearest shore (SD ± 6.4, range = 0 - 29 km; Table 4.6). Swimming speeds during this period, which ranged from 0 to 3.0 km h^{-1}, averaged 0.7 km h^{-1} (SD ± 0.6).

Study-wide, internesting ranges (the geographical extent of documented movement by an individual during the internesting period) were primarily restricted to inner continental shelf waters extending from the Galveston Bay entrance south to Matagorda Bay (Figs. 4.2a & b). Six of seven monitored ridleys immediately traversed coastal waters south to (n=3) or beyond (n=3) nearshore (≤ 10 km from the nearest shoreline) habitats adjacent to East Matagorda Bay (EMB) following tag attachment and release. Of these, only one (74915) did not make corresponding movements northward during the internesting period. Turtles 74913 and 74914, although exhibiting preferences for

Table 4.6. Internesting period movements for Kemp's ridleys (n=8) satellite tagged on the upper Texas coast between 2007-2009 .

Turtle ID	Release Date	Internesting Duration (d)	No. Accepted Daily Locations	Mean Depth (m)	Mean Distance from Shore (km)	Mean SST (^oC)	Mean Speed (km h^{-1})
74912	5/18/2007	0[1]	N/A	N/A	N/A	N/A	N/A
74913	5/18/2007	26	20	4.0	3.8	26.3	0.6
74914	5/26/2007	29	24	3.9	4.7	27.5	0.8
74915	5/18/2007	22	21	11.5	12.1	25.9	0.5
74917	5/1/2008	27	22	3.9	3.1	25.4	0.9
75421	5/14/2008	20	18	9.4	8.2	26.4	0.7
83239	5/20/2008	14	13	5.4	9.6	27.0	0.4
83242	5/2/2009	22	18	5.2	5.1	25.7	0.5
	Mean	**20.0**	**19.4**	**6.1**	**6.4**	**26.3**	**0.7**
	SD	9.3	3.6	6.7	6.4	1.4	0.6
	Range	0 to 29	13 to 24	ASL[2] to 25.6	0 to 29	23.0 to 29.8	0 to 3.0

[1] Turtle 74912 migrated northeast in a directed manner immediately following release.

[2] Filtering criteria permitted inclusion of depths ≤1.0 m above sea level (ASL).

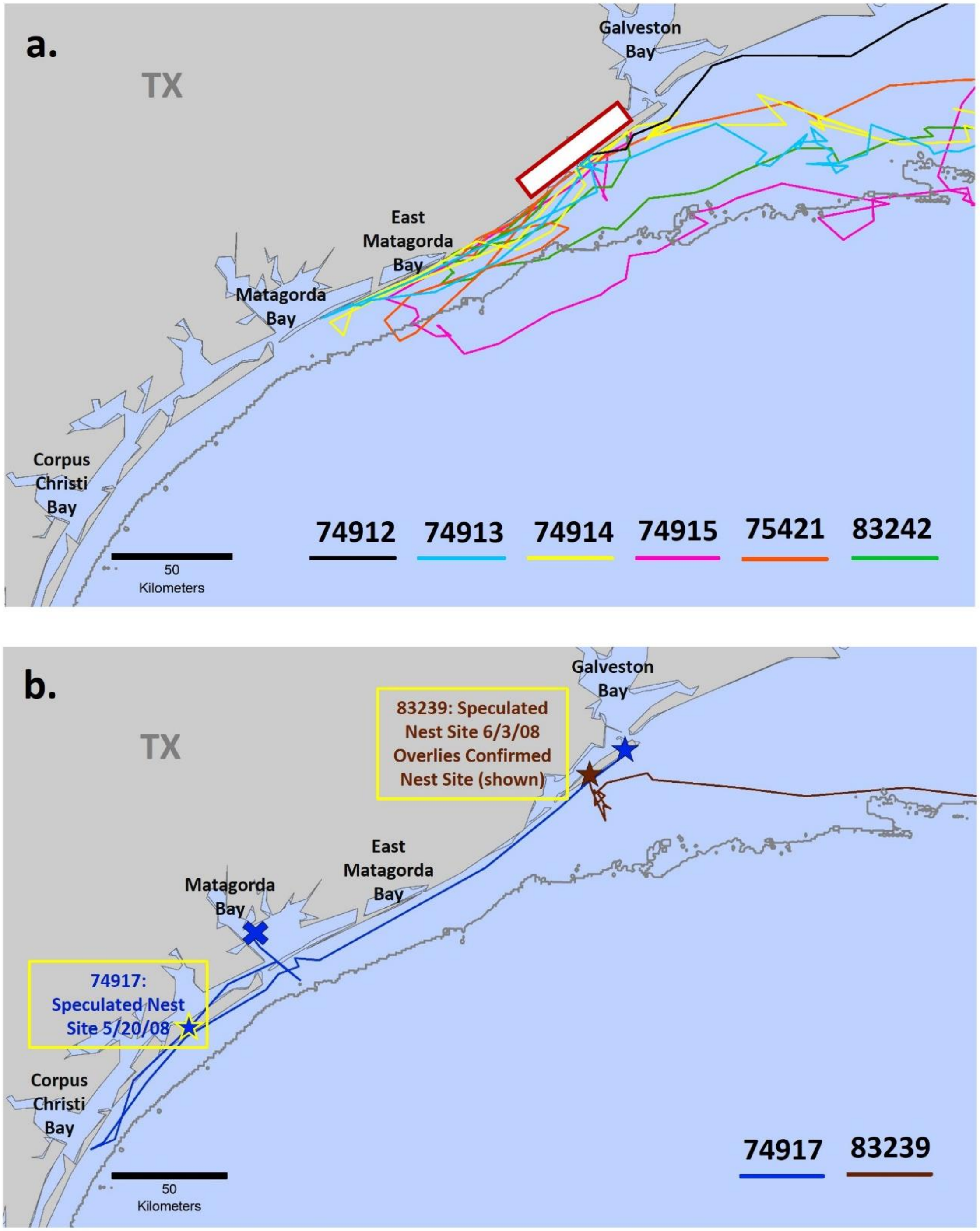


Figure 4.2. Internesting movements of (a) six and (b) two Kemp's ridleys satellite tagged after nesting on the upper Texas coast between 2007-2009. ☆: Denotes specific nesting location, ▭: denotes general nesting location, ✕: denotes final PTT geolocation (74917 only; tracking duration 26 d), —: denotes 20 m isobath. Initial post-nesting movements are also displayed.

nesting habitat on opposite ends of Galveston Island, displayed consistently similar internesting behaviors in 2007 (Fig. 4.2a). Both made directed post-tagging movements south to the coastal midpoint flanking Matagorda Bay before returning northward to Galveston Island in early June, at which point both engaged in post-reproductive migrations east and offshore (>10 km from the nearest shoreline).

Two singular behavioral patterns emerged for females monitored during the internesting period. Female 83239's movements were comparatively confined and restricted to travel perpendicular to her Galveston Island nest location, extending offshore approximately 19 km (Fig. 4.2b). Ridley 74917, whose transmitter failed after 26 d, moved approximately 130 km farther south than other monitored turtles and was the only female whose plotted coordinates (LC 0, A, and B) occurred inside a bay system (Fig. 4.2b).

Nine of ten confirmed (see Chapter II) and postulated UTC nest sites documented during this study (2007-2009; Table 4.5) were located at (n=7) or near (n=2) the northernmost extent of each individual's internesting range (Figs. 4.2b & 4.3a, b, d, e, f); 74912's single nest is excluded from this tally due to an unknown internesting range extent (Fig. 4.2a, Table 4.6). Re-nesting intervals for three presumed nesting emergences identified via satellite telemetry (one each attributed to Turtles 74913, 74917, and 75421) ranged from 19 - 21 d. A nest laid by an unidentified satellite-tagged nester on 3 June 2008 is herein attributed to 83239 based upon this female's demonstrated nest site fidelity and tag location data obtained from all UTC tracked females; 83239 nested 14 d prior in the

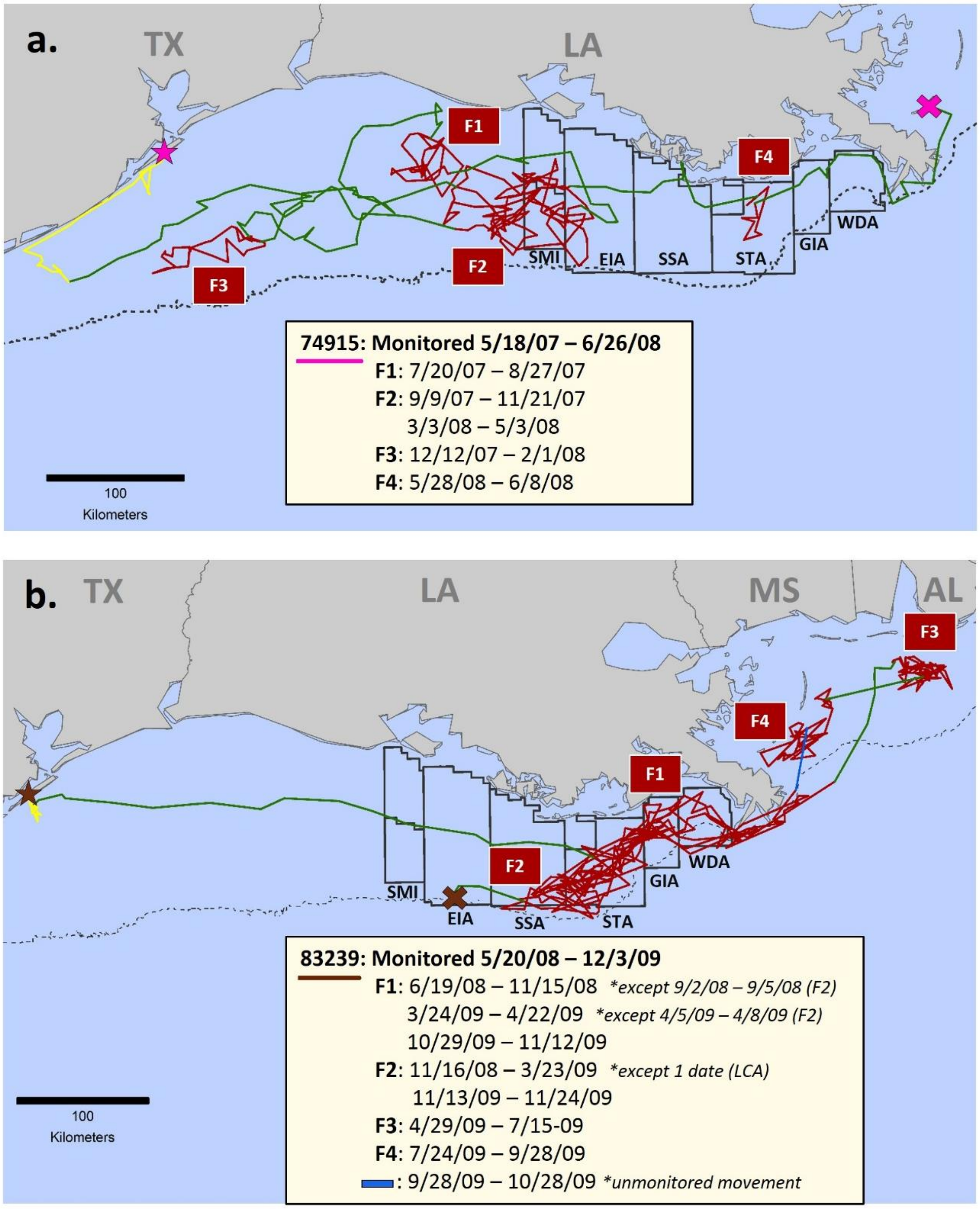


Figure 4.3. Movements of individual Kemp's ridleys (n=6) satellite tracked after nesting on the upper Texas coast between 2007-2009. 🟨: Denotes internesting period movements, 🟩 : denotes migratory movements, 🟥: denotes foraging ground (F) movements, 🟦 : denotes movement between geolocations during extended period of transmitter silence (83239 only),☆: denotes nesting location when tagged, ✕: denotes final PTT geolocation, - - - : denotes 50 m isobath.

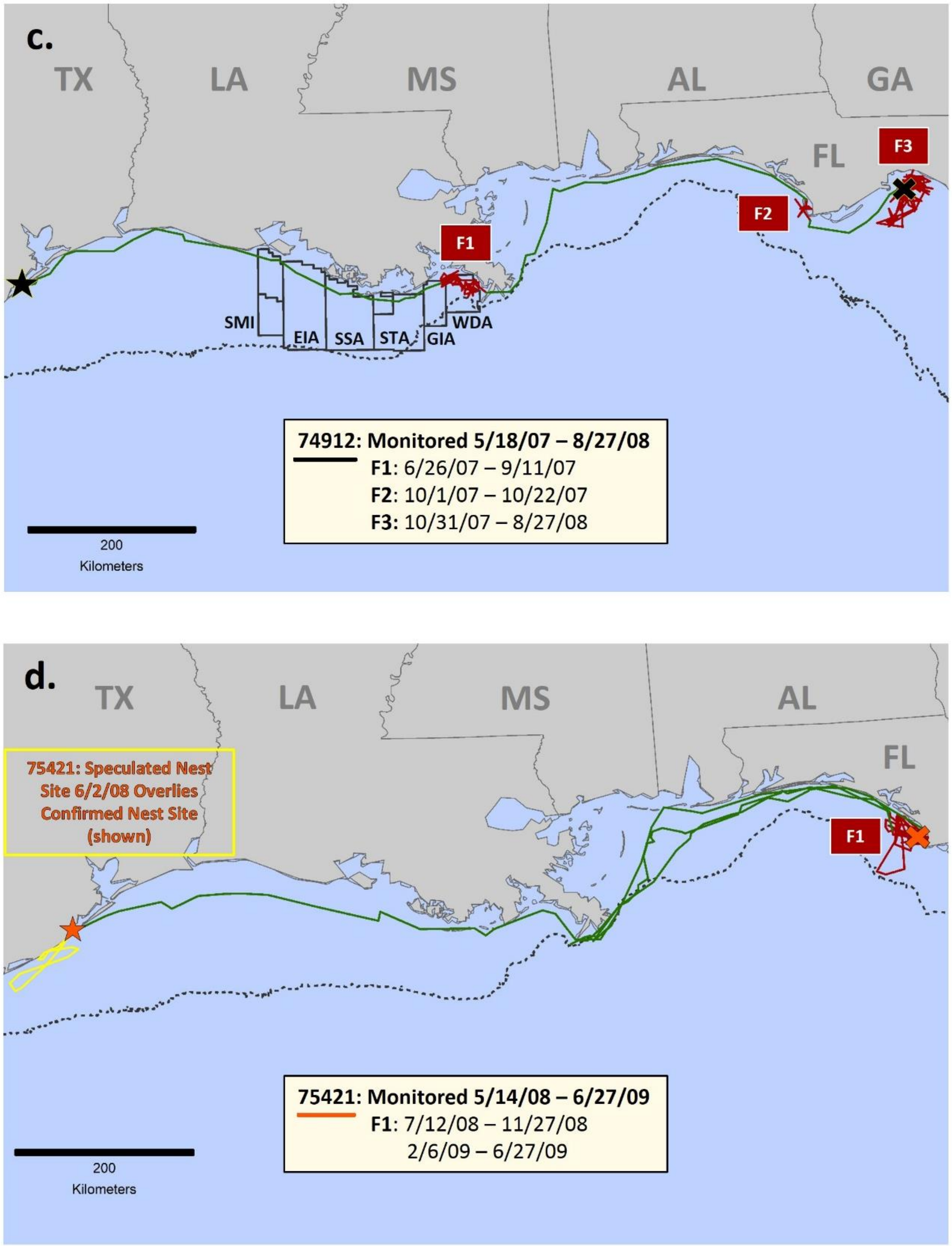


Figure 4.3 cont.

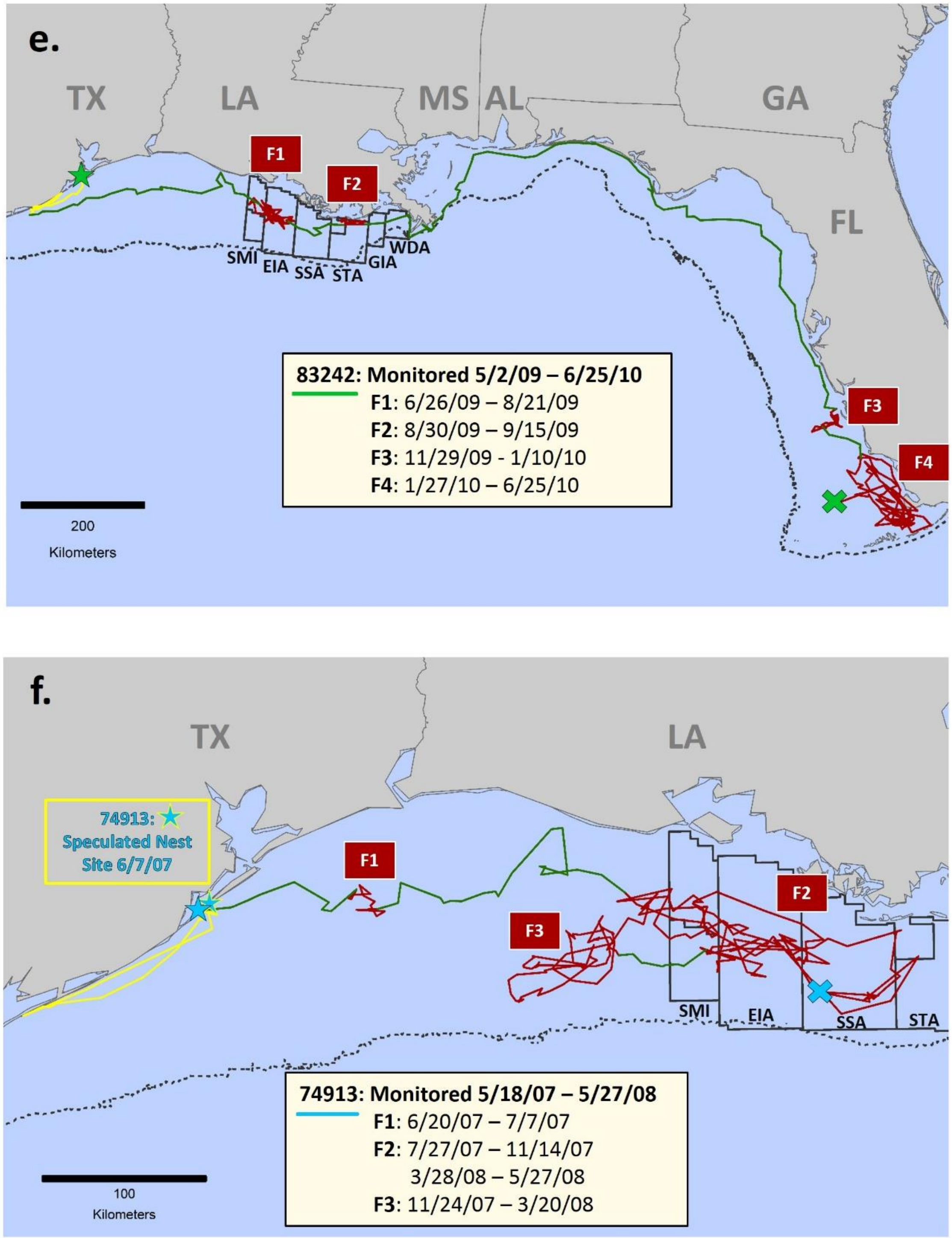


Figure 4.3 cont.

same vicinity. It is likely that all seven females who remained near the UTC prior to their post-nesting migration nested once following tag attachment, a theory supported by ultrasonography results and observed internesting period durations of 14 - 29 d.

Migratory Phases

Post-Nesting Migrations

Migrations from UTC nesting habitats eastward to initial Gulf of Mexico foraging grounds off Texas (n=1), Louisiana (n=5), and Florida (n=1) averaged 27.6 days (SD ± 13.4, range = 7 - 41 d) for the seven ridleys monitored during this phase (Fig. 4.4, Table 4.7). Directed post-nesting movements were initiated in May (n=2) or June (n=5) by females traversing routes a mean distance of 32.4 km from shore (SD ± 24.6, range = 0 - 93 km) in waters averaging 13.4 m in depth (SD ± 9.0, range = 0.7 to -61.6 m) and 28.6ºC SST (SD ± 1.3, range = 24.7 - 30.4ºC). Mean speed of movement, which ranged from 0 - 4.3 km h^{-1}, was 0.9 km h^{-1} (SD ± 0.6).

Isolation of offshore migrations (both post-reproductive and subsequent inter-foraging ground movements) between the UTC and the Ship Shoal Area off Louisiana, which required the exclusion of Turtle 74912's unique coastal movements, permitted identification of a heavily utilized, albeit expansive, migratory corridor (Fig. 4.5). Movements of six females were almost exclusively located between the 10 - 30 m isobaths regardless of gradient magnitude (i.e. proximity of depth contours), with plotted migratory geolocations dispersing or condensing coincident with isobath separation

Table 4.7. Post-nesting migrations to initial foraging areas for Kemp's ridleys (n=8) satellite tagged on the upper Texas coast between 2007-2009 .

Turtle ID	**Start of Migration**	**Duration of Migration (d)**	**No. Accepted Daily Locations**	**Location of Initial Foraging Ground**	**Mean Depth (m)**	**Mean Distance from Shore (km)**	**Mean SST (°C)**	**Mean Speed (km h^{-1})**
74912	5/18/2007	39	26	Western Mississippi River Delta	3.2	7.2	27.6	0.9
74913	6/13/2007	7	7	Waters South of Beaumont, TX	9.4	27.1	29.2	0.6
74914	6/24/2007	19	19	Waters South of Terrebonne Bay, LA	14.7	44.2	29.3	1.2
74915	6/9/2007	41	39	Waters South of Grand Lake, LA	19.9	55.3	29.0	0.6
74917	N/A	0[1]	N/A	N/A	N/A	N/A	N/A	N/A
75421	6/3/2008	38	33	St. Joseph Bay, FL	11.8	14.1	29.0	1.3
83239	6/3/2008	16	16	Western Mississippi River Delta	14.0	39.7	28.8	1.2
83242	5/24/2009	33	30	Waters South of Marsh Island, LA	14.9	33.6	27.8	0.7
	Mean	**27.6**	**24.3**	**Texas (n=1)**	**13.4**	**32.4**	**28.6**	**0.9**
	SD	13.4	11.0	**Louisiana (n=5)**	9.0	24.6	1.3	0.6
	Range	7 to 41	7 to 39	**Florida (n=1)**	ASL[2] to 61.6	0 to 93	24.7 to 30.4	0 to 4.3

[1] Turtle 74917's transmitter failed prior to the documentation of directed movements indicative of migration.

[2] Filtering criteria permitted inclusion of depths ≤1.0 m above sea level (ASL).

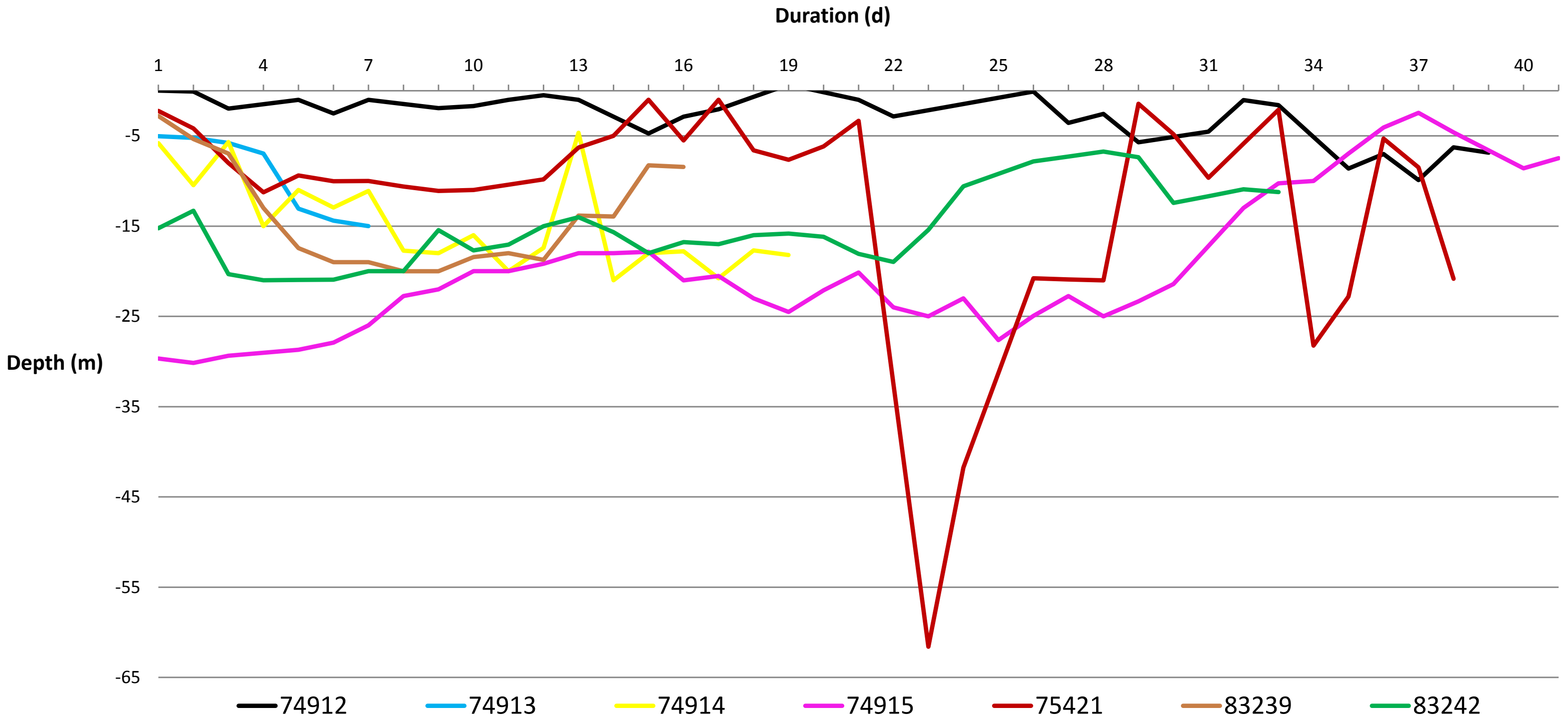


Figure 4.4. Duration and bathymetry[1] of post-nesting migrations to initial foraging grounds by Kemp's ridleys (n=7) nesting on the upper Texas coast between 2007-2009.

[1] **The two greatest documented depths, both associated with turtle 75421, were derived from geolocations of LCA (-41.8 m) and LCB (-61.6 m).**

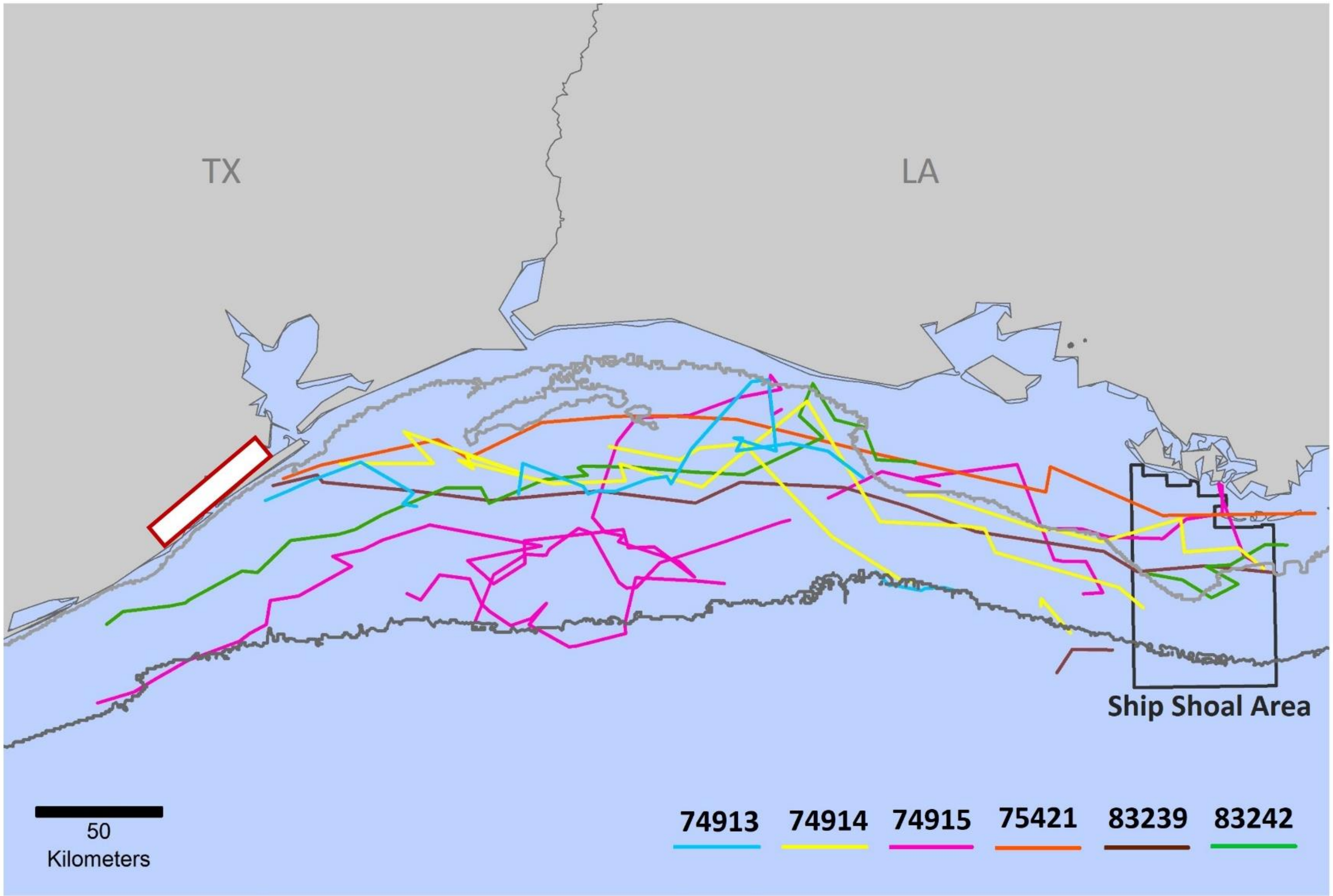


Figure 4.5. Post-reproductive and inter-foraging ground migrations of Kemp's ridleys (n=6) monitored after nesting on the upper Texas coast between 2007-2009. Only movements occurring within the Ship Shoal Area westward are displayed. ▭ : Denotes general nesting location, — : denotes 10 m isobath, —: denotes 30 m isobath.

distance. Six females moved eastward along this corridor during late May (n=1), June (n=6), and July (n=3), including 74914, who also utilized this corridor during two partially documented (via telemetry) westward migrations during March-May (Figs. 4.5 & 4.6).

The two smallest females (74914 and 74915; Figs. 4.3a & 4.6), exhibited multiple deviations from linear routes to foraging destinations, engaging in direction reversals or circular swimming patterns. In contrast, four of the five largest females traversed consistently sequential trajectories (74912, 75421, 83239, and 83242; Figs. 4.3b-e).

Migration Bottleneck - South Pass Area Corridor

Five of seven females monitored post-nesting traversed a relatively narrow corridor through the South Pass Area (SPA) adjacent to the Mississippi River Delta Basin (Fig. 4.7), a neritic zone spatially confined by proximity to the continental shelf. Mean distance from shore while transiting the Delta was 6.3 km (SD ± 3.6, range = 0 - 16 km). Bathymetry during transit averaged 38.2 m (SD ± 21.5, range = 1.0 to 77.8 m). Geolocations obtained from ridleys proximate to the SPA corridor, areas of increased shelf width, were comparatively widespread. Directed eastward crossings of the SPA corridor to foraging areas (n=4) or unknown destinations (n=1) were made by two (74915, 75421; Figs. 4.3a & d) and three females (74912, 83239, 83242; Figs. 4.3b, c, & e), respectively, in June and September; however, corridor usage was documented year-round. Two females (75421, 83239; Figs. 4.3b & d) made multiple treks through this

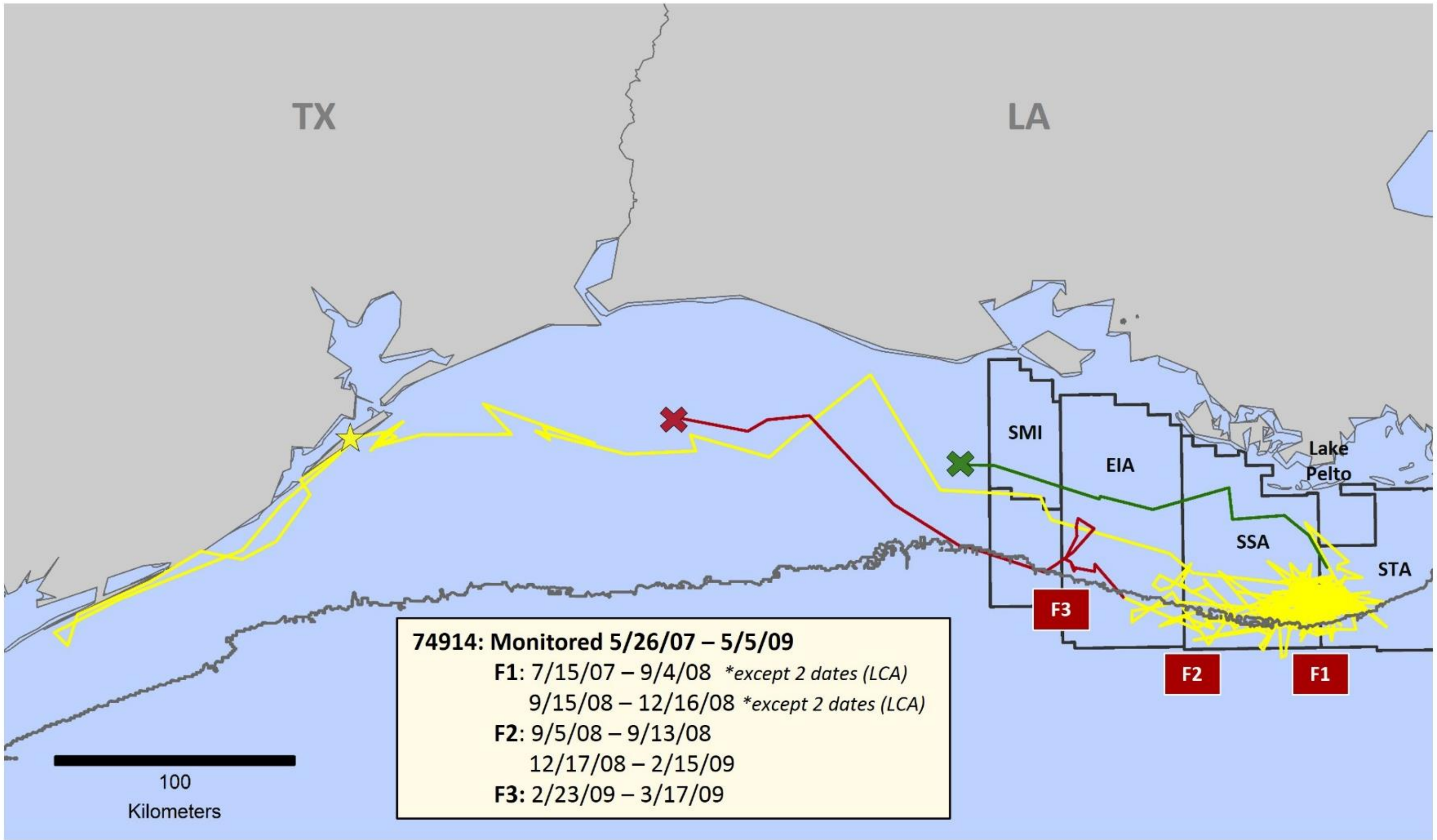


Figure 4.6. Westward movements indicative of nesting beach remigration documented for Kemp's ridley 74914 two years post-tagging. ▬ : Denotes internesting, post-nesting, and foraging ground (F) movements; ▬ : denotes first transit 17 February-26 March 2009; ▬ : denotes second transit 24 April-5 May 2009; ☆ : denotes 2007 non-nesting emergence location; ✕ : denotes final PTT geolocations prior to temporary (red) or permanent (green) cessation of transmissions, ▬ : denotes 30 m isobath. Bureau of Ocean Energy Management Boundary Areas are abbreviated as follows: SMI (South Marsh Island), EIA (Eugene Island Area), SSA (Ship Shoal Area), STA (South Timbalier Area).

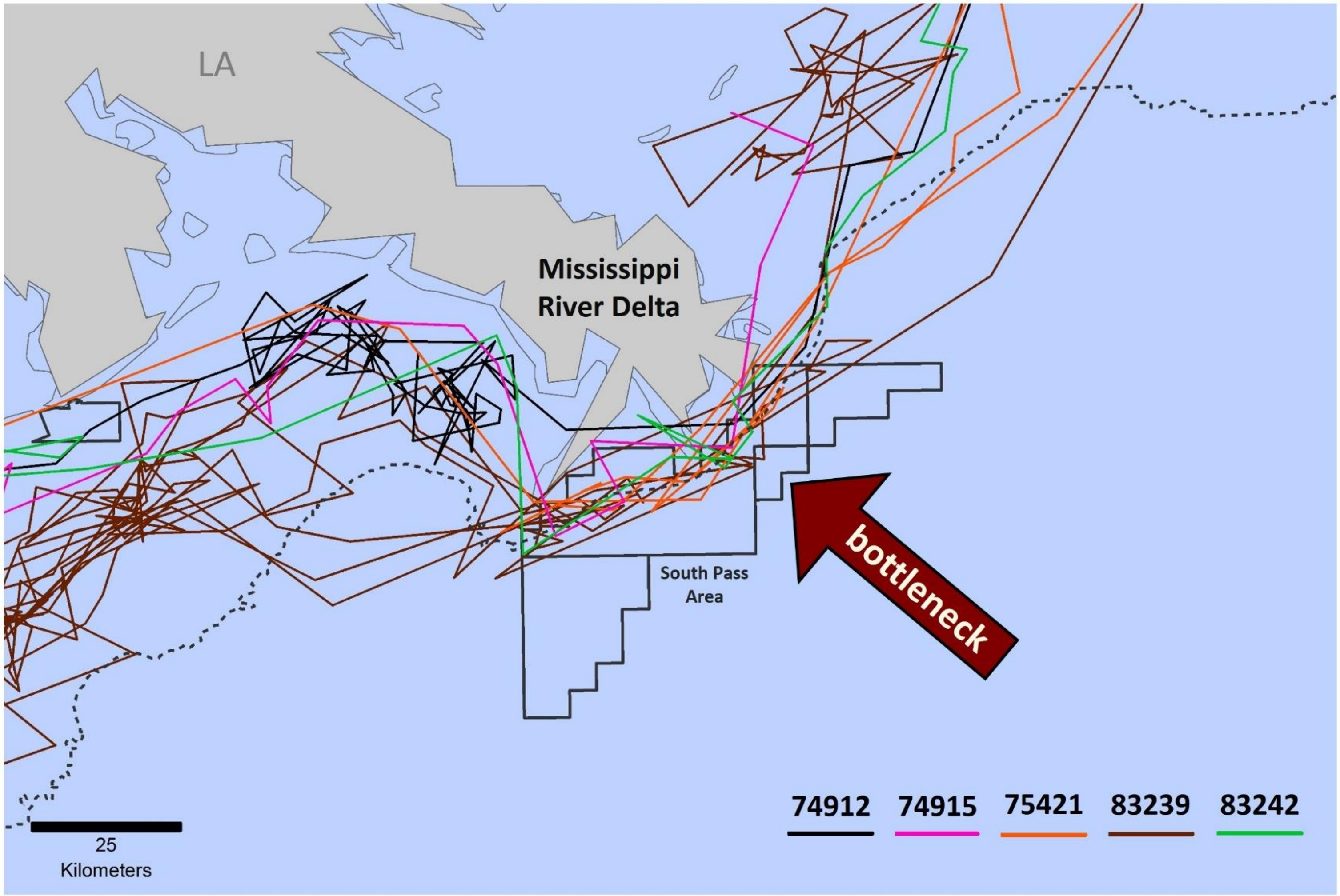


Figure 4.7. Migration corridor “bottleneck” south of the Mississippi River Delta used by 5 of 7 Kemp’s ridleys tracked beyond the internesting period after nesting on the upper Texas coast between 2007-2009. Corridor usage was not confined temporally; two ridleys made multiple passes through this corridor. - - -: denotes 50 m isobath.

corridor, which also comprised the less utilized eastern segment of 83239's largest foraging zone. However, movements by all ridleys excepting 83239 across the southern Delta were entirely transitory in nature. Turtle 75421, who initially traversed the SPA corridor in June en route to Florida, demonstrated fidelity to her corridor route during an extended migratory phase from late December to mid-January in which she passed westward through the corridor to a location just west of East Bay, Louisiana, before returning east to her Florida Panhandle foraging site.

All five females who travelled east of the Mississippi River Delta avoided eastern Louisiana's barrier island-fringed inshore waters, specifically those comprising Breton, Chandeleur, and Mississippi Sounds (Fig. 4.8). Three ridleys (74912, 75421, 83242) remained tens of kilometers east of these barrier islands, transiting a fairly homogeneous northward route toward the Mississippi-Alabama border, at which point all resumed nearshore eastward movements. This was particularly exceptional for turtle 74912, who demonstrated an intense preference for coastal migratory habitats with the sole exception of her linear passage from the Delta through offshore waters en route toward Petit Bois Island (Fig. 4.3c). Turtle 75421 displayed an imprecise fidelity to this offshore passage during three separate transits (Fig. 4.3d).

Nesting Beach Remigration

Although 2 females (74914, 83239) tracked in this study were subsequently witnessed nesting on UTC beaches (Table 4.5), none were actively monitored during confirmed

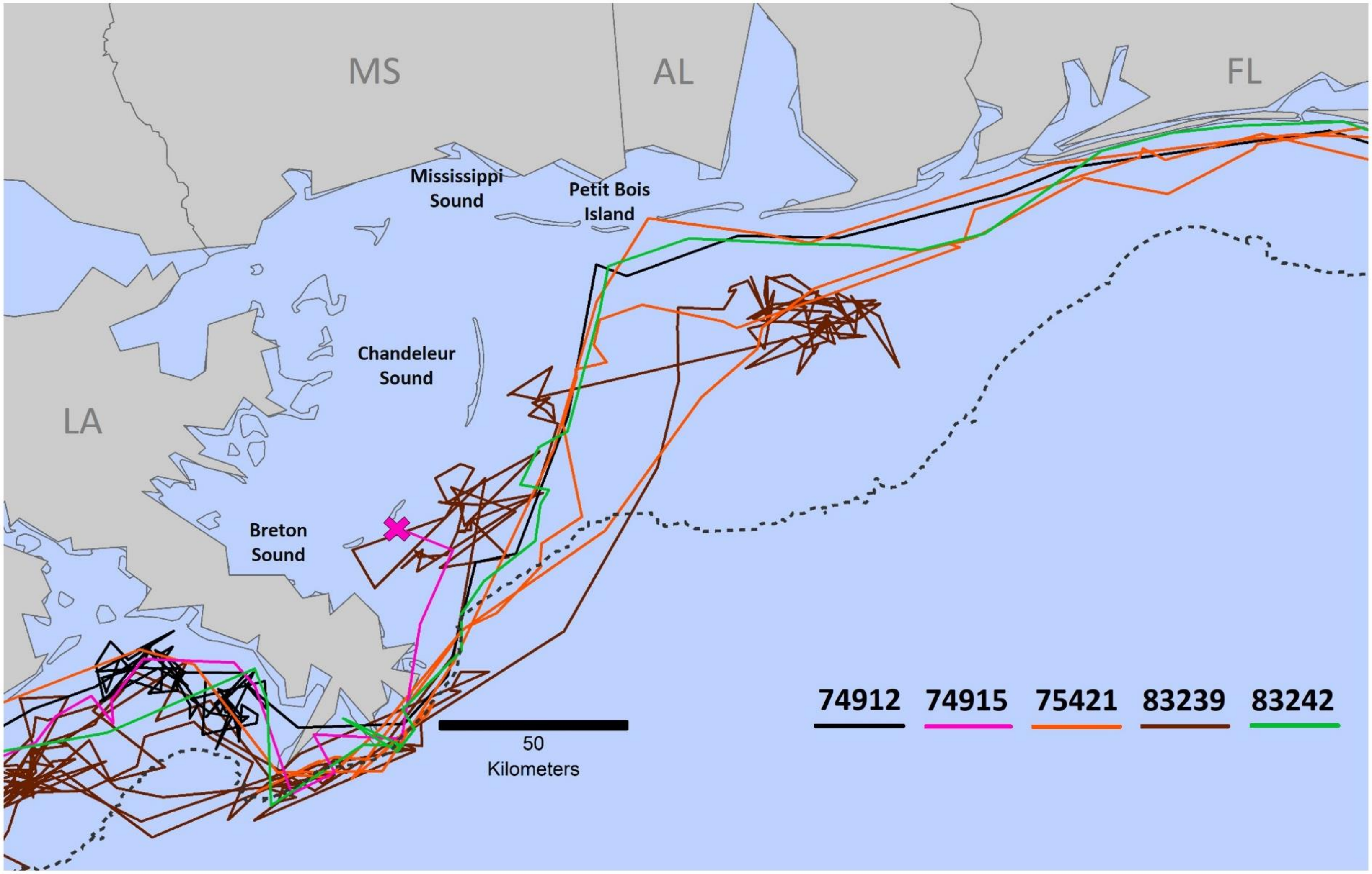


Figure 4.8. Offshore movements of post-nesting Kemp's ridleys (n=5) east of the Mississippi River Delta after nesting on the upper Texas coast between 2007-2009. ✖: denotes final PTT geolocation (74915 only), - - -: denotes 50 m isobath.

remigration intervals. Movements indicative of remigration, however, were obtained from female 74914 two years following tag attachment (Fig. 4.6). In 2009, 74914 initiated directed westward movements toward the UTC on multiple occasions, although transmissions ceased before confirmation of a destination was obtained. Five days of westward movements commenced on 17 February prior to a short-term resumption of non-directional behavior at a novel foraging site. On 18 March, westward migrations resumed and this female traveled to within 120 km of Galveston Island in 9 days (mean speed of movement: 0.8 km h^{-1}). Following nearly a month of transmitter silence, 74914 was geolocated back on her primary foraging ground south of Lake Pelto, Louisiana, for a single day prior to beginning a second westward migration on 24 April (mean speed of movement: 1.0 km h^{-1}). Unfortunately, this ridley's final transmission was received on 5 May at an offshore location 250 km east of Galveston Island, and various transmission parameters do not provide a clear explanation for turtle 74914's odd movement behavior or cessation of transmissions. This female was not observed nesting in 2009. (Responders observed only one nester in 2009 in the course of documenting seven nests on the beaches comprising Galveston Island, Bolivar Peninsula, and Follets Island; see Chapter II.)

Foraging Ground Utilization

Analyses of movements by seven telemetered post-nesting Kemp's ridleys between May 2007 and June 2010 permitted documentation of 22 distinct, albeit intermittently overlapping, neritic foraging grounds located in nearshore or offshore waters ranging from approximately 80 km due south of Galveston Island east to the Florida Keys (Figs. 4.3a-f, 4.6, 4.9, Table 4.8). Females utilized one (n=1), three (n=3), or four (n=3) geographically discrete foraging sites each throughout the duration of their tracking period (376 - 710 d).

Integrating Gulf of Mexico foraging ground data (n=2039 accepted locations) for all individuals (n=7) over the study period permitted general site characterization (Table 4.8). Neritic foraging grounds (n=22) occupied a bathymetric range of 1.0 to -83.0 m (mean = -17.3 m, SD ± 11.9) and were situated 0 - 117.0 km from shore (mean = 35.5 km, SD ± 24.7). Mean speed of movement during foraging phases was 0.4 km h^{-1} (SD ± 0.5, range = 0 - 4.5 km h^{-1}). All females appeared to actively avoid deep oceanic features, including the relatively nearshore Mississippi and DeSoto Canyons (Fig. 4.9). Mean SST documented during foraging phases was 24.8°C (SD ± 4.6, range = 14.2 - 31.9°C). Turtle residency intervals at discrete sites prior to either transmitter failure (n=5) or directed movement between foraging locations (n=27) or to unknown destinations (n=2) ranged from 4 - 418 d (mean = 75.9 d, SD ± 85.1; Figs. 4.3a-f & 4.6). However, comprehensive assessments regarding utilization of discrete sites over each individual's entire tracking period required pooling data pertaining to recurrent use of previously exploited foraging grounds by five females. Mean foraging site residency for pooled data was 117.4 d (SD ± 120.2, range = 12 - 512 d).

Table 4.8. Foraging ground movements for Kemp's ridleys (n=8) monitored between 2007-2010.

Turtle ID	**No. Accepted Daily Locations**	**No. Foraging Grounds Used**	**Mean Depth (m)**	**Mean Distance from Shore (km)**	**Mean SST (^{o}C)**	**Mean Speed (km h^{-1})**
74912	340	3	6.3	14.2	24.4	0.4
74913	210	3	21.8	60.9	24.8	0.4
74914	461	3	21.2	49.6	24.9	0.4
74915	210	4	25.9	65.3	24.6	0.5
74917[1]	N/A	N/A	N/A	N/A	N/A	N/A
75421	219	1	6.5	4.2	23.9	0.3
83239	390	4	25.7	30.5	25.3	0.5
83242	209	4	8.9	25.8	25.3	0.6
Mean	**291.3**	**3.1**	**17.3**	**35.5**	**24.8**	**0.4**
SD	105.0	1.1	11.9	24.7	4.6	0.5
Range	209 to 461	1 to 4	ASL[2] to 83.0	0 to 117	14.2 to 31.9	0 to 4.5

[1] Turtle 74917's transmitter failed prior to commencement of foraging behavior.

[2] Filtering criteria permitted inclusion of depths ≤1.0 m above sea level (ASL).

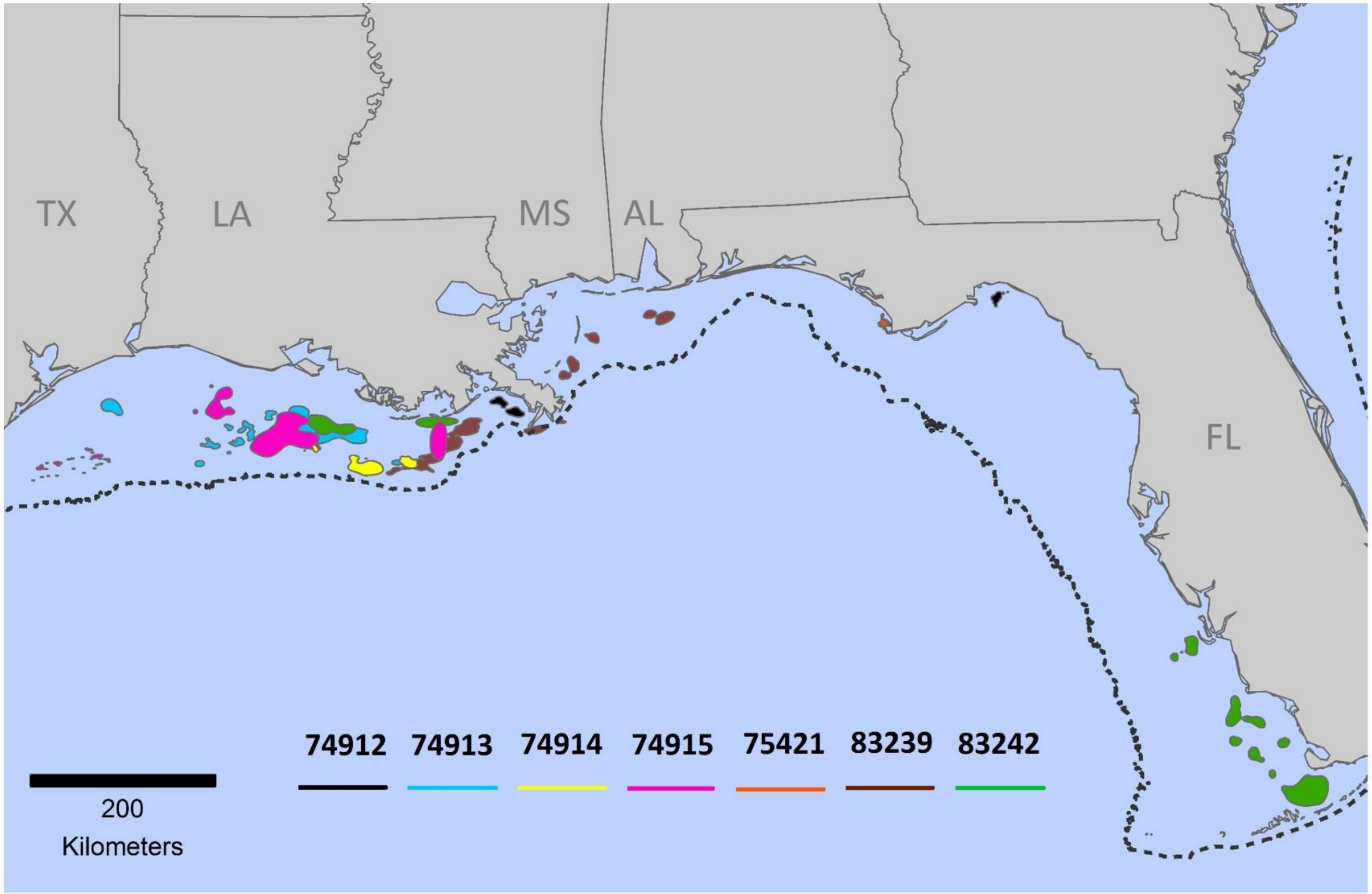


Figure 4.9. Core foraging activity areas (50% KDE; n=22) for Kemp's ridleys (n=7) monitored after nesting on upper Texas coast beaches between 2007-2009. Females each utilized one (n=1), three (n=3), or four (n=3) discrete foraging areas. Geolocations associated with an individual's recurrent use of a discrete foraging site were coalesced to generate a single KDE; comprehensive site utilization durations ranged from 12-512 d. ‒ ‒ ‒ : Denotes 50 m isobath.

Louisiana's Neritic Feeding Grounds

Gulf of Mexico foraging area density (i.e. degree of spatial overlap of all discrete foraging sites identified in this study) was highest in Louisiana's nearshore and offshore waters (Fig. 4.9); this expanse was utilized year-round to some extent by 6 of 7 adult Kemp's ridleys monitored beyond the internesting period. Multiple females established foraging grounds within the South Marsh Island and Eugene Island Areas (herein SMI/EIA; n=4), the Ship Shoal and South Timbalier Areas (SS/STA; n=5), as well as adjacent to the southwestern Mississippi River Delta in the Grand Isle and West Delta Areas (GI/WDA; n=2; Figs. 4.3a-f, 4.6, & 4.10).

Disregarding year of use to achieve a comprehensive assessment of temporal utilization trends for offshore SMI/EIA foraging grounds revealed that one to three of the four turtles associated with this locale (74913, 74914, 74915, 83242) were in residence each month throughout the year (Figs. 4.3a, e, f; 4.6; & 4.10). With the exception of June, two of these four telemetered individuals occupied the SMI portion of their respective foraging sites each month from mid-March through mid-November; females were absent from SMI waters during cooler months (mid-November through mid-March). One to three females were resident within the EIA year-round with the exception of April. Ridley 74914 overwintered on a site spanning the EIA/SSA boundary and was the only female present within the EIA periodically from late December through mid-March (Fig. 4.6). Two individuals (74913, 74915) made directed return movements to previously utilized SMI/EIA sites in March or April after migrating west from respective

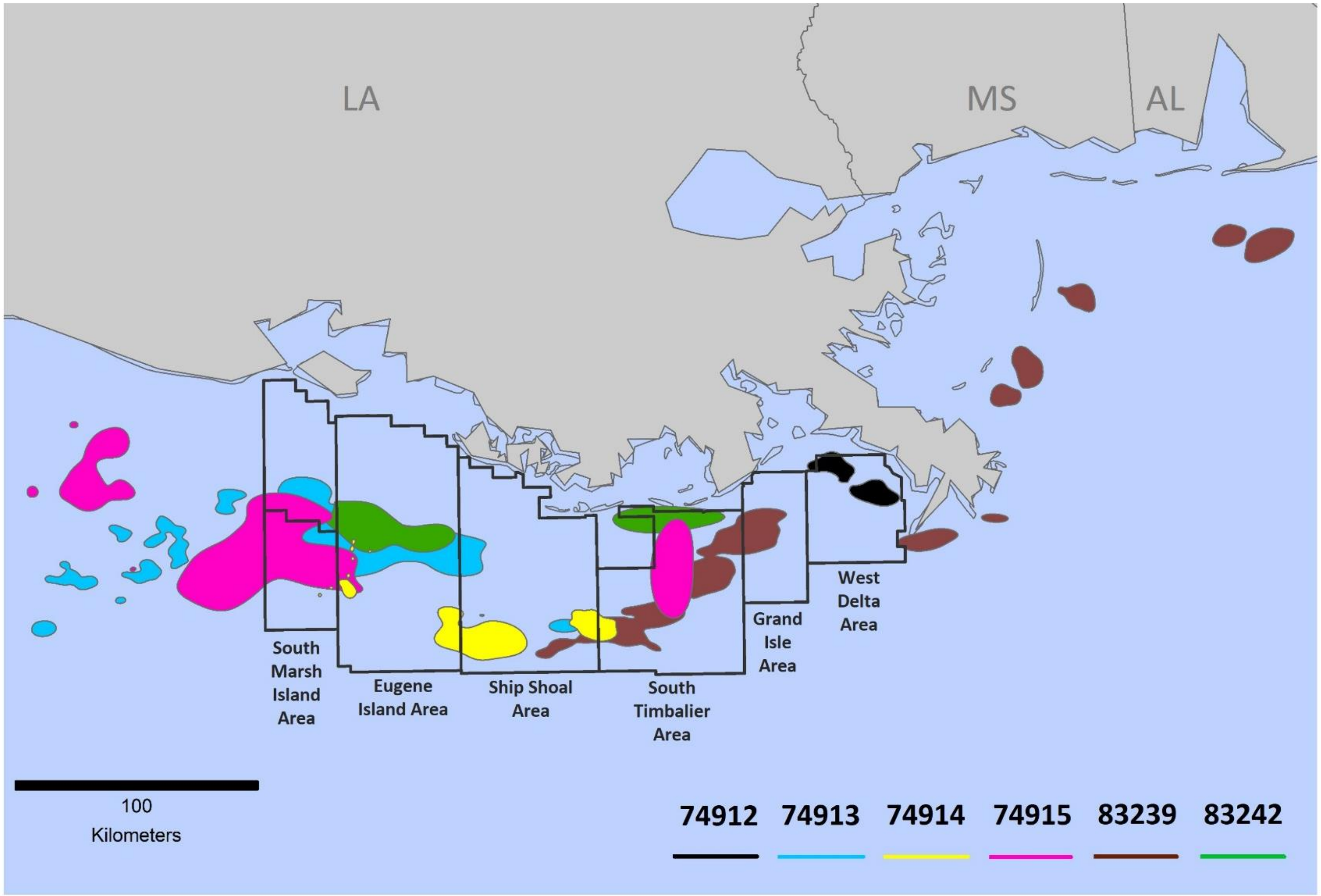


Figure 4.10. Concentration of core foraging activity areas (50% KDE; n=15) for six of seven Kemp's ridleys monitored long-term after nesting on upper Texas coast beaches between 2007-2009. Bureau of Ocean Energy Management Boundary Areas are outlined in dark gray.

overlapping foraging grounds the previous November (Figs. 4.3a & f). Both SMI/EIA-faithful individuals were documented on associated foraging grounds twice, with duration of residency for each occurrence ranging from 61 - 111 d.

Five individuals (74913, 74914, 74915, 83239, 83242) utilized foraging grounds within the Ship Shoal (n=3) and/or South Timbalier (n=5) Areas (Figs. 4.3a, b, e, f; 4.6; & 4.10); both areas were utilized by one to three females each calendar month. As with SMI/EIA sites, SSA foraging grounds overlapped and were restricted to offshore waters, whereas two of the four core activity areas within the STA were situated near the coast and represent the westernmost nearshore foraging hotspots documented in this study.

Relatively brief residency periods at contiguous STA foraging sites of 12 and 17 d, respectively, were documented for 74915 and 83242 during spring or summer months prior to directed movements eastward (Figs. 4.3a & e). While STA foraging ground usage was not limited temporally, tracked females were absent from the Area's eastern waters from mid-November through March. Ridley 83239, who established and maintained a foraging ground extending from eastern STA waters through the Delta from June through November 2008 and reoccupied this site the following spring, limited movements to the STA's western region during this cooler time period (Fig. 4.3b). Ridley 74914 demonstrated intense site fidelity to a localized region spanning the offshore SS/STA border, with initial post-nesting utilization from July 2007 through December 2008 (Fig. 4.6). Despite previously overwintering on this site, 74914's movement behavior during late 2008 coincided with that documented for 83239. Ridley 74914 initiated westward movements and subsequently occupied an adjacent foraging site along the southern EI/SSA boundary until mid-February, prior to being geolocated on her initial SS/STA border site again in April.

Nearshore and offshore waters adjacent to the southwestern Mississippi River Delta (GI/WDA) were utilized by two individuals (74912, 83239; Figs. 4.3b, c; & 4.10), although neither occupied this region from December through March. Ridley 74912 resided in a spatially concentrated, primarily nearshore zone for 78 d from June through September; however, this female displayed a propensity for nearshore migratory and foraging habitats throughout the duration of her tracking period (Fig. 4.3c). Turtle 83239 demonstrated fidelity to this region, which comprised the eastern portion of her largest foraging area, on multiple occasions (Fig. 4.3b). Her initial intermittent presence spanned from mid-July through mid-November, at which point she relocated west to overwintering grounds along the western periphery of STA. She briefly reoccupied the GI/WDA site on two subsequent occasions, remaining for 8 d in April before migrating to nearshore foraging grounds off Alabama, and again for 10 d in November before a second migration to previously utilized foraging grounds offshore Timbalier Bay.

Florida Panhandle's Neritic Feeding Grounds

Additional foraging habitats utilized by two females (74912, 75421) were concentrated along the Florida Panhandle at St. Joseph Bay (n=2) and Apalachee Bay (n=1; Figs.

4.3c, d; 4.9; & 4.11). Turtle 74912 inhabited a restricted foraging area at St. Joseph Bay for 22 d in October before continuing east to her primary foraging grounds in Apalachee Bay, where she remained for 302 d (31 October 2007 – 27 August 2008) prior to cessation of transmissions (Fig. 4.3c). The southernmost geolocations on the Apalachee Bay foraging site, which were predominantly recorded from 3 January through 8 February 2008, represent the farthest offshore foraging positions inhabited by this coast-preferring female on any of her three foraging sites.

St. Joseph Bay usage occurred year-round except during December and January and was turtle 75421's sole foraging site (Fig. 4.3d). After an initial residency period of 139 d, 75421 initiated directed movements west on 29 November 2008. She maintained migratory swimming behavior for 68 d and demonstrated a rudimentary fidelity to her post-nesting route while paralleling the coastline westward through the SPA corridor before reversing direction to return to St. Joseph Bay on 6 February 2009, where she remained until transmissions ceased 142 d later. Deviations between 75421's eastward post-nesting route and subsequent winter migration were only conspicuous while transiting offshore waters east of the Mississippi River Delta to the Alabama-Florida border (Fig. 4.3d). With the exception of outlying geolocations recorded from 6 February to 11 March 2009, a period when this ridley primarily remained in offshore waters composing the western boundary of her relatively diminutive foraging site, she consistently utilized both the interior of the bay itself and proximate Gulf waters.

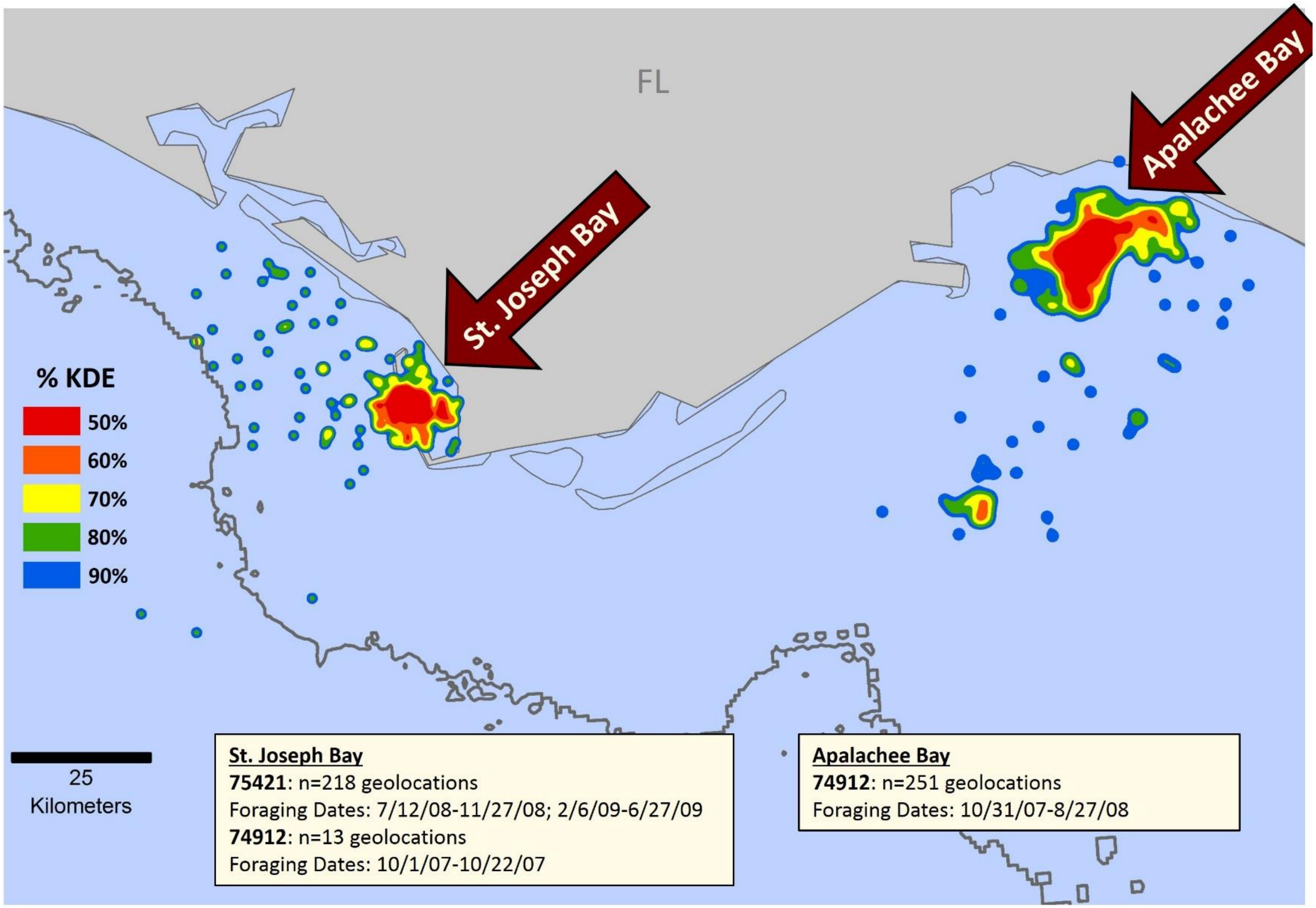


Figure 4.11. Utilization of neritic foraging grounds at St. Joseph Bay and Apalachee Bay, Florida, by Kemp's ridleys (n=2) after nesting on the upper Texas coast during 2007-2009. —: Denotes 30 m isobath.

Seasonal Movements Between Adjacent Feeding Grounds

Three individuals (74913, 74914, 83239) utilized adjacent foraging sites offshore Louisiana on a seasonal basis (Figs. 4.12 a & b; 74915 utilized non-adjacent sites on a seasonal basis). Extensive review of temporal usage of what initially appeared to be expansive foraging grounds for each individual revealed distinct boundaries between relatively larger eastern sites inhabited throughout the majority of the year (herein "summer range") and uniformly smaller western segments used only during cooler months (herein "winter range"). It must be noted, however, that partial overlap occurred between different individual's winter and summer ranges (e.g. 74914's summer range overlied 83239's winter range to some extent). Furthermore, female 74914 demonstrated behavioral plasticity in overwintering on her summer range the first year following transmitter attachment, but established and maintained an adjacent winter range the following year.

All three ridleys initially inhabited eastern summer ranges, two immediately following post-nesting migrations, for a period of 111 - 520 d; these durations disregard brief and possibly unintentional excursions of 4 and 9 d west into winter ranges for 83239 and 74914, respectively, both of which occurred nearly simultaneously the week prior to Hurricane Ike's 13 September 2008 landfall on the UTC (Figs. 4.12a & b). Directed movement west to winter foraging ranges was initiated in mid-November (n=2) or mid-December (n=1). Females remained on winter ranges for 61 - 128 consecutive days prior to re-inhabiting summer ranges in late March (74913, 83239; Fig. 4.12b) or initiating

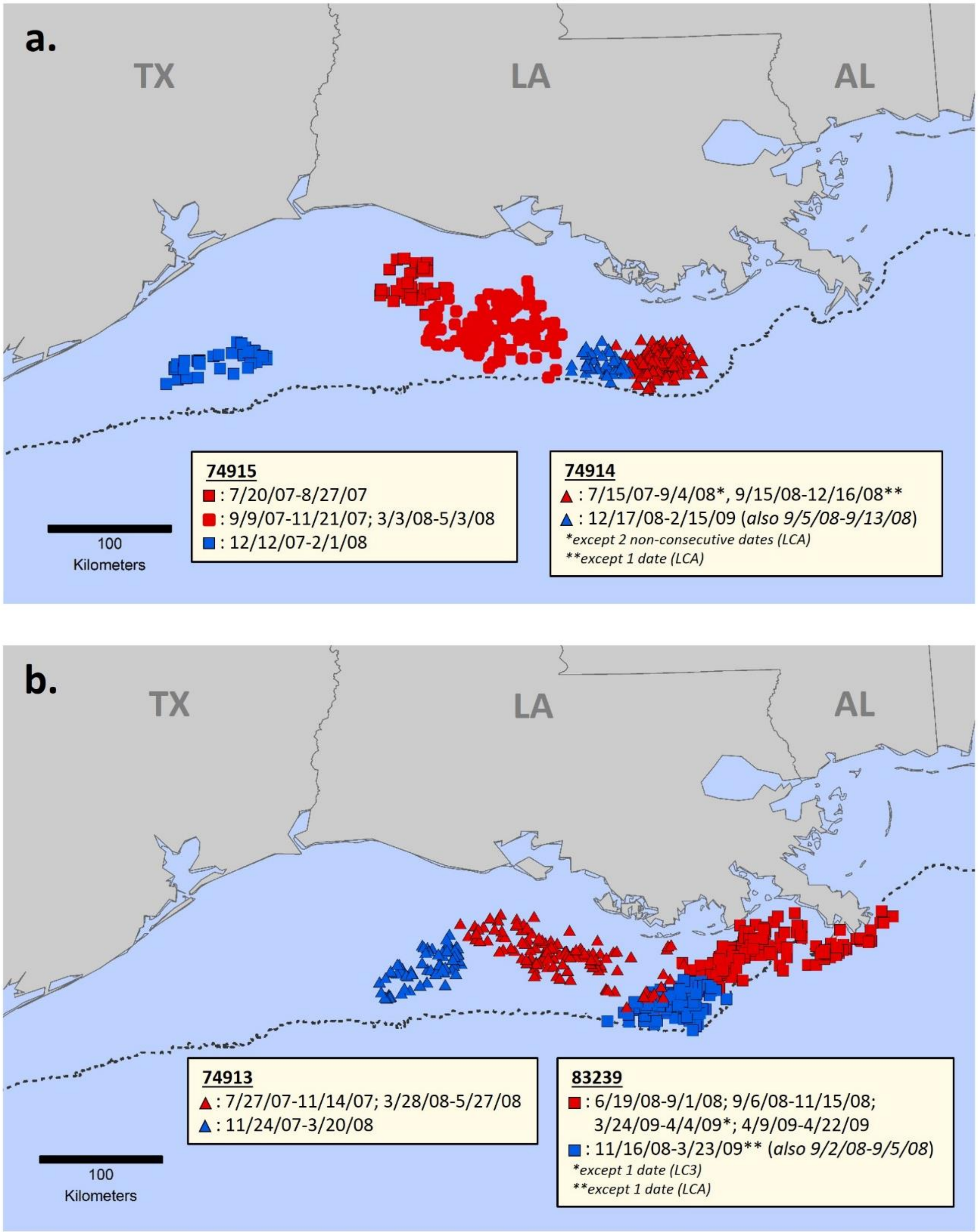


Figure 4.12. Seasonal usage of adjacent foraging grounds by Kemp's ridleys (n=4) after nesting on upper Texas coast beaches between 2007-2009. Locations in blue represent foraging areas used during cooler months; these were uniformly smaller and located west of foraging areas utilized during warmer months. - - - : Denotes 50 m isobath.

migrations toward more westerly foraging grounds and upper Texas coast nesting beaches (74914; Fig. 4.6).

Similar seasonal movement behavior was evident in the foraging and migratory movements of the smallest turtle tracked in this study, 74915 (Fig. 4.12a). Analysis of 74915's tracks revealed multiple, primarily directional lateral movements of 12 - 28 d among three distinct foraging areas inclusively comprised of constrained, primarily non-directional movements (Fig. 4.3a). Ridley 74915 utilized two adjacent easterly sites from July through mid-November and returned to inhabit the larger of these from March through May. Both summer ranges were located approximately 140 km from 74915's winter range, where this female established residency for 52 consecutive days from mid-December through early February. Two migrations of 19 and 28 d, respectively, were made in transitioning between summer and winter ranges.

Kernel Density Analyses

Five foraging grounds with <34 daily locational observations (one each attributed to turtles 74912, 74913, 74914, 74915, and 83242) were excluded from KDE analyses (Table 4.4). Mean core activity area (50% KDE contour) for the remaining 17 was 679.8 km^2 (SD $\underline{+}$ 680.9), while utilization distribution (90% KDE contour) averaged 2313.5 km^2 (SD $\underline{+}$ 2307.2; Table 4.4). Turtle 75421's sole foraging area at St. Joseph Bay represented the smallest established site (50% KDE: 52.8 km^2, n=218); while turtle

83242’s fourth foraging area, also the southernmost identified feeding site, occupied the largest area (50% KDE: 2098.6 km^2, n=105).

DISCUSSION

Collective interpretation of historical Kemp’s ridley satellite tracking data reveals the importance of neritic habitats spanning the entire Gulf of Mexico for mature female conspecifics (Byles 1989, Mysing & Vanselous 1989, Renaud et al. 1996, Renaud & Williams 2005, Shaver & Rubio 2008, Seney & Landry 2011, Shaver et al. 2013). Implementation of effective and enforceable in-water Kemp’s ridley conservation measures, however, will require further analyses to better identify spatially and/or temporally constrained usage of significant migratory corridors and foraging grounds, as well as internesting area boundaries off other lesser known, auxiliary Kemp’s ridley nesting beaches like those comprising the UTC. Discernment of critical habitats supporting concentrations of reproductively mature conspecifics will then permit better identification and mitigation of associated consequential mortality factors through implementation of MPAs, seasonal fishery closures, and/or other justifiable conservation measures.

Internesting Period

While nesting and telemetry data indicate UTC nesters are becoming an increasingly important component of the recovering Kemp's ridley population, current regulations do not provide ridleys using associated habitats protections equivalent to those enforced along the lower Texas coast. A Texas Parks and Wildlife Department (TPWD) regulation instituted in 2000 prohibits shrimp trawling within 8 km of shore along North Padre Island, South Padre Island, and Boca Chica Beach annually from 1 December through mid-May, supplementary to the pre-existing annual Texas Closure of state and federal waters effective from mid-May through mid-July. This additional protection measure, which likely reduces nester mortality (Lewison et al. 2003) while concurrently preventing excessive pressure on shrimp stocks, was based in part upon data provided by Shaver & Rubio (2008) at a time when Kemp's ridley nesting at Padre Island National Seashore never surpassed 16 nests annually. Shaver & Rubio (2008) stated "the new closure likely contributed to the sharp increase in nesting documented on the Texas coast from 2002 to 2007."

Bycatch of Kemp's ridleys in Gulf of Mexico shrimp trawling operations is substantial (Moore et al. 2008; National Marine Fisheries Service 2011; NOAA, NMFS & SERO 2012), and excessive incidental take of nesting females may hinder population recovery efforts. Documented strandings of adult ridleys are typically greater in Texas than in any other U.S. state (Shaver 2012). Historically, lethal and non-lethal strandings of Kemp's ridleys along the Texas Gulf coast have been highest in zone 18, which is centered around Galveston Island (Patella 1975, Lewison et al. 2003). Internesting movement and nesting (Chapter II) data reported herein and for previous years (Seney & Landry 2008) provide unequivocal support for statewide expansion of the effective TPWD seasonal shrimp trawling regulation afforded the lower Texas coast, particularly northward to incorporate documented nearshore nesting and internesting habitats from Matagorda Peninsula to Galveston Island and Bolivar Peninsula.

Migratory Phases

Corridors

Tracking data generated from seven post-nesting females may be insufficient to comprehensively elucidate a suite of migratory behaviors characteristic of upper Texas coast nesters. However, despite expected permutations in transitory movements displayed across individuals (particularly 74912) and years, corresponding trajectories were documented for multiple females across two identified corridors. The first, a functional migratory bottleneck through the South Pass Area (Fig. 4.7), results from the confinement of the continental shelf proximal to the Mississippi River Delta Basin and is analogous to that defined by Griffin et al. (2013) for loggerhead sea turtles (*Caretta caretta*) off Cape Hatteras, North Carolina. Migratory movements of five ridleys east through this corridor were highly concentrated in June and September; June movements are coincident with results obtained by Renaud (1995) for a telemetered adult ridley released off Brownsville, Texas. Additionally, one turtle demonstrated moderate fidelity to her corridor route during additional transits in December and January, evidence that SPA corridor usage is not limited temporally.

A second, more expansive corridor incorporating waters within the 10 - 30 m isobaths extending from the UTC to the Ship Shoal Area offshore Louisiana was utilized during late May, June, and July by six of seven post-nesters progressing eastward toward discrete foraging sites (Fig. 4.5). Eastward UTC-SSA corridor movements were spatially and temporally consistent with those documented for Kemp's ridleys satellite tagged after nesting in Texas by Seney & Landry (2008, 2011) and Shaver & Rubio (2008). This expanse, recently identified as a critical ridley foraging corridor by Shaver et al. (2013), may support consistently elevated concentrations of migrating post-nesters annually during June and July.

The potential exists for these seasonal aggregations of migrating conspecifics, particularly post-nesters moving east through the UTC-SSA corridor in June and July, to further increase in density coincident with ridley nesting in Texas. Identification and mitigation of potential mortality factors impacting reproductively mature females, the population component most critical for species recovery, during intervals of ridley convergence in migratory corridors may facilitate ongoing recovery efforts.

Nesting Beach Remigration

While considerably less knowledge exists regarding ridley movements from Gulf of Mexico foraging areas to Texas' nesting beaches, it can be speculated that westward nesting beach remigrations spatially replicate eastward post-nesting movements (Morreale et al. 2007) and permit arrival to nesting beaches prior to the April-July nesting season, such as was exhibited by one female monitored by Shaver & Rubio (2008). An incomplete westward transit across the SSA-UTC corridor by turtle 74914 (a consistent biennial nester) during March 2009, initiated two years after nesting on Galveston Island, is consistent with expected nesting beach remigration (Fig. 4.6). This female's motivation for subsequently returning to foraging grounds before initiating a second westward corridor transit in late April remains unclear, although plausible causative factors include Hurricane Ike's detrimental effects on UTC nesting beaches in September 2008 (Doran et al. 2009) and potential sub-lethal effects of tag attachment (i.e. inflated metabolic cost of movement associated with increased hydrodynamic drag, associated diving and/or feeding behavior anomalies, etc.; Thompson et al. 1990, Watson & Granger 1998, Jones et al. 2011) leading to insufficient reproductive fitness.

Seasonal Movements

Prior tracking research suggests Kemp's ridleys in the Gulf of Mexico employ multiple strategies in response to seasonally fluctuating thermal conditions; this is consistent with behavioral heterogeneity displayed by females in the current study. Renaud & Williams' (2005) collective interpretation of movements by 106 monitored juvenile and adult Kemp's ridleys revealed fall and winter migrations that were typically south and/or offshore into deeper waters along both the Texas and Florida shorelines, with ridleys returning to coastal feeding environments in spring. In contrast, seasonal movements have not been identified for post-nesting females satellite-tracked after nesting on the Texas coast (Seney & Landry 2008, 2011; Shaver & Rubio 2008; Shaver et al. 2013).

Two disparate seasonal strategies were observed for five of seven females monitored at length after nesting on the UTC. Turtle 75421, the only female restricted to a sole foraging area for the duration of monitoring, engaged in an extended migration from late November to early February prior to reoccupying her St. Joseph Bay foraging site (Fig. 4.3d). Persistent reductions in localized SST to a late November low of 18.3ºC at St. Joseph Bay likely induced this female's prolonged travel, the initiation of which was temporally consistent with seasonal movements documented by Schmid & Witzell (2006) for six immature ridleys that departed from western Florida foraging sites when mean SSTs reached 17ºC. Geolocations recorded during 75421's first month of reoccupation comprised the western offshore boundary of this feeding site, while subsequent positions from mid-March until cessation of transmissions in late June were primarily within a nearshore utilization hotspot. This late winter propensity to restrict use of an established foraging site to waters comprising the offshore boundary mirrors that documented for coast-preferring ridley 74912 on her Apalachee Bay foraging ground, also situated along the Florida Panhandle. While the drivers behind protracted winter migrations and late winter offshore positioning remain unclear, environmental parameters, particularly thermal regime, likely provide the proximate stimulus (Godley et al. 2008).

Four females (74913, 74914, 74915, 83239) displayed compelling movements consistent with temperature-induced longitudinal migrations in Louisiana's offshore waters, transiting west from larger easterly summer ranges to truncated winter ranges in

November (n=3) or December (n=1) and returning east to previously established summer ranges in March (n=3) or April (n=1; Figs. 4.12a & b). Migration periods and contrastive seasonal foraging area sizes coincide with that described by Broderick et al. (2007) for green (*Chelonia mydas*) and loggerhead sea turtles in the Mediterranean, wherein the authors hypothesized smaller winter ranges were the result of cooler temperatures reducing an individual's propensity for movement. Waters below 20ºC induce physiological and behavioral alterations, including hypophagia, in captive reared juvenile Kemp's ridleys (Moon et al. 1997). Therefore, it is plausible mature female conspecifics also exhibit a similar, temperature-dependent reduction in food intake and, thus, require less supportive habitat during the cold season. This theory is supported by mean winter range SSTs of 20.0º C (SD ± 1.4, range = 18.0 - 22.8°C), 18.3º C (SD ± 1.0, range = 17.0 – 20.7°C), 19.6º C (SD ± 1.5, range = 17.3 – 22.0°C), and 20.3º C (SD ± 1.2, range = 18.1 – 23.2°C) for females 74913, 74914, 74915, and 83239, respectively.

Variability between individuals with presumably disparate tolerances for cooler temperatures, as well as variances in annual thermal regimes and prey abundance, likely contribute to the partial correspondence of summer and winter ranges documented herein. In addition to these factors, this study's limited sample size precludes conclusive delineation of regions unsuitable for overwintering ridleys. However, the lack of previously resident females inhabiting the SMI Area (December-February), eastern STA (December-March), and GI/WDA (December-March) during cooler months suggests ridleys may be absent from associated areas at predictable intervals. Further research to confirm regions that are consistently inhospitable for overwintering ridleys may permit increased anthropogenic utilization of localized resources without restrictions associated with this endangered species. In addition, seasonally accurate spatial knowledge of the Kemp's ridley population will maximize the efficient implementation and enforcement of federal and state management strategies.

Foraging Behaviors

The significance of Louisiana's coastal waters for foraging Kemp's ridleys, particularly between Sabine Pass and the Mississippi River, has been established for decades (Hildebrand 1982). Corroborative, spatially delineated data published by Shaver et al. (2013) reveal concentrations of female conspecifics, originally intercepted on nesting beaches in both Texas and Mexico, subsequently congregated in Louisiana's neritic zone, waters also utilized by four females tracked after nesting on the UTC by Seney & Landry (2008). Appreciable utilization of Louisiana's waters <50 m in depth by six of seven captive reared and wild UTC females monitored post-nesting in the current study substantiates the importance of this region for post-nesting Kemp's ridleys regardless of natal origin (Fig. 4.9).

Dissimilarities exist, however, in attributes characterizing UTC post-nesters versus that documented by Shaver et al. (2013) for 18 females sourced from the lower Texas coast and Mexico, although this may simply be an artifact of the current study's reduced sample size (n=7). While foraging site residency intervals for pooled data garnered from

UTC nesters were comparable to that described for "final" foraging sites by Shaver et al. (2013), UTC ridleys utilized deeper waters farther from shore over a much broader range of temperatures (Table 4.8). Mean SST reported by both studies was similar, however, and upper temperature range limits herein coincide with that obtained by Seney & Landry (2008). The increased use of deeper waters over an expanded temperature range (14.2 - 31.9ºC) by UTC Kemp's ridleys is likely attributable to this study's longer average tracking duration resulting in a greater proportion of overwintering data.

Post-reproductive UTC females each occupied one to four discrete foraging areas spanning from northern Texas to the Florida Keys (Fig. 4.9, Table 4.8). In contrast to Louisiana's numerous nearshore and offshore Kemp's ridley feeding grounds, all four foraging sites associated with Florida's Gulf Coast (St. Joseph Bay, Apalachee Bay, Charlotte Harbor region, and Florida Keys) were situated adjacent to the coastline, as evidenced by reduced mean values characterizing distance from shoreline and depth during foraging periods for three associated females (74912, 75421, 83242; Table 4.8). All three were located at St. Joseph Bay during October (Figs. 4.3c, d, & e), although duration of residency was brief for two individuals. Female 75421 demonstrated fidelity to St. Joseph Bay on two occasions; however, this individual's movement and temperature data indicate this site is inhospitable for Kemp's ridleys during December and January (Fig. 4.3d). In contrast with results obtained by Hawkes et al. (2011) for telemetered loggerheads, the Charlotte Harbor region may also be temporally limited at indeterminate intervals. Ridley 83242, the sole female geolocated here, initiated directed movements south to the Florida Keys in early January following two consecutive days of temperatures below 17ºC, the two lowest SST recorded for this turtle (Fig. 4.3e). Year-round residency did occur, however, at Apalachee Bay, situated 125 km east of St. Joseph Bay along the Florida Panhandle (74912; Fig. 4.3c). Nonetheless, it must be noted that associated SST values were intermittently documented below 16ºC from January through March. This temporally unconstrained inhabitation of the Apalachee Bay region is consistent with results obtained for juvenile and sub-adult ridleys by Rudloe et al. (1991).

Mean foraging site core utilization area (50% KDE: 679.8 km^2; Table 4.4) corresponds to that identified by Shaver et al. (2013; 660.8 km^2) but not with that previously established for six UTC females by Seney & Landry (2011; 1389 km^2). However, comparability is inhibited by each study's employment of disparate tracking durations and methodologies used in telemetry data analysis. The utilization of a more advanced model to differentiate between migratory and foraging movements, such as switching state-space modeling, is not expected to significantly alter the results presented herein. However, such a model may be beneficial in further refining conclusions regarding post-nesting ridley movements (particularly in regards to ridley 74915) and in increasing comparability of results herein with other published Kemp's ridley data.

Interannual Fidelity

The strict nesting beach fidelity demonstrated by UTC Kemp's ridley nesters has facilitated the attachment of multiple satellite transmitters to four post-nesting females since 2006 (Seney & Landry 2008, 2011; K. Reich, pers. comm.). Individuals were predominantly faithful to internesting areas, migratory routes, and foraging sites during subsequent tracking events, consistent with results documented by Shaver & Rubio (2008) for telemetered ridleys nesting farther south in Texas, as well as within other sea turtle populations (Broderick et al. 2007, Marcovaldi et al. 2010, Hawkes et al. 2011). Minor disparities between tracking events may be attributed to plasticity in environmental resources and/or physical conditions.

Conservation Implications

Kemp's ridley sea turtles face numerous anthropogenic threats in the marine environment that contribute to the imperiled status of this species. Potential in-water mortality factors include, but are not limited to, development and/or degradation of critical habitats and associated permutations in prey resources, vessel strikes, physical and chemical pollution, and commercial and recreational fishery bycatch (NMFS, USFWS & SEMARNAT 2011). Environmental perturbations associated with prolific extraction of oil and gas resources offshore Louisiana must also be considered in relation to Kemp's ridley recovery efforts.

Female Kemp's ridleys from beaches throughout their nesting range demonstrate disparate predilections in internesting, migratory, and foraging behaviors that preclude an oversimplified determination of critical habitats worthy of population conservation measures. Recently, significant contributions to quantify “important marine foraging, breeding, and inter-nesting habitats” in support of a Priority 1 Recovery Task in the Kemp’s Ridley Recovery Plan have been made (Seney & Landry 2008, 2011; Shaver & Rubio 2008; Shaver et al. 2013). Results provided herein not only augment these efforts but also reveal temporally limited inhabitation of specific areas by mature females during internesting, migratory, and foraging phases. This information is provided to aid environmental and extractable resource managers in implementing minimally restrictive, seasonally adaptable conservation measures to minimize lethal pressures and ensure the sustained recovery of this population. Ultimately, increased emphasis is needed on conservation activities to maintain or improve the health and accessibility of known feeding grounds, migratory corridors, and internesting areas in the Gulf of Mexico deemed critical for adult conspecifics.

CHAPTER V

MOVEMENTS OF AN ADULT MALE KEMP'S RIDLEY (*LEPIDOCHELYS KEMPII*) FOLLOWING STRANDING AND REHABILITATION ON THE TEXAS COAST

INTRODUCTION

Legal protections for the Critically Endangered Kemp's ridley sea turtle (*Lepidochelys kempii*; IUCN 2011) were independently enacted by the Mexican and U.S. governments nearly a half-century ago (Márquez 1994; NMFS, USFWS & SEMARNAT 2011). Since that time, a diverse array of conservation initiatives have sought to identify and mitigate anthropogenic threats in both terrestrial and marine environments; these efforts have resulted in an auspicious beginning to the recovery of this species (NMFS, USFWS & SEMARNAT 2011). Reproductive output at major rookeries [including Rancho Nuevo, Tamaulipas, Mexico, and Padre Island National Seashore (PAIS), Texas, USA], a consistent barometer of population magnitude for this species, has increased at an exponential rate for more than a decade (NMFS, USFWS & SEMARNAT 2011).

Research and recovery efforts for the Kemp's ridley have predominantly focused on maximizing reproductive outcomes and/or minimizing lethal commercial fishery interactions (TEWG 2000; NMFS, USFWS & SEMARNAT 2011). While in-water protection measures, such as turtle excluder devices (TEDs), may benefit both male and female conspecifics at different life stages (Epperly 2003, Lewison et al. 2003), the majority of conservation resources have been directed toward nesting beaches and increasing survivorship of terrestrially-accessible individuals (nesting females, eggs, and hatchlings; Coyne & Landry 2007). The ongoing recovery of the Kemp’s ridley sea turtle is being measured in terms of reproductive success (NMFS, USFWS & SEMARNAT 2011), yet insufficient quantitative data exist in regards to reproductive behaviors and associated environmental requirements of a crucial contributor: adult males. Despite recent insights into the spatial ecology of juvenile (Morreale & Standora 2005, Renaud & Williams 2005, Mansfield 2006, McClellan 2009, Seney & Landry 2011, Lyn et al. 2012) and post-nesting female ridleys (Seney & Landry 2008, 2011; Shaver & Rubio 2008; Shaver et al. 2013; see Chapter IV), breeding aggregations, migratory movements, and foraging behaviors of adult males remain largely unknown (Shaver et al. 2005).

The current paradigm suggests that mature male Kemp's ridleys primarily reside in neritic foraging habitats in the vicinity of the nesting beach year-round and predominantly engage in courtship and mating activities in March, immediately prior to the commencement of the April-July nesting season (Owens 1980, Rostal 1991, Rostal et al. 1998, Rostal 2005, Shaver et al. 2005). In addition, field observations of mounted pairs near known nesting beaches have occurred between October-May (Rancho Nuevo) and in early June (PAIS), although confirmation of copulation is lacking (Pritchard & Márquez 1973, Shaver et al. 2005). This tendency for male Kemp’s ridleys to establish year-round residency near rookeries is behaviorally disparate from seasonal migratory movements displayed by mature female conspecifics (Seney & Landry 2008, 2011; Shaver & Rubio 2008; Shaver et al. 2013; see Chapter IV) and male sea turtles of other species (*L. olivacea*: Beavers & Cassano 1996, Plotkin et al. 1996; *Caretta caretta*: Arendt et al. 2012b, Casale et al. 2013; *Chelonia mydas*: Limpus 1993, Hays et al. 2001b; *Dermochelys coriacea*: James et al. 2005).

Identification of spatially- and temporally-defined areas frequented by adult male ridleys for breeding, migrating, and/or foraging purposes is necessary to accomplish a Priority 1 Recovery Task in the Kemp's Ridley Recovery Plan that mandates the protection and management of important marine habitats (NMFS, USFWS & SEMARNAT 2011). Implementation of marine protected areas (MPAs) and/or other conservation measures to facilitate the protection of mature male conspecifics utilizing critical habitats will require a comprehensive effort to better delineate habitat boundaries, assess localized sources of mortality and, in foraging areas, to quantify and qualify prey resources and physical site characteristics. Published scholarly information on adult male Kemp's ridleys is currently limited to a single source describing the movements of eleven individuals incidentally captured from waters near Rancho Nuevo (Shaver et al. 2005); thus, the long-term movements of a single adult male Kemp's ridley from Texas described herein may provide valuable insight for conservation purposes. Research objectives addressed in this chapter include:

1) Identification of migratory and foraging behaviors displayed by an adult male Kemp's ridley, including quantification of spatial and temporal use of feeding grounds.
2) Ascertainment of potential breeding site(s) and frequency of reproductive activity.
3) Discernment of correlations between movement behaviors exhibited by a rehabilitated adult male versus that documented for both non-rehabilitated male and female conspecifics.

METHODS

The adult male Kemp's ridley (herein YYN955) selected for satellite tagging was encountered stranded with no external injuries 19 April 2009 on Harbor Island near Corpus Christi, Texas. Sex was determined based on external morphology (Pritchard & Márquez 1973, Bentivegna 2002, Hays et al. 2010); this turtle possessed robust curved flipper claws and a prehensile tail that extended beyond the carapace margin (Rostal 1991, Márquez 1994; Fig. 5.1). Morphometrics were obtained coincident with the application of flipper and passive integrated transponder (PIT) tags 18 July 2009; YYN955 measured 66.3 cm maximum straight carapace length (SCL), 69.1 cm maximum curved carapace length (CCL), and weighed 31.2 kg. Following a 95-day rehabilitation period at the University of Texas Marine Science Institute's Animal Rehabilitation Keep (ARK) in Port Aransas, YYN955 was outfitted with a satellite

Figure 5.1. Rehabilitated adult male Kemp's ridley YYN955 upon release 23 July 2009 on Mustang Island, Texas. (Photo by Tasha Metz.)

transmitter and released 23 July 2009 on Mustang Island, Texas (27.781067, 97.094300; Fig. 5.2).

Satellite Telemetry

Transmitter Attachment

YYN955 was dry-docked within a suitably confining plastic container at ARK throughout the 3-hour PTT attachment process. A 480 g Sirtrack KiwiSat 101 PTT, powered by a 2 x C cell battery package and programmed to broadcast messages at a frequency of 401.65 MHz using a 40 s repetition rate, was activated at 0900 GMT (0400 CDT) and set to operate with a duty cycle of 6 h on:6 h off. Preparation and attachment of the PTT to the turtle's first and second vertebral scutes with the 4NC antenna oriented anteriorly essentially followed protocol established by Seney & Landry (2008). Pertinent portions of the turtle's carapace and the sides and bottom of the PTT (previously coated in aerosol anti-fouling paint) were primed with 60-grit sandpaper followed by an acetone wash. Two layers of Power-Fast two-part standard set epoxy were applied and manipulated to minimize hydrodynamic drag; each coat remained exposed to ambient air until it was no longer pliable. Six tubes of Sonic-Weld marine epoxy (Mansfield 2006) were then distributed over the entire attachment and permitted to solidify (approximately 10 min). Lastly, the tag (excluding PTT saltwater switches and antenna) and cured attachment materials were coated with a brush-on antifouling paint.

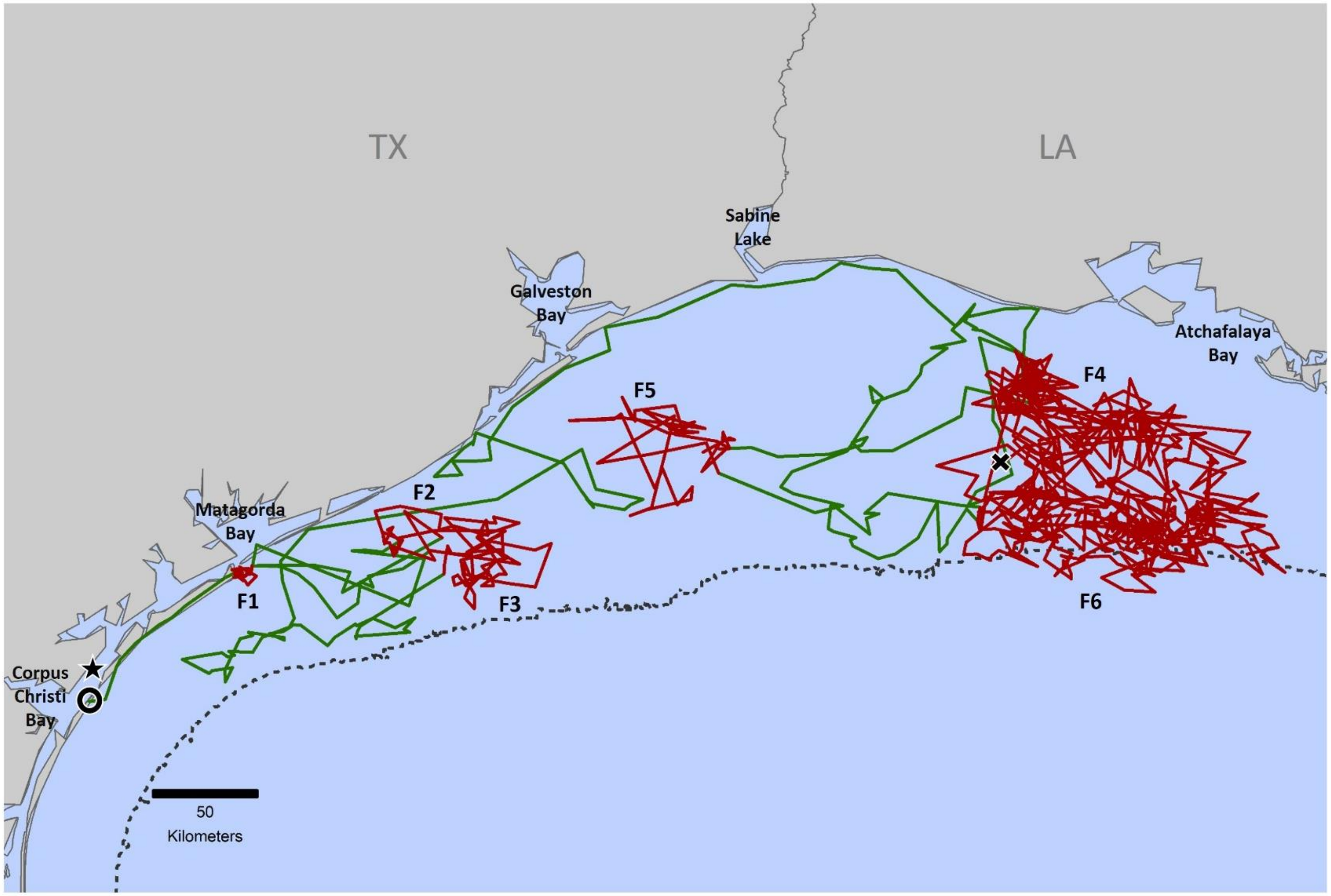


Figure 5.2. Movements of rehabilitated adult male Kemp's ridley sea turtle YYN955, 2009-2013. ☆: Denotes 19 April 2009 stranding location; ◎: denotes 23 July 2009 release location; ✕: denotes 29 July 2013 final PTT geolocation, 🟩: denotes migratory movements, 🟥: denotes foraging ground (F) movements, - - -: denotes 50 m isobath.

Data Analysis

Geographic location data, generated based upon the Doppler shift between successive transmissions by a PTT to NOAA's Polar Orbiting Environmental Satellites (POES), were processed and communicated by CLS America's Argos Service. Location information derived from ≥4 transmissions was classified (LC) based upon estimates of accuracy as follows: LC 3 (<150 m), LC 2 (150 – 350 m), LC 1 (350 – 1000 m), and LC 0 (>1000 m; Argos 1996). Locations provided with no estimate of accuracy were classified based on derivation as LC A (3 messages) or LC B (2 messages); transmissions of LC Z indicated a processing failure (Argos 1996).

Archived PTT location information, paired with relevant integrated environmental data including sea surface temperature [SST; source: Advanced Very High Resolution Radiometer (AVHRR) satellite-based sensors] and oceanic bathymetry [source: General Bathymetric Chart of the Oceans (GEBCO)], was compiled by the Satellite Tracking and Analysis Tool (STAT; Coyne & Godley 2005). The STAT filtering algorithm was utilized to remove locations of class Z and those with elevations exceeding 1.0 m. The traditional location class hierarchy (LC 3 > 2 > 1 > 0 > A > B; Costa et al. 2010) was then employed to generate a single "best" daily location (Hawkes et al. 2011, Arendt et al. 2012a); limiting use to the first occurrence of the highest quality LC during each 24-hour period minimized autocorrelation in subsequent spatial analyses. Finally, a filtering protocol developed by Arendt et al. (2011) that simultaneously identified implausible locations requiring turning angles <5° and/or linear swimming speeds exceeding 5 km h^{-1} (Renaud 1995) was applied. If filtering criteria were not met by the initial best daily location, corresponding alternate tracking information was systematically substituted or that day's location was omitted from the data set. This protocol resulted in 18 substitutions and permitted retainment of 98.8% of the 1064 original observation days.

Esri's ArcGIS 9.3 was employed to visualize retained coordinates. Discernibly spurious geolocations consisting of LC 0 (n=5), LC A (n=27), and LC B (n=19) were manually omitted. Directionality and displacement of plotted geolocations from YYN955's release site were scrutinized to deduce foraging versus migratory behaviors, similar to criteria used by Hawkes et al. (2011). Per criteria established for mature females tracked from upper Texas coast (UTC) beaches (see Chapter IV; UTC beaches are located approximately 250 km northeast of YYN955's stranding location), migratory phases primarily consisted of consecutive directional movements (Griffin et al. 2013), while foraging areas were characterized by restricted, primarily non-directional movements utilized by an individual for a minimum of 12 consecutive days (≥11 geolocations). This temporally- and behaviorally-based termination of migratory behavior is more robust than that utilized in other sea turtle tracking studies (Zbinden et al. 2008, Marcovaldi et al. 2010).

Home Range Tools (HRT; Rodgers et al. 2007) for ArcGIS was used to generate migratory routes to and kernel density estimates (KDE; 50% and 90%) for each foraging ground with ≥34 daily locations (Millspaugh & Marzluff 2001). Recurrent use of spatially distinct feeding sites was coalesced to generate single cohesive KDE contours representative of use over the duration of the entire tracking period. Migratory phases were deemed terminated when the directional path traversed the previously established foraging zone boundary (Griffin et al. 2013), resulting in the potential inclusion of up to several days of directional movement within the foraging ground for KDE estimate generation. Core activity areas (50% probability contour; Hooge et al. 1999) and utilization distributions (90% probability contour; Borger et al. 2006) were calculated for each foraging ground using the fixed least squares cross-validation smoothing factor and rescaling to unit variance if the ratio of standard deviations exceeded 1.5.

Official Protraction Diagram and Leasing Map boundaries, disseminated by the Bureau of Ocean Energy Management (BOEM), were plotted in conjunction with retained geolocations to provide a relevant spatial reference for movements by a mature male Kemp's ridley in relation to the intense exploration, development, and extraction of the Gulf of Mexico's profuse mineral resources. Displayed Boundary Areas situated on the federal continental shelf may aid in coordinating sea turtle conservation efforts with Gulf of Mexico resource extraction interests.

RESULTS

YYN955's PTT transmitted location and sensor data for 1468 d (1000 retained geolocations between 23 July 2009 - 29 July 2013). All documented movement occurred within neritic western Gulf of Mexico waters extending from YYN955's release site on Mustang Island, Texas, northeast to offshore waters due south of Atchafalaya Bay, Louisiana, within the western Ship Shoal Area (Figs. 5.2 & 5.3a). This male remained almost exclusively in waters less than 50 m in depth during both migratory and foraging phases. Migratory movements (denoted as "M") and foraging grounds (denoted as "F") described herein are followed by a numerical designation denoting sequence of occurrence (migration) or initial use (foraging ground).

Migratory Phases

Eight distinct migrations, ranging in duration from 6 - 113 d (mean = 26.5, SD ± 35.7), were made by YYN955 in transitioning to or among foraging sites (Fig. 5.4). Directed movements were initiated in January (n=1), May (n=1), July (n=2), August (n=2), and October (n=2) on routes situated a mean distance of 46.2 km from shore (SD ± 39.1, range = 0 – 136.0 km) in waters averaging 22.6 m in depth (SD ± 13.8, range = 1.0 to -44.9 m) and 23.3ºC SST (SD ± 5.7, range = 14.1 – 31.6ºC). Mean speed of movement, which ranged from 0 – 3.3 km h^{-1}, was 0.5 km h^{-1} (SD ± 0.5).

Nearshore (≤ 10 km from the nearest shoreline) migrations, including post-release movements (M1) and the latter portion of this ridley's itinerant movements from 16 January – 8 May 2010 (M4), were principally composed of sequential linear trajectories that paralleled the coastline (Fig. 5.4). However, transitional movements in deeper waters, while consistently advancing and thus void of persistent delays or periodic

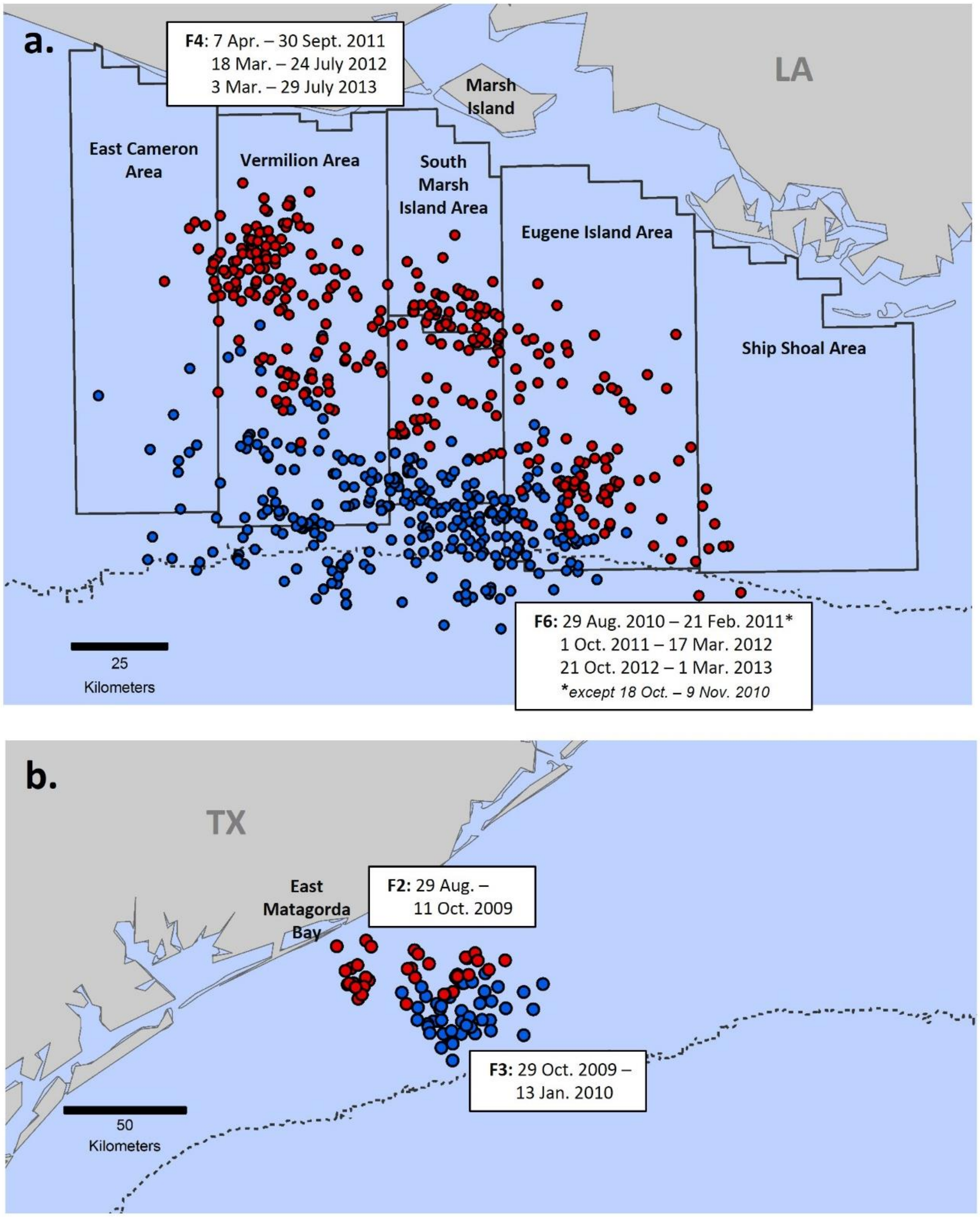


Figure 5.3. Seasonal usage of adjacent foraging grounds (a) F2 and F3 and (b) F4 and F6 by rehabilitated adult male Kemp's ridley sea turtle YYN955. 🔴: Denotes summer range geolocations; 🔵: denotes winter range geolocations; - - -: denotes 50 m isobath.

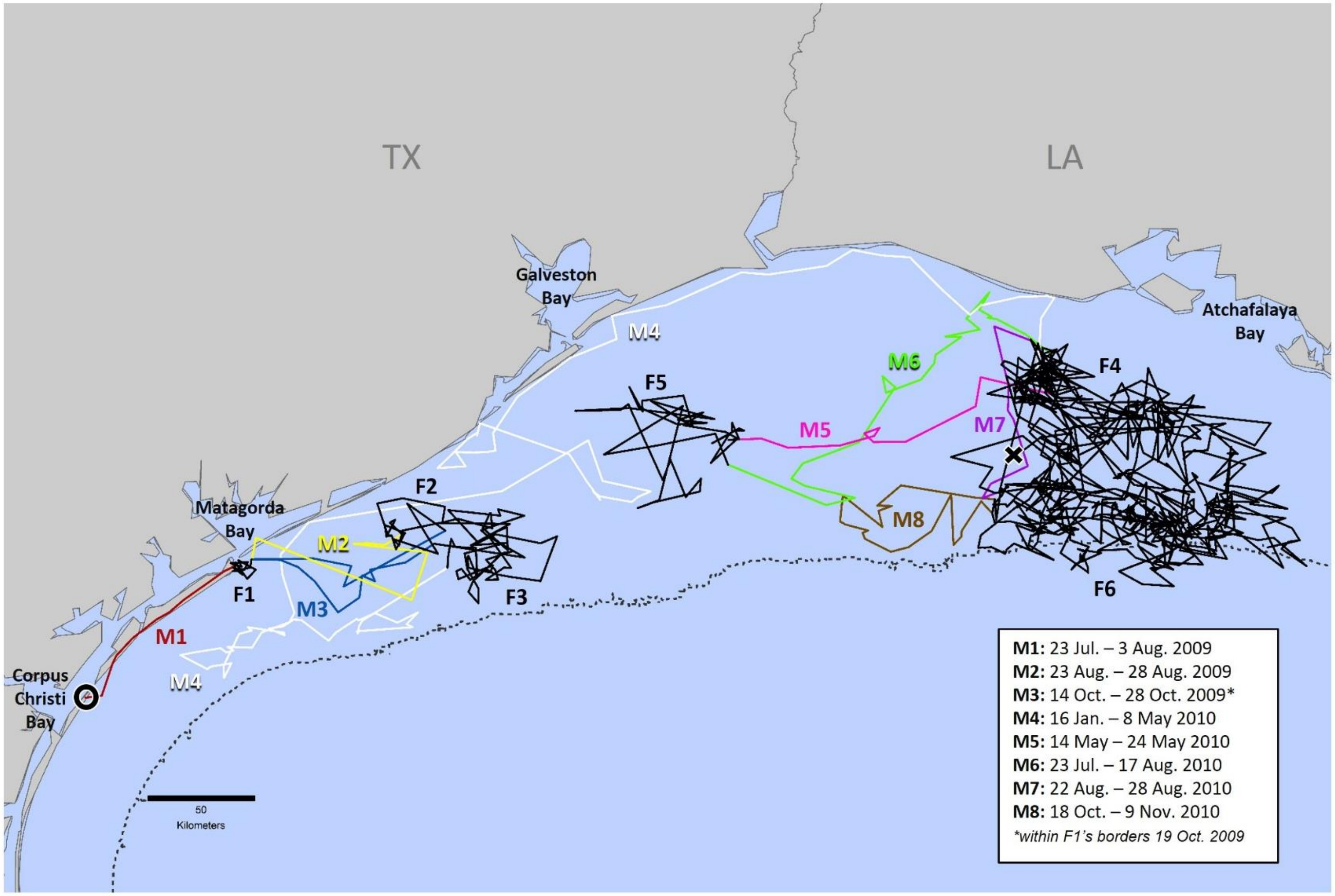


Figure 5.4. Migratory (M) movements of rehabilitated adult male Kemp's ridley sea turtle YYN955, 2009-2013. ◎: Denotes 23 July 2009 release location; ✕: denotes 29 July 2013 final PTT geolocation, ▬: denotes foraging ground (F) movements, - - -: denotes 50 m isobath.

direction reversals indicative of foraging behavior, intermittently incorporated circular swimming patterns. Four discrete circuitous movements were documented during YYN955's protracted 113 d migration (M4) in which he transitioned from offshore (>10 km from the nearest shoreline) feeding grounds (F3) east of Matagorda Bay, Texas, to a foraging site (F4) south of Atchafalaya Bay, Louisiana (Figs. 5.4 & 5.5a). In addition, two migratory routes commenced and concluded at roughly concordant locations (Fig. 5.5b). Circuits occurred during a 14 d transition (M3) between adjacent foraging areas (F2 and F3) located east of East Matagorda Bay, Texas (a direction reversal occurred following a single day within F1's borders, the most westerly geolocation) and subsequently in the course of a 23 d trek (M8) to and from F6, a feeding site offshore Louisiana (Figs. 5.4 & 5.5b).

Extended Migratory Movements Encompassing the Kemp's Ridley Breeding Season (March - April)

YYN955's initial movements following inception of a prolonged 113 d migration (M4) from foraging site F3 on 16 January 2010 were gradual (mean speed of movement: 0.2 ± 0.2 km h^{-1}) and in a southwesterly direction until arrival at a southern terminus 1 March 2010 (Fig. 5.5a). YYN955 then proceeded northeast, moving inshore adjacent to Matagorda and East Matagorda Bays in mid-March before transitioning offshore on approach to (but not utilization of) feeding site F5 by late March. On 3 April, geolocations again became coastal adjacent to Follets Island and this male remained just southwest of Galveston Island until 19 April. Straight-line distance traveled between 1

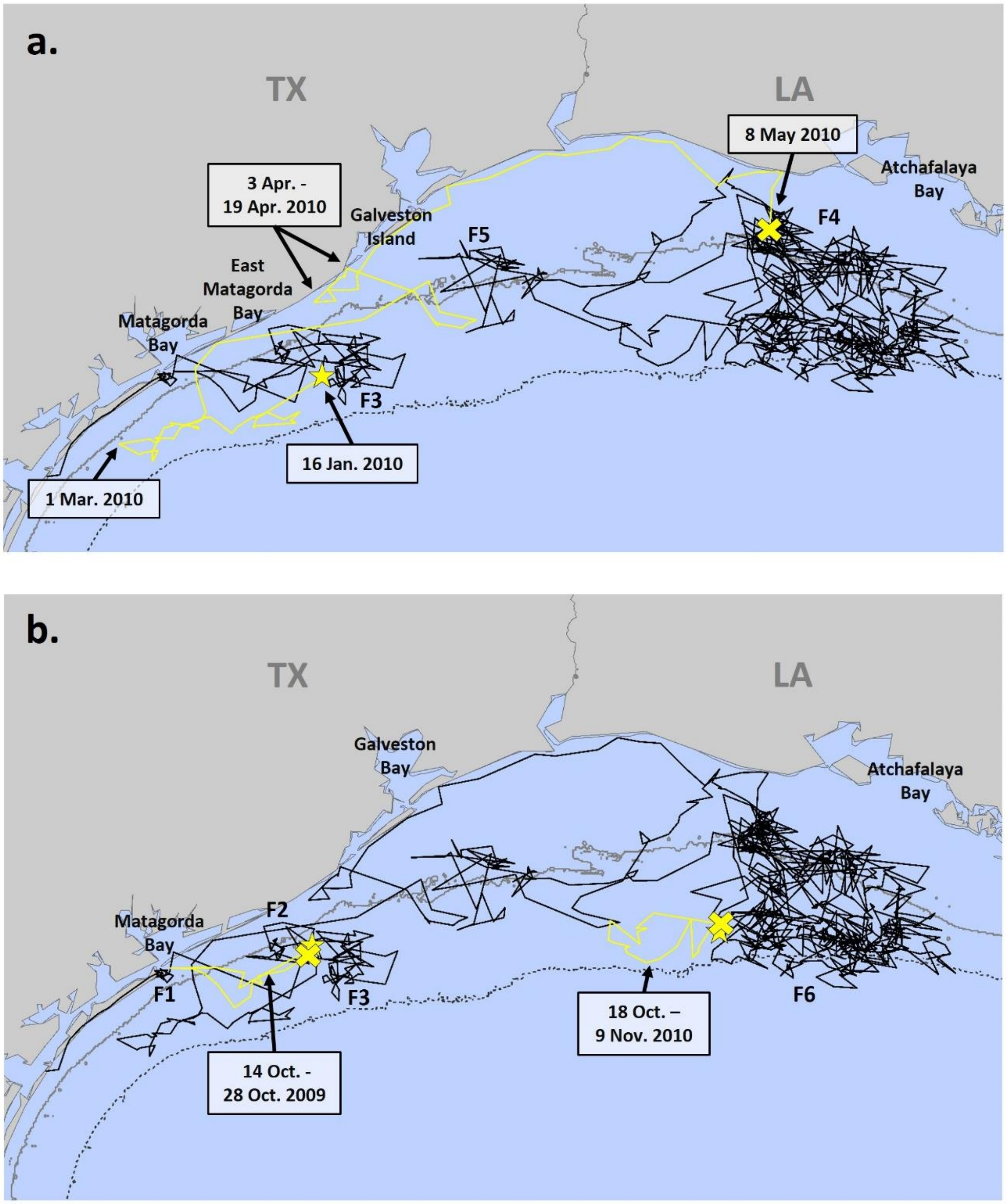


Figure 5.5. Extended (a) and circuitous (b) migratory movements of rehabilitated adult male Kemp's ridley sea turtle YYN955. ▭ : Denotes (a) extended migration 16 January – 8 May 2010 and (b) circuits 14 October – 28 October 2009 and 18 October – 9 November 2010; ▬ : denotes remainder of track 23 July 2009 – 29 July 2013; ☆ : denotes migration start; ✕: denotes migration end; ▬ : denotes 20 m isobath; - - - : denotes 50 m isobath.

March and 19 April was approximately 180 km at a mean speed of 0.5 km h^{-1} (SD ± 0.4). Beginning 20 April, YYN955's movements became more directed and paralleled the coastline northward until arrival at feeding ground F4 off Louisiana 10 May 2010. Rate of travel averaged 0.8 km h^{-1} (SD ± 0.7) through shallow waters (mean depth: 1.9 ± 2.1 m) during the coastal segment of this extended migratory phase.

Foraging Ground Utilization

Six distinct neritic foraging grounds were identified in nearshore or offshore waters ranging from the southern reaches of Matagorda Peninsula in Texas east to Louisiana's southwestern Ship Shoal Area (Figs. 5.2 & 5.3a). Integrating Gulf of Mexico foraging ground data (n=828 geolocations) over the study period permitted generation of a set of parameters characteristic of the physical environment utilized by this individual during non-migratory phases (Table 5.1). Neritic feeding sites occupied a bathymetric range of 0.8 to -66.3 m (mean = 31.0 m, SD ± 12.6) and were situated 0 – 128 km from shore (mean = 71.3 km, SD ± 28.7). SST during feeding periods averaged 24.5°C (SD ± 4.3, range = 15.9 – 31.7°C). Mean speed of movement during foraging phases was 0.4 km h^{-1} (SD ± 0.4, range = 0 – 4.3 km h^{-1}). Residency intervals at discrete sites prior to directed movement between foraging locations ranged from 1 - 177 d (mean = 79.7 d, SD ± 63.3). However, comprehensive assessments regarding site utilization over YYN955's entire tracking period required pooling data pertaining to recurrent use of previously exploited foraging grounds (n=3). Mean foraging site residency for pooled data was 186 d (SD ± 211.9, range 20 - 462 d).

Table 5.1. Western Gulf of Mexico foraging grounds (n=6) utilized by an adult male Kemp's ridley sea turtle, 2009-2013.

			KDE			**Site Characterization**		
Foraging Site	**Duration of Foraging (d)**	**Mean Swim Speed (km h^{-1})**	**No. Accepted Daily Locations**	**50% (km^2)**	**90% (km^2)**	**Mean Depth (m)**	**Mean Distance from Shore (km)**	**Mean SST (^{o}C)**
F1	20	0.2 (SD ± 0.2)	19	N/A[1]	N/A[1]	3.6 (SD ± 4.1)	2.4 (SD ± 2.7)	29.5 (SD ± 1.0)
F2	44	0.5 (SD ± 0.5)	35	354.5	1147.9	23.3 (SD ± 5.7)	29.4 (SD ± 10.8)	28.8 (SD ± 0.9)
F3	77	0.4 (SD ± 0.3)	51	677.3	2139.2	34.9 (SD ± 3.8)	54.2 (SD ± 9.1)	21.6 (SD ± 2.6)
F4	462	0.5 (SD ± 0.4)	328	1702.9	6087.0	22.6 (SD ± 8.4)	54.6 (SD ± 16.3)	25.9 (SD ± 4.1)
F5	58	0.6 (SD ± 0.4)	40	880.5	3020.6	19.6 (SD ± 4.9)	61.1 (SD ± 17.4)	29.0 (SD ± 0.9)
F6	455	0.3 (SD ± 0.3)	355	1348.4	4195.6	41.7 (SD ± 7.3)	98.2 (SD ± 12.6)	22.5 (SD ± 3.7)
Mean	**186**	**0.4**	**138**	**992.7**	**3318.1**	**31.0**	**71.3**	**24.5**
SD	211.9	0.4	158.2	536.3	1912.1	12.6	28.7	4.3
Range	20 to 462	0 to 4.3	19 to 355	354.5 to 1702.9	1147.9 to 6087.0	ASL[2] to 66.3	0 to 128.0	15.9 to 31.7

[1] **Excluded from calculations due to an insufficient number of geolocations.**

[2] **Filtering criteria permitted inclusion of depths ≤ 1.0 m above sea level (ASL).**

Residency Near A Known Kemp's Ridley Rookery

In mid-May 2010, approximately one year post-rehabilitation and release, YYN955 initiated directed movements west (M5) from foraging grounds offshore Louisiana to a feeding site (F5) located east of a recently established ridley rookery centered on Galveston Island, Texas (Fig. 5.4). From 25 May – 21 July 2010, a residency period of 58 d, this male remained a mean distance of 61.1 km from shore (SD $\pm$ 17.4 km) in waters averaging 19.6 m in depth (SD $\pm$ 4.9 m; Table 5.1). Mean swim speed while resident on F5 (0.6 ± 0.4 km h^{-1}) was the highest documented for this male on any foraging site and met (n=1) or exceeded (n=5) that recorded during 6 of 8 migratory phases. Upon departure from F5, YYN955 returned east and established two distinct foraging grounds offshore Louisiana, where he remained for the duration of the tracking period (1103 d).

Seasonal Movements Between Adjacent Feeding Grounds

YYN955 established two sets of adjacent feeding sites in which waters closer to shore were utilized during warmer months (herein "summer range"), while offshore areas were inhabited during cooler periods of the year (herein "winter range"). East of East Matagorda Bay, Texas, a convergent boundary differentiated foraging areas F2 (summer range) and F3 (winter range), both of which were occupied during a single interval throughout YYN955's duration of monitoring (Fig. 5.3b, Table 5.1). Initial usage of the more coastal F2 site (mean distance from shore: 29.4 $\pm$ 10.8 km) occurred from 29 August – 11 October 2009 (44 d). YYN955 then engaged in a 14 d circuitous migration

(M3) prior to overwintering to the southeast on F3 from 29 October 2009 - 13 January 2010 (77 d; mean distance from shore: 54.2 ± 9.1 km). SST while resident on F2 averaged 28.8°C (SD ± 0.9); water temperatures averaged 27.8°C (SD ± 0.5) during the final week of occupation. Mean winter range SST within F3 was 21.6°C (SD ± 2.6).

Offshore Louisiana, recurrent seasonal transitions were made between contiguous feeding grounds that extended from the East Cameron Area east to the southwestern sector of the Ship Shoal Area (Fig. 5.3a, Table 5.1). YYN955 initially established residency within F6, a winter range located a mean distance of 98.2 km (SD ± 12.6 km) from shore, from 29 August 2010 - 21 February 2011 [this date range disregards a 23 d circuitous migration (M8) to and from F6 that occurred between 18 October – 9 November 2010]. Following a temporary cessation of transmissions, this male was geolocated on summer range F4 (mean distance from shore: 54.6 ± 16.3 km) from 7 April – 30 September 2011. Consistent north/south transitions across the common F4/F6 partition, which occurred annually in October and March, were documented for an additional two years until PTT transmissions ceased permanently on 29 July 2013. Mean SST recorded during YYN955's inhabitation of the relatively smaller winter range was 22.5°C (SD ± 3.7°C), while summer range SST averaged 25.9°C (SD ± 4.1°C). Mean site-specific rates of travel were also divergent (F6: 0.3 ± 0.3 km h^{-1}, F4: 0.5 ± 0.4 km h^{-1}).

Kernel Density Analyses

Mean core activity area (50% KDE contour) for five identified foraging sites (F2-F6) occupied by YYN955 was 992.7 km^2 (SD ± 536.3 km^2), while utilization distributions (90% KDE contour) averaged 3318.1 km^2 (SD ± 1912.1 km^2; Fig. 5.6, Table 5.1). KDE contours were not generated for this male's initial foraging site (F1) due to an insufficient number of geolocations (n=19). The two most substantial foraging grounds (F4 and F6), in terms of both physical expanse and duration of utilization, were located offshore Louisiana; all remaining sites were situated in nearshore or offshore Texas' waters.

DISCUSSION

The ability to draw constructive conclusions on a suite of behaviors potentially characteristic of reproductively mature male Kemp's ridleys based upon the movements of the single individual described herein is limited, both in terms of an insufficient sample size and by the inability to identify potential short- or long-term repercussions associated with this individual's stranding and rehabilitation (i.e. post-release fitness, habituation, etc.). Nonetheless, the prolonged monitoring duration of 1468 d and the fact that this ridley is a wild conspecific that survived to maturity without previous medical intervention (based upon lack of prior tags) mean that information advantageous to our understanding of mature male conspecifics may be gleaned from his movements.

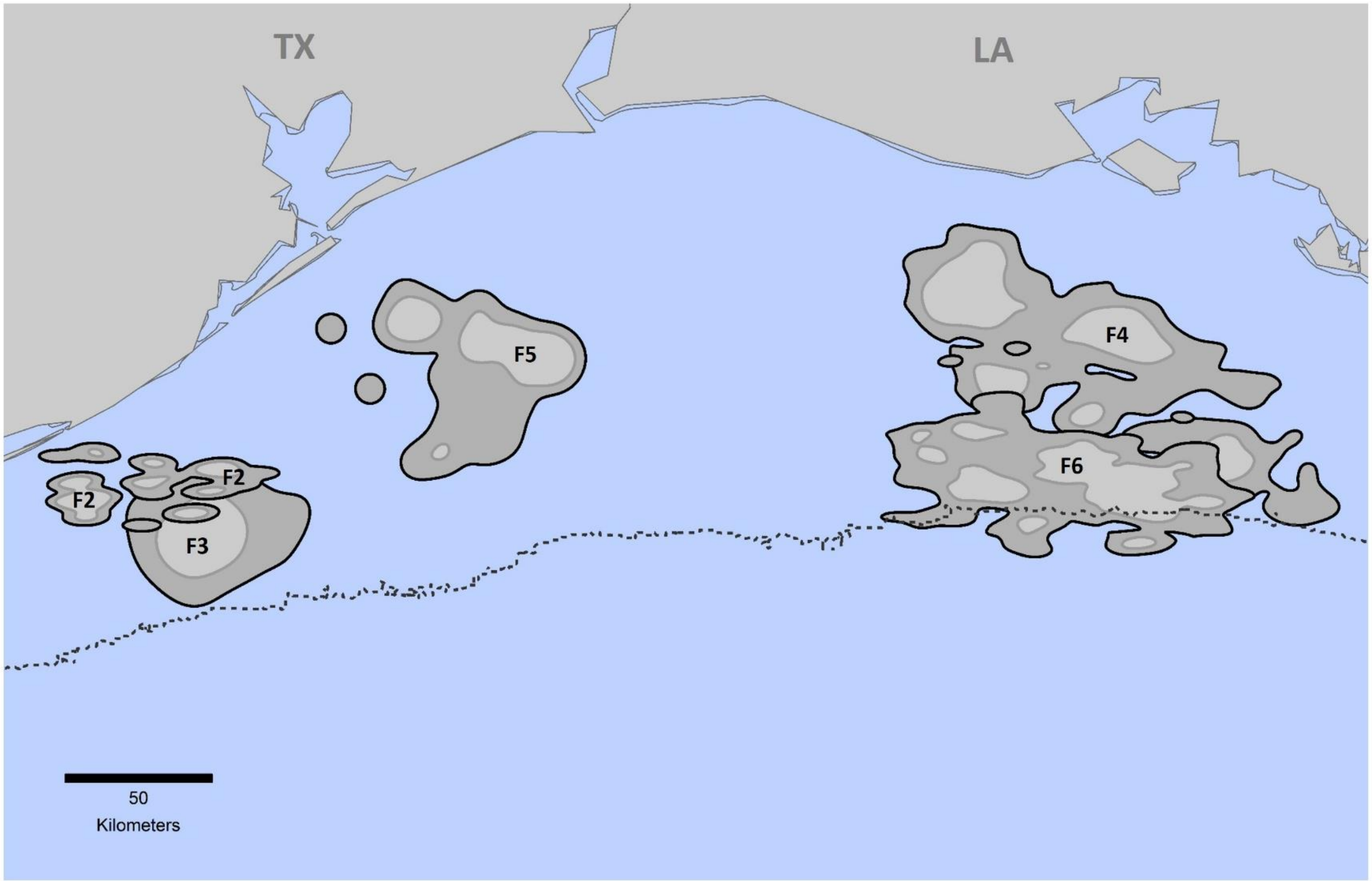


Figure 5.6. Core foraging activity areas (50% KDE; light gray) and utilization distributions (90% KDE; dark gray) for foraging grounds (n=5) utilized by rehabilitated adult male Kemp's ridley sea turtle YYN955, 2009-2013. Geolocations associated with this individual's recurrent use of three discrete sites (F2, F4, F6) were coalesced to generate a single KDE; comprehensive site utilization durations ranged from 20 – 462 d. ▬ ▬ ▬: Denotes 50 m isobath.

Movement Behaviors Indicative of Breeding

Male Kemp's ridleys exhibit seasonal reproductive behaviors in confluence with the relatively precise seasonality displayed by nesting female conspecifics (Owens 1980, Rostal et al. 1998, Rostal 2005). Direct observations of captive, reproductively mature Kemp's ridleys held at the Cayman Turtle Farm (Grand Cayman, Cayman Islands) revealed male courtship and mounting behaviors increased in frequency in March and were not prevalent between June-January (Rostal et al. 1998, Rostal 2007). Thus, movements by YYN955 spanning the pre-nesting (March) and early nesting (April) periods during each of the four years he was tracked were of particular interest.

Six months post-release, YYN955 initiated an extended migratory phase (M4) in January in which he initially traveled southwest from offshore Texas foraging site F3 (Fig. 5.5a) in waters averaging 16.2°C (SD ± 0.9°C) at a relatively sedentary rate (mean swim speed: 0.2 ± 0.2 km h^{-1}), a reduced swim speed consistent with expected metabolic deceleration during periods of cool temperatures. In early March, YYN955 reversed direction and traversed relatively more coastal waters between Matagorda Bay (mid-March) and Follets Island (early April) at an increased rate of speed (0.5 ± 0.4 km h^{-1}), then remained in nearshore waters just south of Galveston Island until 19 April (Fig. 5.5a). This unabridged nearshore environment, particularly that contained within the 20 m isobath where YYN955 was often located, has been identified as an internesting corridor annually frequented in May and June by numerous females comprising the UTC nesting cohort following nest deposition on associated beaches (Seney & Landry 2008, 2011; see Chapter IV).

While the spatial and temporal parameters associated with breeding by UTC nesters remain unknown, it is likely that associated females return to identified internesting ranges in March or early April (see Chapter IV) in accordance with documented ridley remigrations to Rancho Nuevo (Renaud et al. 1996) and PAIS (Shaver & Rubio 2008). Furthermore, it can be speculated that ridleys also breed in the vicinity of UTC nesting beaches following remigration from distant foraging grounds, in line with temporal peaks in breeding activity observed off Rancho Nuevo and PAIS (Pritchard & Marquez 1973; Rostal 2007; NMFS, USFWS & SEMARNAT 2011). Thus, it is plausible that YYN955's movements within this internesting corridor during the probable breeding period were purposeful and that this male may be associated with the UTC nesting cohort. The classification of YYN955's movements during this time as migratory (based on displacement and general directionality) may be an artifact of the relatively small size of the recently established UTC nesting cohort and this male's consequential need to search for suitable mates, thus also justifying his moderate rate of movement and circuitous (i.e. searching) swimming behavior. On 20 April, just prior to the 24 April 2010 documented start of ridley nesting in Texas (Shaver 2011), YYN955 initiated linearly directed movements along the 2-m depth contour at an increased rate of speed (0.8 ± 0.7 km $^{h-1}$) to feeding grounds off Louisiana (Fig. 5.5a). This directed withdrawal from speculated breeding grounds and subsequent transit to a known Kemp's ridley foraging hotspot (Seney & Landry 2008, 2011; Shaver et al. 2013; see Chapter IV) is temporally consistent with the estimated conclusion of copulation activities (Rostal 2007) and this individual's behavioral shift toward replenishment of nutritional reserves depleted during reproduction. This departure is also in accordance with that observed for wild, post-breeding male olive ridleys (*L. olivacea*) that typically withdrew from the vicinity of the nesting beach coincident with the mid-season peak in egg laying by female conspecifics (Plotkin et al. 1996).

If nearshore waters adjacent to the UTC function as breeding grounds for the small but increasing number of ridleys annually nesting on associated beaches (see Chapter IV), conjecture which is supported by the movements of YYN955 during March and April 2010, then serious consideration must be given to the expansion of a Texas Parks and Wildlife Department (TPWD) regulation instituted in 2000 for the protection of conspecifics nesting on lower Texas coast beaches (Lewison et al. 2003, Shaver & Rubio 2008). The TPWD regulation currently prohibits shrimp trawling, a principal source of anthropogenic mortality for the Kemp's ridley (Moore et al. 2008, National Marine Fisheries Service 2011), within 8 km of the shoreline along North Padre Island, South Padre Island, and Boca Chica Beach annually from 1 December through mid-May. Extension of the marine environment impacted by this regulation northward to incorporate waters adjacent to the UTC would reduce the potential for fisheries-associated mortality of conspecifics annually congregating for reproductive purposes, thus consequentially supporting the potential proliferation of the northernmost cohort of the Kemp’s ridley sea turtle.

YYN955’s movements throughout the subsequent three breeding periods (2011 - 2013), during which he maintained strict fidelity to foraging grounds offshore Louisiana and thus did not migrate to breeding areas in the vicinity of nesting beaches, were not discernibly indicative of archetypal reproductive activity.

Foraging Ground Utilization

YYN955 established and maintained two foraging sites (F4 and F6) offshore central Louisiana in waters recently identified as “critical foraging habitat” for post-nesting female conspecifics sourced from both Rancho Nuevo and PAIS (Shaver et al. 2013). This aforementioned habitat is also heavily utilized by post-nesting females tracked from UTC beaches (Seney & Landry 2011, see Chapter IV). Although monitoring of this rehabilitated male and that of seven UTC post-nesting females during the foraging phase (see Chapter IV) occurred over heterogeneous time scales, significant overlap of core use activity areas (50% KDE) and/or utilization distributions (90% KDE) was identified (Fig. 5.7a&b). Collectively, UTC females’ use of Louisiana’s waters for foraging purposes on an annual basis was similar to that identified for YYN955, although female foraging areas had a broader longitudinal distribution. Moreover, proximity of the northern boundaries of all calculated utilization distribution contours to Louisiana’s shoreline was similar for all monitored adult male (n=1) and female (n=7) ridleys, thus potentially indicative of reduced foraging activity by mature conspecifics in waters less

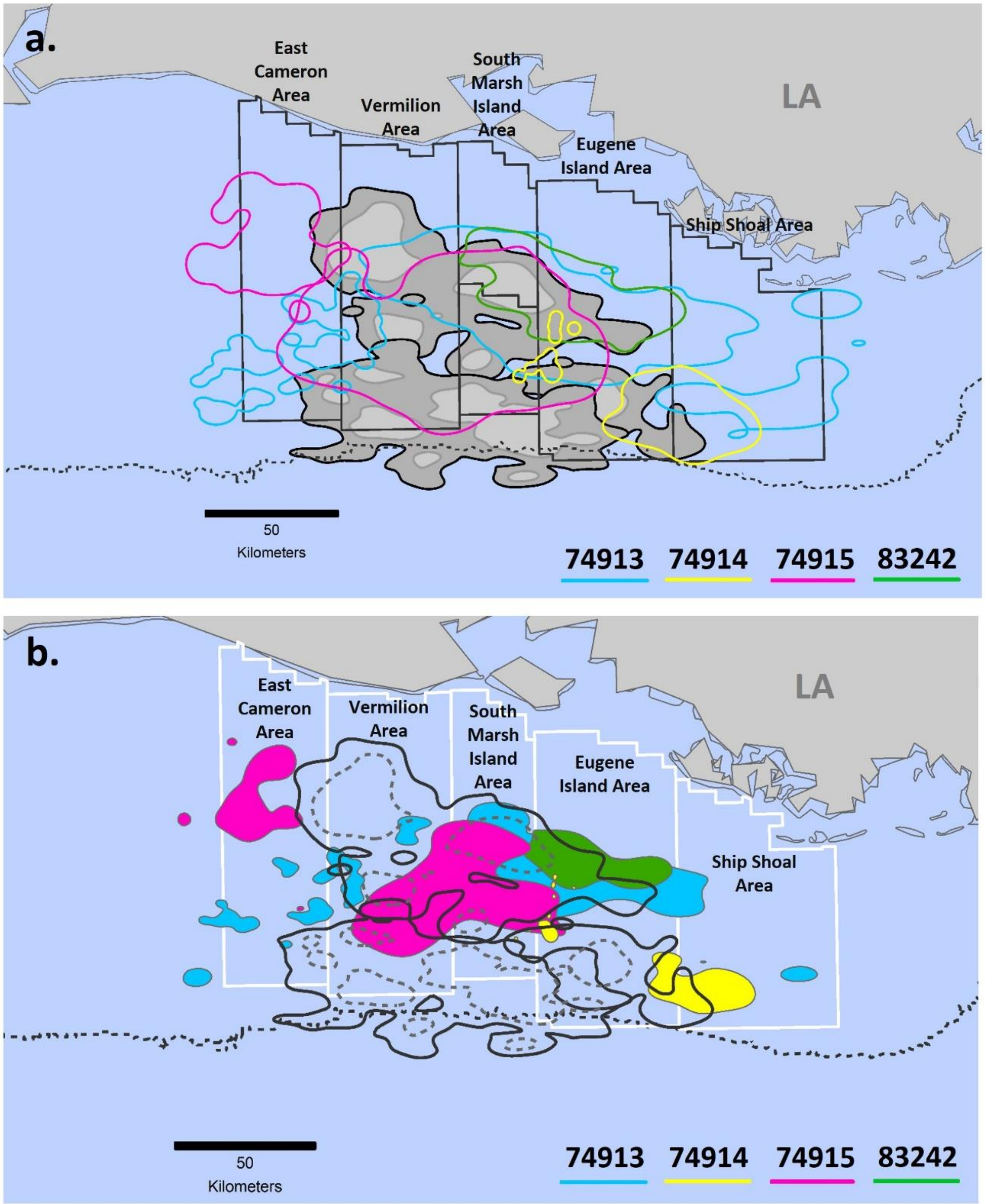


Figure 5.7. Spatial relationship of foraging grounds (F4 and F6) offshore Louisiana used by rehabilitated adult male Kemp's ridley YYN955 from 2010-2013 versus feeding sites (n=7) used by mature female conspecifics (n=4) during 2007-2009 (see Chapter IV). Male 50% (light gray) and 90% (dark gray) KDE contours are displayed as (a) polygons or (b) lines. Female foraging activity is represented by individually colored (a) lines (90% KDE) and (b) polygons (50% KDE). - - - : denotes 50 m isobath.

than approximately 25 km from shore between the East Cameron and Ship Shoal Areas (Fig. 5.7a). In contrast, this male's primary winter range (F6) extended farther offshore (mean distance: 98.2 ± 12.6 km) into deeper waters (mean depth: 41.7 ± 7.3 m; Table 5.1) than that documented for previously tracked UTC nesters during winter months, likely due to documented disparities in seasonal orientation of this male (north-south) versus that for UTC females (east-west; see Chapter IV).

Seasonal Movements Between Adjacent Feeding Grounds

Renaud & Williams' (2005) analyses of movements by 106 juvenile and adult Kemp's ridleys, including 3 individuals tracked from either the UTC or western Louisiana, detected temperature-induced positional shifts consisting of migrations south and/or offshore during the fall and winter and a subsequent return to coastal environments in the spring. YYN955's southeasterly transition from F2 to F3 in October 2009 (Fig. 5.3b) and successive return to the nearshore environment in March 2010 (Fig. 5.5a) is consistent with this premise of seasonal shifts in locales effected by alterations in the thermal regime. In addition, YYN955 demonstrated similar seasonal migratory behavior while resident on, and faithful to, foraging grounds off central Louisiana from 10 November 2010 until PTT transmissions ceased 29 July 2013. During this period, YYN955 made five sequential transitions between a relatively smaller offshore winter range (F6) consistently inhabited from October through mid-March and a larger, more northern (i.e. coastal) summer range (F4) occupied from mid-March through September (Fig. 5.3a). Abiotic site parameters characterizing winter ranges F3 and F6 correlate with

Renaud & Williams' (2005) results regarding the use of deeper offshore waters during cooler periods. Furthermore, oceanic bathymetry associated with summer ranges F2 (mean depth: 23.3 ± 5.7 m) and F4 (mean depth: 22.6 ± 8.4 m; Table 5.1) correspond to the 21.7 m depth identified by Renaud & Williams (2005) as characteristic of foraging grounds used by Kemp's ridleys from April – September.

In contrast, this adult male's ostensibly conventional seasonal transitions are at variance with those identified for UTC post-nesting ridleys (n=4; see Chapter IV), as well as the lack of seasonality documented for adult males seemingly resident year-round near Rancho Nuevo (Shaver et al. 2005) and other adult female conspecifics monitored after clutch deposition on Texas' beaches (Seney & Landry 2008, 2011; Shaver & Rubio 2008; Shaver et al. 2013). Four UTC females who established residency offshore Louisiana, including three whose feeding grounds partially overlaid YYN955's F4 and/or F6 sites (74913, 74914, 74915; Fig. 5.7a&b), executed longitudinal fall (November/December) and spring (March/April) migrations between larger easterly summer ranges and truncated western winter ranges (see Chapter IV). Despite this difference in migration directionality, YYN955's seasonal movements were similar to that of these mature females in: 1) the establishment of contiguous feeding sites offshore Louisiana, 2) the timing of seasonal movement, and 3) the contrastive size of winter versus summer ranges, the latter of which has also been described for green and loggerhead turtles (Broderick et al. 2007). The lack of detectable seasonality in the monitored movements of other mature male and female Kemp's ridleys may simply be an artifact of tracking durations averaging less than one year.

Kernel Density Analyses

This adult male's mean foraging ground core utilization area (50% KDE: 992.7 ± 536.3 km^2; Table 5.1) fell within the range of means (660.8 – 1389 km^2) identified for mature female conspecifics sourced from nesting beaches in both Texas and Mexico (Seney & Landry 2011, Shaver et al. 2013, see Chapter IV). The majority of stated females also established foraging grounds within the U.S. Gulf of Mexico, particularly in Louisiana waters proximate to YYN955's F4 and F6 sites. Conversely, YYN955's mean foraging area size (i.e. 50% contour) was appreciably larger than that associated with seven males monitored by Shaver et al. (2005) who appeared to reside in the vicinity of the nesting beach year-round (mean home range: 95 km^2). Comparability between the two studies is nearly futile, however, in light of potential sampling biases and disparate tracking durations and methodologies used in telemetry data analysis.

Prolonged Foraging Site Fidelity

YYN955's long-term fidelity (29 August 2010 – 29 July 2013) to foraging grounds offshore Louisiana begets questions regarding his reproductive fitness during this protracted interval, particularly in light of potential breeding behavior observed during March and April 2010, less than one year following his stranding and subsequent release from a rehabilitation facility. The lack of telemetry data describing adult male Kemp's ridley movements, combined with behavioral plasticity inherent among individuals within a population, result in an inability to draw conclusions about the potential abnormality of a foraging site residency period of nearly three years. Female Kemp's ridleys foraging in a similar region offshore Louisiana have previously engaged in consistent biennial remigrations to the UTC (see Chapter IV), which suggests that associated foraging grounds are sufficient to meet the nutritional needs of cancrivorous and reproductively active Kemp's ridleys. That being said, the long-term ramifications of the 20 April 2010 Deepwater Horizon oil spill on both sea turtles and prey resources within these important foraging grounds remain unclear. Exposure to environmental toxins and a reduction in prey availability both have the potential to negatively alter an individual's physiological status and, thus, ability to devote nutritional reserves to reproduction. However, limited prey availability may consequently induce relocation to more productive feeding sites, but migrations to other destinations were not observed.

Lack of sexual maturity is unlikely the causative factor of the extended residency period given this male's SCL (66.3 cm) in relation to other male ridleys considered reproductively active (Pritchard & Marquez 1973, Rostal 1991, Shaver et al. 2005). Additionally dubious is the theory of serious, long-term infirmity on the part of this male, especially when considered in conjunction with the consistency of timely seasonal migrations throughout the residency period. Verification of YYN955's sex via blood work or laparoscopy was not obtained and identification based on physical traits alone is not definitive (Hamann et al. 2003), but this individual's secondary sexual characteristics were well developed (Fig. 5.1).

Barring a complete lack of reproductive fitness, it is plausible this male was opportunistically breeding, likely asynchronously and potentially unsuccessfully, with female ridleys inhabiting proximate offshore Louisiana foraging grounds (Morreale et al. 2007, D. Owens pers. comm., P. Plotkin pers. comm.). Although female receptivity is reduced outside of the predicted courtship and mating period (Owens 1980, Rostal et al. 1998), a breeding dichotomy wherein less competitive males (i.e. smaller and/or of reduced vigor) can gain access to mates on common foraging grounds may be advantageous. In addition, the longevity of YYN955's tracking duration may in itself be an indication of a lack of competitive (male-male) mounting behavior known to occur among sea turtles (D. Owens pers. comm.) as this type of contact may potentially dislodge PTTs epoxied to carapacial scutes or damage the antenna.

Asynchronous and opportunistic breeding behavior may also account for this male's increased level of activity on F5 (mean swim speed: 0.6 ± 0.4 km h^{-1}), a foraging site situated east and offshore Galveston Island (Fig. 5.2). YYN955's temporal utilization of this site from 25 May – 21 July 2010 corresponds with the typical annual culmination period for the UTC nesting season and the initiation of post-nesting migrations by associated females (see Chapter IV). Although monitoring occurred over temporally divergent periods, generation of a composite map displaying the post-nesting migratory routes for seven telemetered UTC females (2007 - 2009) and YYN955's F5 utilization distribution contour reveals distinct spatial overlap, with the post-nesting routes of four females bisecting this male's foraging site (Fig. 5.8). Female occurrence within F5's boundaries occurred from early to mid-June and was typically of short duration due to the migratory nature of post-nesting movements, although one nester (74913) remained on a small adjacent feeding site through 7 July prior to moving eastward. While reduced female receptivity and the highly transitory nature of post-nesting movements might negate any true breeding opportunities available to YYN955 while resident on F5, this timely spatial overlap provides evidence of the ability of male ridleys to reconvene with mature female conspecifics at spatially and temporally predictable locations following periods of separation, including those induced by disparities in reproductive periodicity.

Conservation Implications

The ecological niche of adult male Kemp's ridley sea turtles is poorly understood. Additional long-term monitoring of elusive male ridleys associated with both highly productive and small scale rookeries in Texas and Mexico is needed to fulfill significant gaps in our understanding of the ecological requirements of this critical population component during breeding, migratory, and foraging phases. Such data will permit development and implementation of inclusive conservation strategies in support a Priority 1 Recovery Task in the Kemp's Ridley Recovery Plan that mandates the protection and management of important marine foraging and breeding habitats utilized by this species.

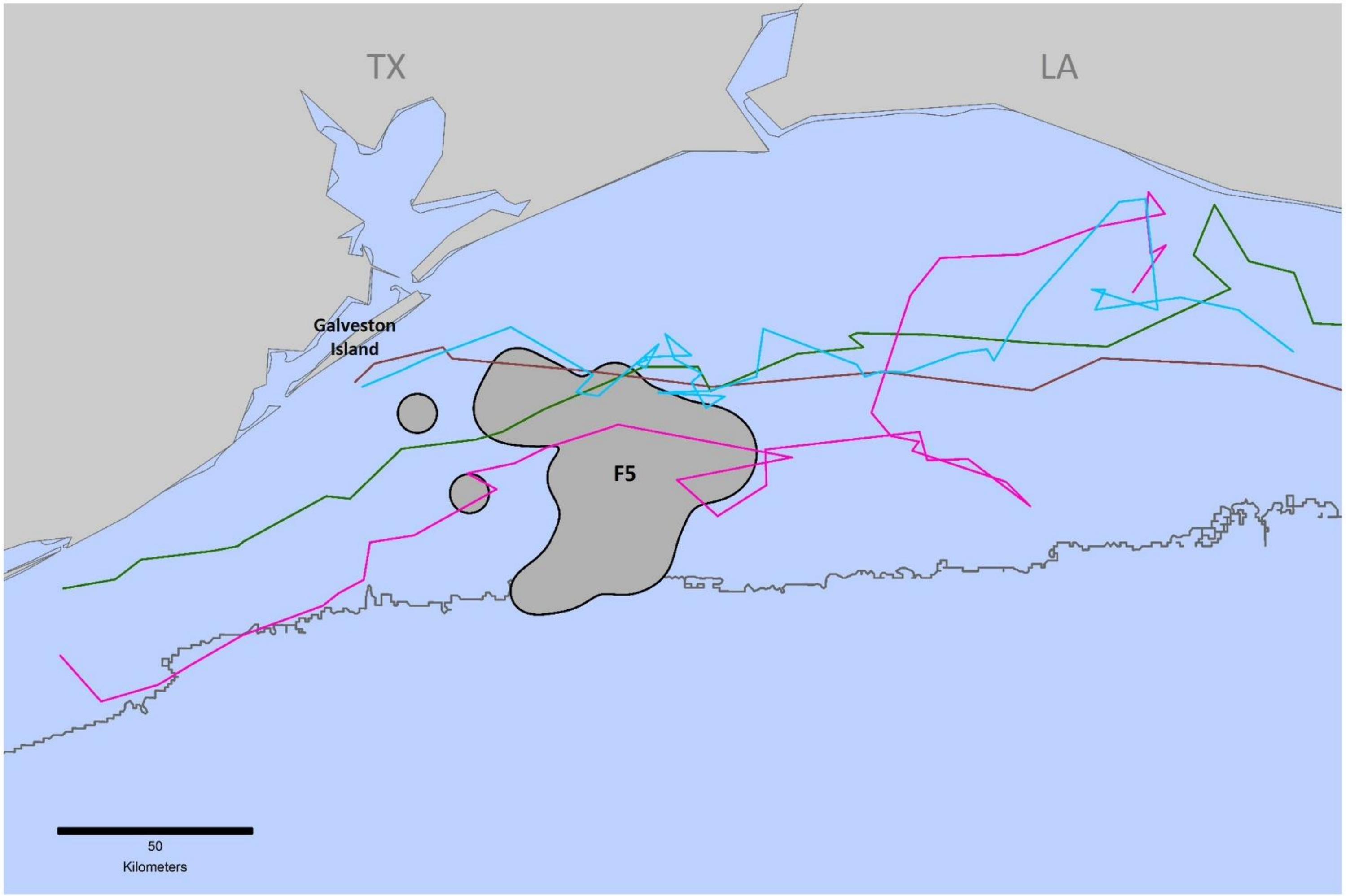


Figure 5.8 Spatial relationship of foraging site F5 (90% KDE shown) used by rehabilitated adult male Kemp’s ridley sea turtle YYN955 from 25 May – 21 July 2010 versus June post-nesting migrations of four female conspecifics monitored between 2007-2009. ▬: denotes 30 m isobath.

CHAPTER VI

CONCLUSIONS & RECOMMENDATIONS

Information supplied in the preceding chapters provides substantive evidence regarding the viability of a self-sustaining cohort of Kemp's ridley sea turtles dependent upon UTC nesting beaches. This recently established cohort is primarily composed of young females between 10-19 years of age at nesting (through 2009) sourced from the joint U.S. and Mexico Kemp's ridley headstart experiment (USFWS & NMFS 1992, Shaver 2005b, Shaver & Rubio 2008). The origin of these nesters may engender concerns regarding unintended consequences of the headstart program and associated ecological ramifications as these experimentally imprinted individuals were intended to recruit to Mexico's nesting beaches (Shaver 2005b), and historic nesting by this species on UTC beaches remains unconfirmed (Vielé 1858, Hildebrand 1963, Doughty 1984). However, documentation of no fewer than five wild nesters concurrently utilizing UTC habitats through 2009, including two with demonstrated intra- or inter-annual nest site fidelity, supports postulation regarding a natural northward expansion of the Kemp's ridley's nesting range coincident with more than two decades of exponential increases in reproductive output at Rancho Nuevo, this species' primary nesting location (NMFS, USFWS & SEMARNAT 2011).

Regardless of its genesis, relevant local, state, and federal entities must assume responsibility for the protection of Critically Endangered Kemp's ridleys (IUCN 2011) utilizing UTC nesting beaches. Safeguarding this breeding population in associated terrestrial and marine environments will support current and future Kemp's ridley conservation efforts through: 1) an expanded species distribution less susceptible to reproductive failure associated with catastrophic natural (i.e. hurricanes) and anthropogenic (i.e. oil spills) events (Heppell et al. 2007) and 2) augmented protection against a potential "massive feminizing bias" (Mrosovsky 1984) resulting from rising temperatures associated with climate change, as northern UTC beaches likely provide relatively cooler nest incubation environments (based on latitudinal temperature gradients) than do established rookeries at PAIS in Texas or in Mexico. In consideration of the fact that arribada nesting beaches are ephemeral by nature and undergo a natural decline in recruitment over time (Pritchard 2007b), reproductive output sourced from recently established and emergent rookeries operating below carrying capacity, such as that on the UTC, should not be underestimated with regard to sustaining future population growth.

CONSERVATION IN THE TERRESTRIAL ENVIRONMENT

UTC beaches used as nesting habitat by Kemp's ridleys (see Chapter III) are fairly unique when compared to the almost continuously undeveloped beaches from PAIS south through central Veracruz, Mexico (Pritchard 2007b) in regard to the degree of anthropogenic alteration and development the former receive. While increased human presence on UTC beaches presents unique management challenges, it does not preclude significant anthropogenic utilization of associated coastal habitats compatible with the persistence of nesting sea turtles. Beach management and/or restoration efforts should render nesting habitats that are attractive to nesting females (vegetated dunes, adequate beach width and slope, free of hazardous obstacles), provide a suitable egg deposition and incubation environment (appropriate hydric and thermal environment suitable for gas exchange), and support seafinding by hatchlings (lack of artificial lighting, presence of horizon elevation cues). Provision of these attributes would likely concurrently impart economic benefits to local UTC communities by: 1) promoting tourism, particularly on tourism-dependent Galveston Island and Bolivar Peninsula, 2) facilitating associated ecotourism and educational outreach activities (Wilson & Tisdell 2001), and 3) enabling naturalized barrier island beach ecosystems to mitigate wind and wave energy associated with episodic storm events like Hurricane Ike (Doran et al. 2009) and, thus, protect proximate residential and commercial development from costly damage.

The first formal sea turtle nesting patrols instituted on the UTC (see Chapter II) were remarkably successful in documenting nesting activity on the beaches of Galveston Island (2007-2009), Bolivar Peninsula (2008-2009), and Follets Island (2009). Stated nest detection efforts aided confirmation of near annual increases in reproductive output on the UTC coincident with that occurring at both Rancho Nuevo and PAIS (NMFS, USFWS & SEMARNAT 2011). In addition, patrol efforts safeguarded nesters and nest products; fostered notable participation by local communities; persistently disseminated educational information to beachgoers and beach workers regarding sea turtles' use of beach habitats and prompt reporting of nesting activity; facilitated in-water research efforts (see Chapters IV & V); and cultivated collaborative relationships with local, state, and federal agencies charged with sea turtle management. Notably, the cooperative institution and administration of these UTC sea turtle nesting patrols served to educate and engage leaders in local municipalities and counties in the conservation of the Kemp's ridley and the beach habitats it is dependent upon for reproduction. Stated nest detection patrols initiated for this study continue today under the guidance of Texas A&M University at Galveston researchers (K. Reich pers. comm.).

The intra- and inter-annual nest site fidelity demonstrated by multiple UTC females, as well as the 91.8% mean emergence success rate documented for four clutches incubated *in situ* on UTC habitats through 2009 (D. Shaver pers. comm.), provide compelling evidence regarding the suitability of associated beach environments to successfully support increasing numbers of nesting sea turtles. However, it is doubtful if the UTC nesting cohort can be sustained long-term without significant alterations in current nest product management policies that mandate transfer of all UTC clutches to PAIS for incubation and subsequent hatchling release. A management option whereby UTC clutches are instead relocated to a centralized corral at Galveston Island State Park (GISP) and secured throughout incubation and hatchling release by on-site Texas Parks & Wildlife Department (TPWD) personnel (with the support of other major stakeholders) has numerous merits, particularly a reduced risk of embryonic mortality associated with excessive transport time to PAIS and the preclusion of the loss of the UTC nesting contingent. Although the imprinting process that facilitates natal homing by mature female sea turtles remains somewhat enigmatic (Lohmann et al. 2008), it is plausible that hatchlings sourced from UTC clutches incubated and released at PAIS will demonstrate fidelity to PAIS, and not the UTC, at maturity. This artificial alteration in nest site fidelity may hinder Kemp's ridley conservation efforts by limiting or preventing the observed natural expansion (see Chapter II) of a nesting range already considered the most restricted of any sea turtle species in the world. In addition, the transport of all UTC clutches to PAIS negates the numerous educational benefits associated with a corral located at GISP. Corrals successfully operated at PAIS and on South Padre Island enable conservation education via public hatchling releases (C. Hughes pers. obs.). A similar corral facility at GISP, in conjunction with educational interpretation by park rangers, would likely promote better reporting of UTC sea turtle nesting activity and stewardship of beach and dune habitats by beachgoers while concurrently reducing anthropogenic sources of mortality for nesters and nest products (i.e. vehicle strikes, entrapment, etc.).

CONSERVATION IN THE MARINE ENVIRONMENT

Telemetry data sourced from eight nesting females intercepted on UTC beaches during 2007-2009 (see Chapter IV) permitted further insight into research initiated by Seney and Landry (2008, 2011) regarding movement behaviors characteristic of this nesting cohort. Spatially and/or temporally constrained use of marine habitats, knowledge critical for effective conservation planning such as the implementation of Marine Protected Areas (MPAs), was identified for adult female ridleys within the Gulf of

Mexico during internesting, migratory, and foraging phases. Of note is the restriction of internesting period movements primarily to shallow (mean depth: 5.6 m) nearshore (mean distance from shore: 6.4 km) waters extending from the Galveston Bay entrance south to Matagorda Bay. Serious consideration should be given to the statewide expansion of a TPWD shrimp trawling regulation, currently applicable only in Texas' waters south of the Corpus Christi Fish Pass, to protect this annual concentration of reproductively active UTC females. This regulation, which prohibits trawling within 8 km of shore from 1 December through mid-May each year, has likely reduced nester mortality on the lower Texas coast (Lewison et al. 2003, Shaver & Rubio 2008) and would safeguard augmentation of ridley nesting on the UTC. Furthermore, enactment of this regulation within UTC waters would serve to protect known assemblages of immature ridleys (Metz 2004, Landry et al. 2005, Seney & Landry 2011) foraging within, or traversing, associated nearshore habitats.

Essential information regarding the spatial ecology of adult male Kemp's ridleys, of which very little is known (Shaver et al. 2005), was gained via long-term monitoring (tracking duration: 1468 d) of rehabilitated adult male YYN955 (see Chapter V). Despite initially stranding on the mid-Texas coast in the vicinity of the PAIS rookery in early April 2009, a time period speculated to reflect the annual culmination of the ridley breeding season (Rostal 1991, Rostal et al. 1998), YYN955's movements during the subsequent 2010 breeding and nesting season were primarily restricted to nearshore environments associated with the UTC and may be indicative of this male's association with the UTC Kemp's ridley nesting cohort. Although extensive in-water research is still required to accurately depict a suite of movement behaviors characteristic of adult male Kemp's ridleys associated with rookeries throughout the nesting range, YYN955's long-term movements do provide critical insight necessary for effective conservation of this elusive life stage in the marine environment. In-water capture and monitoring of reproductively mature males associated with Texas' nesting contingents (including the UTC) should be prioritized to approximate population size and facilitate quantification of the role these individuals play in reproductive success, ridley population genetics, and the long-term recovery of this endangered species.

Satellite tracking data provided in Chapters IV and V contribute to a Priority 1 Recovery Task in the Kemp's Ridley Recovery Plan (NMFS, USFWS & SEMARNAT 2011) that mandates the protection and management of conspecifics in the marine environment via the identification of "important marine foraging, breeding, and inter-nesting habitats." Telemetry research herein permitted ascertainment of potential spatial and/or temporal constraints on adult male and female ridley movements during breeding, internesting, migratory, and/or foraging phases, including documented seasonal movements between adjacent foraging sites. While additional long-term monitoring (tracking duration >2 years) of mature conspecifics is needed to confirm these marine habitat utilization patterns, such information may be conducive to the development of marine conservation policies (MPAs, seasonal fisheries closures, etc.) that promote the recovery of this endangered species while concurrently minimizing potential detrimental effects on stakeholders and other marine resources. Inclusion of Bureau of Ocean Energy (BOEM) Official Protraction Diagram and Leasing Map boundaries in the description of ridley movements may facilitate improved coordination between conservation and resource extraction interests, as both serve crucial functions in the Gulf of Mexico.

FUTURE RESEARCH PRIORITIES

In conclusion, significant gaps remain in our understanding of the ecology of the Kemp’s ridley sea turtle. In the terrestrial environment, an in-depth assessment is needed to quantify the suitability of UTC beach habitats to support nesting sea turtles and nest products. The UTC provides a unique environment to ascertain the effects of numerous common anthropogenic habitat alterations (development, artificial lighting, nourishment, beach grooming, etc.) on the reproductive success of Kemp’s ridleys, as such information cannot be gleaned from federally protected nesting beaches which preclude the normal coexistence of humans and sea turtles in coastal areas. In the marine environment, much remains to be discovered regarding the in-water dynamics of all life stages, particularly reproductively mature male Kemp's ridleys. Marine habitat assessments are needed to understand the association of these marine reptiles with various biotic and abiotic ecosystem components. The recently revised Kemp’s Ridley Recovery Plan (NMFS, USFWS & SEMARNAT 2011) provides necessary guidance regarding prioritized recovery tasks deemed appropriate to support the resurgence of this endangered species; such efforts will be aided via conservation management policies that promote the proliferation of the UTC Kemp’s ridley nesting contingent.

REFERENCES

Agardy MT (1990) Preliminary assessment of the impacts of Hurricane Hugo on sea turtle populations of the eastern Caribbean. In: Richardson TH, Richardson JI, Donnelly M (compilers) Proc 10th Annual Workshop on Sea Turtle Biology and Conservation. NOAA Tech Mem NMFS-SEFC-278, p 63-64

Andersen T (1987) The Kemp's ridley puzzle. Oceans 20(3):42-49

Arendt MD, Segars AL, Byrd JI, Boynton JI, Whitaker JD, Parker L, Owens DW, Blanvillain G, Quattro JM, Roberts MA (2011) Distributional patterns of adult male loggerhead sea turtles (*Caretta caretta*) in the vicinity of Cape Canaveral, Florida, USA during and after a major annual breeding aggregation. Mar Biol 159:101-112

Arendt MD, Segars AL, Byrd JI, Boynton J, Whitaker JD, Parker L, Owens DW, Blanvillain G, Quattro JM, Roberts MA (2012a) Seasonal distribution patterns of juvenile loggerhead sea turtles (*Caretta caretta*) following capture from a shipping channel in the northwest Atlantic Ocean. Mar Biol 159:127-139

Arendt MD, Segars AL, Byrd JI, Boynton J, Schwenter JA, Whitaker JD, Parker L (2012b) Migration, distribution, and diving behavior of adult male loggerhead sea turtles (*Caretta caretta*) following dispersal from a major breeding aggregation in the western North Atlantic. Mar Biol 159:113-125

Argos (1996) Argos User's manual. Toulouse, France

Arroyo B, Burchfield P, Peña LJ, Hodgson L, Luevano P (2003) The Kemp's ridley: recovery in the making. Endanger Species Bull 28(3):7-10

Beavers SC, Cassano ER (1996) Movements and dive behavior of a male sea turtle (*Lepidochelys olivacea*) in the eastern Pacific Ocean. J Herpetol 30(1):97-104

Benedet L, Finkl CW, Campbell T, Klein A (2004) Predicting the effect of beach nourishment and cross-shore sediment variation on beach morphodynamic assessment. Coast Eng 51:839-861

Bentivegna F (2002) Intra-Mediterranean migrations of loggerhead sea turtles (*Caretta caretta*) monitored by satellite telemetry. Mar Biol 141:795-800

Bertolotti L, Salmon M (2005) Do embedded roadway lights protect sea turtles? Environ Manage 36:702-710

Bjorndal KA (1995) Biology and conservation of sea turtles. Smithsonian Institution Press, Washington, D.C.

Borger L, Franconi N, De Michele G, Gantz A, Meschi F, Manica A, Lovari S, Coulson T (2006) Effects of sampling regime on the mean and variance of home range size estimates. J Anim Ecol 75:1393-1405

Bourgeois S, Gilot-Fromont E, Viallefont A, Boussamba F, Deem SL (2009) Influence of artificial lights, logs and erosion on leatherback sea turtle hatchling orientation at Pongara National Park, Gabon. Biol Conserv 142:85-93

Bowen BW, Clark AM, Abreu-Grobois FA, Chaves A, Reichart HA, Ferl RJ (1998) Global phylogeography of the ridley sea turtles (*Lepidochelys* spp.) as inferred from mitochondrial DNA sequences. Genetica 101:179-189

Brock KA, Reece JS, Ehrhart LM (2008) The effects of artificial beach nourishment on marine turtles: differences between loggerhead and green turtles. Restoration Ecol 17(2):297-307

Broderick AC, Coyne MS, Fuller WJ, Glen F, Godley BJ (2007) Fidelity and overwintering of sea turtles. Proc R Soc Lond Biol Sci 274:1533-1539

Burchfield PM, Foley FJ (1989) Standard operating procedures for collecting Kemp's ridley sea turtle eggs for the head start project. In: Caillouet CW Jr, Landry AM Jr (eds) Proc 1st International Symposium on Kemp's Ridley Sea Turtle Biology, Conservation and Management. Texas A & M University Sea Grant College Program, Galveston, p 67-70

Burchfield PM (2005) Texans, turtles, and the early Kemp's ridley restoration project, 1963-67. Chelonian Conserv Biol 4(4):835-837

Burchfield PM (2009) Report on the Mexico/United States of America population restoration project for the Kemp's ridley sea turtle, *Lepidochelys kempii*, on the coasts of Tamaulipas, Mexico. Brownsville, TX: Gladys Porter Zoo

Byles RA (1989) Satellite telemetry of Kemp's ridley sea turtle, *Lepidochelys kempi*, in the Gulf of Mexico. In: Eckert SA, Eckert KL, Richardson TH (compilers) Proc 9th Annual Workshop on Sea Turtle Conservation and Biology. NOAA Tech Mem NMFS-SEFSC-232, p 25-26

Byles R (1993) Head-start experiment no longer rearing Kemp's ridleys. Mar Turtle Newsl 63:1-3

Caillouet CW (2012) Editorial: do male-producing Kemp's ridley nesting beaches exist north of Tamaulipas, Mexico? Mar Turtle Newsl 134:1-2

Carls EG, Fenn DB, Chaffey SA (1995) Soil contamination by oil and gas drilling and production operations in Padre Island National Seashore, Texas, U.S.A. J Environ Manage 45:273-286

Carr AF (1952) Handbook of turtles: the turtles of the United States, Canada and Baja California. Comstock Publishing Associates, Ithaca, NY

Carr A (1967) So excellent a fishe: a natural history of sea turtles. Natural History Press, Garden City, NY

Carr A (1975) The Ascension Island green turtle colony. Copeia 3:547-555

Carr A (1977) Crisis for the Atlantic ridley. Mar Turtle Newsl 4:2-3

Casale P, Freggi D, Ciná A, Rocco M (2013) Spatio-temporal distribution and migration of adult male loggerhead sea turtles (*Caretta caretta*) in the Mediterranean Sea: further evidence of the importance of neritic habitats off North Africa. Mar Biol 160:703-718

Chaloupka M, Zug GR (1997) A polyphasic growth function for the endangered Kemp’s ridley sea turtle, *Lepidochelys kempii*. Fish Bull 95(4):849-856

Chen H, Cheng I, Hong E (2007) The influence of the beach environment on the digging success and nest site distribution of the green turtle, *Chelonia mydas*, on Wan-an Island, Penghu Archipelago, Taiwan. J Coast Res 23(5):1277-1286

CITES species database. Kemp’s ridley turtle (*Lepidochelys kempii*). www.cites.org/eng/resources/species.html (accessed 20 March 2012)

Costa DP, Robinson PW, Arnould JPY, Harrison A-L, Simmons SE (2010) Accuracy of ARGOS locations of pinnipeds at-sea estimated using Fastloc GPS. PLoS ONE 5(1):e8677

Coyne MS, Godley BJ (2005) Satellite Tracking and Analysis Tool (STAT): an integrated system for archiving, analyzing and mapping animal tracking data. Mar Ecol Prog Ser 301:1–7

Coyne M, Landry AM (2007) Population sex ratio and its impact on population models. In: Plotkin PT (ed) Biology and Conservation of Ridley Sea Turtles. Johns Hopkins University Press, Baltimore, p 191-211

Crain DA, Bolten AB, Bjorndal KA (1995) Effects of beach nourishment on sea turtles: review and research initiatives. Restoration Ecol 3:95-104

de Araujo MCB, da Costa MF (2008) Environmental quality indicators for recreational beaches classification. J Coastal Res 24(6):1439-1449

Doran KS, Plant NG, Stockdon HF, Sallenger AH, Serafin KA (2009) Hurricane Ike: Observations of Coastal Change: U.S. Geological Survey Open-File Report 2009-1061

Doughty RW (1984) Sea turtles in Texas: a forgotten commerce. Southwestern Historical Quarterly 88:43-70

Eckert KL, Bjorndal KA, Abreu-Grobois FA, Donnelly M (eds) (1999) Research and management techniques for the conservation of sea turtles. IUCN/SSC Marine Turtle Specialist Group Publication No. 4

Eckert SA, Crouse D, Crowder LB, Maceina M, Shah A (1994) Review of the Kemp's ridley sea turtle headstart program. U.S. Dep. Commer., NOAA Tech Mem NMFS-OPR-3, p 1-11

Eich AML (2009) Evolutionary and conservation implications of sex determination and hatchling depredation in Kemp's ridley sea turtles. PhD dissertation, University of Alabama at Birmingham, Birmingham, AL

Epperly SP (2003) Fisheries-related mortality and turtle excluder devices (TEDs). In: Lutz PL, Musick JA, Wyneken J (eds) The biology of sea turtles volume II. CRC Press, New York, p 339-353

Feagin RA, Sherman DJ, Grant WE (2005) Coastal erosion, global sea-level rise, and the loss of sand dune plant habitats. Front Ecol Environ 3:359-364

Ficetola GF (2007) The influence of beach features on nesting of the hawksbill turtle *Eretmochelys imbricata* in the Arabian Gulf. Oryx 41(3):402-405

Fish MR, Cote IM, Horrocks JA, Mulligan B, Watkinson AR, Jones AP (2008) Construction setback regulations and sea-level rise: mitigating sea turtle nesting beach loss. Ocean Coast Manage 51:330-341

Fontaine C, Shaver D (2005) Head-starting the Kemp's ridley sea turtle, *Lepidochelys kempii*, at the NMFS Galveston Laboratory, 1978-1992: a review. Chelonian Conserv Biol 4(4):838-845

Frazier J, Arauz R, Chevalier J, Formia A, Fretey J, Godfrey MH, Márquez MR, Pandav B, Shanker K (2007) Human-turtle interactions at sea. In: Plotkin PT (ed) Biology and Conservation of Ridley Sea Turtles. Johns Hopkins University Press, Baltimore, p 253-295

Fuentes MMPB, Limpus CJ, Hamann M (2011) Vulnerability of sea turtle nesting grounds to climate change. Global Change Biol 17:140-153

Garmestani AS, Percival HF, Portier KM, Rice KG (2000) Nest-site selection by the loggerhead sea turtle in Florida's Ten Thousand Islands. J Herpetol 34(4):504-510

Gerber LR, Heppell SS (2004) The use of demographic sensitivity analysis in marine species conservation planning. Biol Conserv 120:121-128

Girondot M, Fretey J (1996) Leatherback turtles, *Dermochelys coriacea*, nesting in French Guiana, 1978-1995. Chelonian Conserv Biol 2:204-208

Gladys Porter Zoo (2005) Report on the Mexico/United States of America population restoration project for the Kemp's ridley sea turtle, *Lepidocheyls kempii*, on the coasts of Tamaulipas and Veracruz, Mexico. Report submitted to the US Fish and Wildlife Service, Department of Interior

Godfrey MH, Barreto R (1995) Beach vegetation and seafinding orientation of turtle hatchlings. Biol Conserv 74:29-32

Godley BJ, Blumenthal JM, Broderick AC, Coyne MS, Godfrey MH, Hawkes LA, Witt MJ (2008) Satellite tracking of sea turtles: where have we been and where do we go next? Endang Species Research 4:3-22

Griffin DB, Murphy SR, Frick MG, Broderick AC, Coker JW, Coyne MS, Dodd MG, Godfrey MH, Godley BJ, Hawkes LA, Murphy TM, Williams KL, Witt MJ (2013) Foraging habitats and migration corridors utilized by a recovering subpopulation of adult female loggerhead sea turtles: implications for conservation. Mar Biol:1-16

Hamann M, Limpus CJ, Owens DW (2003) Reproductive cycles of males and females. In: Lutz PL, Musick JA, Wyneken J (eds) The biology of sea turtles volume II. CRC Press, New York, p 135-161

Hawkes LA, Witt MJ, Broderick AC, Coker JW, Coyne MS, Dodd M, Frick MG, Godfrey MH, Griffin DB, Murphy SR, Murphy TM, Williams KL, Godley BJ (2011) Home on the range: spatial ecology of loggerhead turtles in Atlantic waters of the USA. Divers Distrib 17:624-640

Hays GC, Akesson S, Godley BJ, Luschi P, Santidrian P (2001a) The implications of location accuracy for the interpretation of satellite tracking data. Anim Behav 61:1035-1040

Hays GC, Broderick AC, Glen F, Godley BJ, Nichols WJ (2001b) The movements and submergence behaviour of male green turtles at Ascension Island. Mar Biol 139:395-399

Hays GC, Fossette S, Katselidis KA, Schofield G, Gravenor MB (2010) Breeding periodicity for male sea turtles, operational sex ratios, and implications in the face of climate change. Conserv Biol 24(6):1636-1643

Heppell SS, Crowder LB, Menzel TR (1999) Life table analysis of long-lived marine species with implications for conservation and management. In: Musick J (ed) Life in the slow lane: ecology and conservation of long-lived marine animals. Proc Symp Cons Long-Lived Marine Animals, Amer Fish Soc Symp, Monterey, p 137-148

Heppell SS, Crouse DT, Crowder LB, Epperly SP, Gabriel W, Henwood T, Márquez R, Thompson NB (2005) A population model to estimate recovery time, population size, and management impacts on Kemp's ridley sea turtles. Chelonian Conserv Biol 4(4):767-773

Heppell SS, Burchfield PM, Peña LJ (2007) Kemp's ridley recovery – how far have we come, and where are we headed? In: Plotkin PT (ed) Biology and conservation of ridley sea turtles. Johns Hopkins University Press, Baltimore, p 325-335

Hildebrand H (1963) Hallazgo del area de anidacion de la tortuga "lora" *Lepidochelys kempii* (Garman) en la costa occidental del Golfo de Mexico. Ciencia (Mexico) 22:105-112

Hildebrand H (1982) A historical review of the status of sea turtle populations in the western Gulf of Mexico. In: Bjorndal KA (ed) Biology and Conservation of Sea Turtles. Smithsonian Institution Press, Washington, D.C., p 447-453

Hooge PN, Eichenlaub WM, Solomon EK (1999) Using GIS to analyze animal movements in the marine environment. US Geol Surv, Glacier Bay Field Station, AK Available at: www.absc.usgs.gov/glba/gistools/anim_mov_useme.pdf

Horrocks JA, Scott NMcA (1991) Nest site location and nest success in the hawksbill turtle *Eretmochelys imbricata* in Barbados, West Indies. Mar Ecol Prog Ser 69:1-8

Huang JCK (1997) Climate change and integrated coastal management: a challenge for small island nations. Ocean Coast Manage 37(1):95-107

IPCC (2007) Summary for policymakers. In: Solomon S., Qin D, Manning M, Chen Z, Marquis M, Averyt KB, Tignor M, Miller HL (eds) Contribution of working group I to the fourth assessment report of the Intergovernmental Panel on Climate Change. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA: p 1-18

IUCN Red List of Threatened Species. Kemp's ridley turtle (*Lepidochelys kempii*) www.iucnredlist.org/apps/redlist/details/11533/0 (accessed 27 August 2011)

James MC, Eckert SA, Myers RA (2005) Migratory and reproductive movements of male leatherback turtles (*Dermochelys coriacea*). Mar Biol 147:845-853

Jiménez-Quiroz MDC, Filonov A, Tereshchenko I, Márquez MR (2005) Time-series analyses of the relationship between nesting frequency of the Kemp's ridley sea turtle and meteorological conditions. Chelonian Conserv Biol 4(4):774-780

Jones TT, Bostrom BL, Carey M, Imlach B, Mikkelsen J, Ostafichuk P, Eckert S, Opay P, Swimmer Y, Seminoff JA, Jones DR (2011) Determining transmitter drag and best practice attachment procedures for sea turtle biotelemetry studies. NOAA Tech Mem NMFS-SWFSC-480

Kichler K, Holder MT, Davis SK, Márquez MR, Owens DW (1999) Detection of multiple paternity in the Kemp's ridley sea turtle with limited sampling. Mol Ecol 8:819-830

Lamont MM, Carthy RR (2007) Response of nesting sea turtles to barrier island dynamics. Chelonian Conserv Biol 6(2):206-212

Landry AM Jr, Costa DT, Kenyon FL II, Coyne MS (2005) Population characteristics of Kemp's ridley sea turtles in nearshore waters of the upper Texas and Louisiana coasts. Chelonian Conserv Biol 4(4):801-807

Lebuff CR, Haverfield EM (1992) Nesting success of the loggerhead turtle (*Caretta caretta*) on Captiva Island, Florida–a nourished beach. In: Salmon M, Wyneken J (compilers) Proc 11th Annual Workshop on Sea Turtle Biology and Conservation, p 69-71

Lewison RL, Crowder LB, Shaver DJ (2003) The impact of turtle excluder devices and fisheries closures on loggerhead and Kemp's ridley strandings in the western Gulf of Mexico. Conserv Biol 17(4):1089-1097

Limpus CJ, Baker V, Miller JD (1979) Movement induced mortality of loggerhead eggs. Herpetologica 35(4):335-338

Limpus CJ (1993) The green turtle, *Chelonia mydas*, in Queensland: breeding males in the southern Great Barrier Reef. Wildlife Res 20(4):513-523

Lohmann KJ, Putman NF, Lohmann CMF (2008) Geomagnetic imprinting: a unifying hypothesis of long-distance natal homing in salmon and sea turtles. PNAS 105:19096-19101

Lyn H, Coleman A, Broadway M, Klaus J, Finerty S, Shannon D, Solangi M (2012) Displacement and site fidelity of rehabilitated immature Kemp's ridley sea turtles (*Lepidochelys kempii*). Marine Turtle Newsl 135:10-13

Magnuson JJ, Bjorndal KA, DuPaul WD, Graham GL, Owens DW, Peterson CH, Pritchard PCH, Richardson JI, Saul GE, West CW (1990) Decline of the sea turtles: causes and prevention. Committee on Sea Turtle Conservation, Board on Environmental Studies and Toxicology, Board on Biology, Commission on Life Sciences, National Research Council. National Academy Press, Washington, DC

Mansfield KL (2006) Sources of mortality, movements and behavior of sea turtles in Virginia. PhD dissertation, College of William and Mary, Williamsburg, VA

Mansfield KL, Saba VS, Keinath JA, Musick JA (2009) Satellite tracking reveals a dichotomy in migration strategies among juvenile loggerhead sea turtles in the Northwest Atlantic. Mar Biol 156:2555-2570

Marcovaldi MA, Lopez GG, Soares LS, Lima EHSM, Thomé JCA, Almeida AP (2010) Satellite-tracking of female loggerhead turtles highlights fidelity behavior in northeastern Brazil. Endanger Species Res 12:263-272

Márquez MR, Ríos OD, Sánchez PJM, Díaz J (1989) Mexico's contribution to Kemp's ridley recovery. In: Caillouet CW Jr, Landry AM Jr (eds) Proc 1st International Symposium on Kemp's Ridley Sea Turtle Biology, Conservation, and Management. Texas A & M University Sea Grant College Program, Galveston, p 4-6

Márquez MR (1990) FAO Species Catalogue. Vol.11: Sea turtles of the world. An annotated and illustrated catalogue of sea turtle species known to date. FAO Fisheries Synopsis 125, p 1-81

Márquez MR (1994) Synopsis of biological data on the Kemp's ridley turtle, *Lepidochelys kempi* (Garman, 1880). NOAA Tech Mem NMFS SEFSC-343 p1-91

Márquez MR, Burchfield PM, Díaz FJ, Sánchez PM, Carrasco AM, Jiménez QC, Leo PA, Bravo GR, Peña VJ (2005) Status of the Kemp's ridley sea turtle, *Lepidochelys kempii*. Chelonian Conserv Biol 4(4):761-766

Mazaris AD, Matsinos G, Pantis JD (2009) Evaluating the impacts of coastal squeeze on sea turtle nesting. Ocean Coast Manage 52:139-145

McAtee JW, Drawe DL (1981) Human impact on beach and foredune microclimate on North Padre Island, Texas. Environ Manage 5(2):121-134

McClellan CM (2009) Behavior, ecology, and conservation of sea turtles in the North Atlantic Ocean. PhD dissertation, Duke University, Durham, NC

McFarlane RW (1963) Disorientation of loggerhead hatchlings by artificial road lighting. Copeia 1963(1):153

Metz TL (2004) Factors influencing Kemp's ridley sea turtle (*Lepidochelys kempii*) distribution in nearshore waters and implications for management. PhD dissertation, Texas A&M University, College Station, TX

Meylan AB, Bowen BW, Avise JC (1990) A genetic test of the natal homing versus social facilitation models for green turtle migration. Science 248:724-727

Millspaugh JJ, Marzluff JM (eds) (2001) Radio tracking and animal populations. Academic Press, San Diego, CA

Montague CL (2008) Recovering the sand deficit from a century of dredging and jetties along Florida's Atlantic coast: a revolution of beach nourishment as an essential tool for ecological conservation. J Coast Res 24(4):899-916

Moon D, MacKenzie DS, Owens DW (1997) Simulated hibernation of sea turtles in the laboratory: I. feeding, breathing frequency, blood pH, and blood gases. J Exp Zool 278:372-380

Moore JE, Wallace BP, Lewison RL, Zydelis R, Cox TM, Crowder LB (2008) A review of marine mammal, sea turtle and seabird bycatch in USA fisheries and the role of policy in shaping management. Mar Policy 33(3):435-451

Morreale SJ, Standora EA (2005) Western north Atlantic waters: crucial developmental habitat for Kemp's ridley and loggerhead sea turtles. Chelonian Conserv Biol 4(4):872-882

Morreale SJ, Plotkin PT, Shaver DJ, Kalb HJ (2007) Adult migration and habitat utilization: ridley turtles in their element. In: Plotkin PT (ed) Biology and Conservation of Ridley Sea Turtles. Johns Hopkins University Press, Baltimore, p 213-229

Mrosovsky N (1984) Editorial. Mar Turtle Newsl 28:1-2

Mrosovsky N (2006) Distorting gene pools by conservation: assessing the case of doomed turtle eggs. Environ Manage 38:523-531

Mrosovsky N, Godfrey MH (2010) Editorial: thoughts on climate change and sex ratio of sea turtles. Mar Turtle Newsl 128:7-11

Mysing JO, Vanselous TM (1989) Status of satellite tracking of Kemp’s ridley sea turtles. In: Caillouet CW Jr, Landry AM Jr (eds) Proc 1st International Symposium on Kemp's Ridley Sea Turtle Biology, Conservation and Management. Texas A & M University Sea Grant College Program, Galveston, p 112-115

National Marine Fisheries Service (2011) U.S. National Bycatch report. Karp WA, Desfosse LL, Brooke SG (eds) U.S. Dep. Commer., NOAA Tech Mem NMFS-F/SPO-117E

National Marine Fisheries Service, U.S. Fish and Wildlife Service, SEMARNAT (2011) Bi-national recovery plan for the Kemp's ridley sea turtle (*Lepidochelys kempii*), second revision. National Marine Fisheries Service, Silver Spring, p 1-156 p + appendices

National Oceanic and Atmospheric Administration, National Marine Fisheries Service, Southeast Regional Office (2012) Reinitiation of Endangered Species Act (ESA) Section 7 consultation on the continued implementation of the sea turtle conservation regulations, as proposed to be amended, and the continued authorization of the southeast U.S. shrimp fisheries in federal waters under the Magnuson-Stevens Act.

National Research Council (2010) Assessment of sea-turtle status and trends: integrating demography and abundance. The National Academies Press, Washington, DC

Nelson DA, Dickerson DD (1988) Effects of beach nourishment on sea turtles. In: Tait LS (compiler) Proc 5th Annual National Conference on Beach Preservation Technology: new directions in beach management. Florida Shore and Beach Preservation Assessment, Tallahassee, p 285-294

Owens DW (1980) The comparative reproductive physiology of sea turtles. Am Zool 20(3):549-563

Owens DW (1997) Hormones in the life history of sea turtles. In: Lutz PL, Musick JA (eds) The Biology of Sea Turtles. CRC Press, Boca Raton, p 315–341

Patella F (1975) Water surface area within statistical subareas used in reporting Gulf coast shrimp data. Mar Fish Rev 37:22-24

Peña LJ, Flores ALC, Munguia LV, Reyes DJL, Marin SG, Rosas S, Tolentino TOP (2005) Report on the Mexico/United States of America population restoration project for the Kemp’s ridley sea turtle, *Lepidochelys kempii*, on the coasts of Tamaulipas and Veracruz, Mexico, 2005. U.S. Dept. of the Interior, Fish and Wildlife Service, p 1-19

Peterson CH, Bishop MJ (2005) Assessing the environmental impacts of beach nourishment. BioScience 55:887-896

Pike DA (2008) Environmental correlates of nesting in loggerhead turtles, *Caretta caretta*. Anim Behav 76:603-610

Plotkin PT (1994) Migratory and reproductive behavior of the olive ridley turtle *Lepidochelys olivacea* (Eschscholtz 1829), in the eastern Pacific Ocean. PhD dissertation, Texas A&M University, College Station, TX

Plotkin PT, Owens DW, Byles RA, Patterson R (1996) Departure of male olive ridley turtles (*Lepidochelys olivacea*) from a nearshore breeding ground. Herpetologica 52(1): 1-7

Pritchard PCH, Márquez MR (1973) Kemp’s ridley turtle or Atlantic ridley, *Lepidochelys kempi*. Unwin Brothers Limited, Surrey, England, p 1-29

Pritchard PCH (1989) Evolutionary relationships, osteology, morphology, and zoogeography of Kemp’s ridley sea turtle. In: Caillouet CW Jr, Landry AM Jr (eds) Proc 1st International Symposium on Kemp's Ridley Sea Turtle Biology, Conservation, and Management. Texas A & M University Sea Grant College Program, Galveston, p 157-164

Pritchard PCH (2007a) Evolutionary relationships, osteology, morphology, and zoogeography of ridley sea turtles. In: Plotkin PT (ed) Biology and Conservation of Ridley Sea Turtles. Johns Hopkins University Press, Baltimore, p 45-57

Pritchard PCH (2007b) *Arribadas* I have known. In: Plotkin PT (ed) Biology and conservation of ridley sea turtles. Johns Hopkins University Press, Baltimore, p 7-21

Putman NF, Shay TJ, Lohmann KJ (2010) Is the geographic distribution of nesting in the Kemp's ridley turtle shaped by the migratory needs of offspring? Integ Comp Biol 50(3):305-314

Renaud ML (1995) Movements and submergence patterns of Kemp’s ridley turtles (*Lepidochelys kempii*). J Herpetol 29(3):370-374

Renaud ML, Carpenter JA, Williams JA, Landry AM (1996) Kemp's ridley sea turtle (*Lepidochelys kempii*) tracked by satellite telemetry from Louisiana to nesting beach at Rancho Nuevo, Tamualipas, Mexico. Chelonian Conserv Biol 2(1):108-109

Renaud ML, Williams JA (2005) Kemp's ridley sea turtle movements and migrations. Chelonian Conserv Biol 4:808–816

Rodgers AR, Carr AP, Beyer HL, Smith L, Kie JG (2007) HRT: Home Range Tools for ArcGIS. Version 1.1. Ontario Ministry of Natural Resources, Centre for Northern Forest Ecosystem Research, Thunder Bay, Ontario, Canada

Rostal DC, Robeck TR, Owens DW, Kraemer DC (1990) Ultrasound imaging of ovaries and eggs in Kemp's ridley sea turtles (*Lepidochelys kempi*). J Zoo Wildl Med 21(1):27-35

Rostal DC (1991) The reproductive behavior and physiology of the Kemp's ridley sea turtle, *Lepidochelys kempi* (Garman, 1880). PhD dissertation, Texas A&M University, College Station, TX

Rostal DC, Owens DW, Grumbles JS, MacKenzie DS, Amoss MS Jr (1998) Seasonal reproductive cycle of the Kemp's ridley sea turtle (*Lepidochelys kempi*). Gen Comp Endocrinol 109:232-243

Rostal DC (2005) Seasonal reproductive biology of the Kemp's ridley sea turtle (*Lepidochelys kempii*): comparison of captive and wild populations. Chelonian Conserv Biol 4(4):788-800

Rostal DC (2007) Reproductive physiology of the ridley sea turtle. In: Plotkin PT (ed) Biology and Conservation of Ridley Sea Turtles. Johns Hopkins University Press, Baltimore, p 151-165

Royer F, Lutcavage M (2008) Filtering and interpreting location errors in satellite telemetry of marine animals. J Exper Mar Biol Ecol 359:1-10

Rudloe A, Rudloe J, Ogren L (1991) Occurrence of immature Kemp's ridley turtles, *Lepidochelys kempi*, in coastal waters of northwest Florida. Northeast Gulf Sci 12:49-53

Rumbold DG, Davis PW, Perretta C (2001) Estimating the effect of beach nourishment on *Caretta caretta* (loggerhead sea turtle) nesting. Soc Ecol Restor 9:304-310

Salmon M, Tolbert MG, Painter DP, Goff M, Reiners R (1995) Behavior of loggerhead sea turtles on an urban beach. II. Hatchling orientation. J Herpetol 29:568-576

Santos KC, Tague C, Alberts AC, Franklin J (2006) Sea turtle nesting habitat on the US naval station, Guantanamo Bay, Cuba: a comparison of habitat suitability index models. Chelonian Conserv Biol 5:175-187

Schmid JR, Witzell WN (2006) Seasonal migrations of immature Kemp's ridley turtles (*Lepidochelys kempii* Garman) along the west coast of Florida. Gulf Mex Sci 2006:28-40

Scott JA (2006) Use of satellite telemetry to determine ecology and management of loggerhead turtle (*Caretta caretta*) during the nesting season in Georgia. Master's Thesis, University of Georgia, Athens, GA

Seney EE (2008) Population dynamics and movements of the Kemp's ridley sea turtle, *Lepidochelys kempii*, in the northwestern Gulf of Mexico. PhD dissertation, Texas A&M University, College Station, TX

Seney EE, Landry AM (2008) Movements of Kemp's ridley sea turtles nesting on the upper Texas coast: implications for management. Endanger Species Res 4:73-84

Seney EE, Higgins BM, Landry AM (2010) Satellite transmitter attachment techniques for small juvenile sea turtles. J Exp Mar Biol Ecol 384:61-67

Seney EE, Landry AM (2011) Movement patterns of immature and adult female Kemp's ridley sea turtles in the northwestern Gulf of Mexico. Mar Ecol Prog Ser 440:241-254

Shaver DJ, Owens DW, Chaney AH, Caillouet CW Jr, Burchfield P, Márquez MR (1988) Styrofoam box and beach temperatures in relation to incubation and sex ratios of Kemp's ridley sea turtles. In: Schroeder BA (compiler) Proc 8th Annual Workshop on Sea Turtle Conservation and Biology, NOAA Tech Mem NMFS-SEFSC-214, p 1-136

Shaver DJ, Caillouet CW (1998) More Kemp's ridley turtles return to south Texas to nest. Mar Turtle Newsl 82:1-5

Shaver DJ (2000) Padre Island National Seashore Kemp's ridley sea turtle project and Texas sea turtle nesting and stranding 1999 report. U. S. Department of the Interior, Corpus Christi, TX

Shaver DJ (2001) Padre Island National Seashore Kemp's ridley sea turtle project and Texas sea turtle nesting and stranding 2000 report. U. S. Department of the Interior, Corpus Christi, TX

Shaver DJ (2002a) Kemp's ridley sea turtle project at Padre Island National Seashore and Texas sea turtle nesting and stranding 2001 report. U. S. Department of the Interior, Corpus Christi, TX

Shaver DJ (2002b) Research in support of the restoration of sea turtles and their habitat in national seashores and areas along the Texas coast, including the Laguna Madre. Final NRPP Report. U.S. Geological Survey, Department of the Interior

Shaver DJ (2004) Kemp's ridley sea turtle project at Padre Island National Seashore and Texas sea turtle nesting and stranding 2002 report. U. S. Department of the Interior, Corpus Christi, TX

Shaver DJ (2005a) Kemp's ridley sea turtle project at Padre Island National Seashore and Texas sea turtle nesting and stranding 2003 report. U. S. Department of the Interior, Corpus Christi, TX

Shaver DJ (2005b) Analysis of the Kemp's ridley imprinting and headstart project at Padre Island National Seashore, Texas, 1978-88, with subsequent nesting and stranding records on the Texas coast. Chelonian Conserv Biol 4(4):846-859

Shaver DJ, Schroeder BA, Byles RA, Burchfield PM, Peña J, Márquez MR, Martinez HJ (2005) Movements and home ranges of adult male Kemp's ridley sea turtles (*Lepidochelys kempii)* in the Gulf of Mexico investigated by satellite telemetry. Chelonian Conserv Biol 4(4):817–827

Shaver DJ (2006a) Kemp's ridley sea turtle project at Padre Island National Seashore and Texas sea turtle nesting and stranding 2004 report. U. S. Department of the Interior, Corpus Christi, TX

Shaver DJ (2006b) Kemp's ridley sea turtle project at Padre Island National Seashore and Texas sea turtle nesting and stranding 2005 report. U. S. Department of the Interior, Corpus Christi, TX

Shaver DJ (2007) Texas sea turtle nesting and stranding 2006 report. U.S. Department of the Interior, Corpus Christi, TX

Shaver DJ, Wibbels T (2007) Head-starting the Kemp's ridley sea turtle. In: Plotkin PT (ed) Biology and Conservation of Ridley Sea Turtles. Johns Hopkins University Press, Baltimore, p 297-323

Shaver DJ (2008) Texas sea turtle nesting and stranding 2007 report. U.S. Department of the Interior, Corpus Christi, TX

Shaver DJ, Rubio C (2008) Post-nesting movement of wild and head-started Kemp's ridley sea turtles *Lepidochelys kempii* in the Gulf of Mexico. Endanger Species Res 4:43-55

Shaver DJ (2009) Texas sea turtle nesting and stranding 2008 report. U.S. Department of the Interior, Corpus Christi, TX

Shaver DJ (2010) Texas sea turtle nesting and stranding 2009 report. U.S. Department of the Interior, Corpus Christi, TX

Shaver DJ (2011) Texas sea turtle nesting and stranding 2010 report. U.S. Department of the Interior, Corpus Christi, TX

Shaver DJ (2012) Texas sea turtle nesting and stranding 2011 report. U.S. Department of the Interior, Corpus Christi, TX

Shaver DJ, Hart KM, Fujisaki I, Rubio C, Sartain AR, Peña J, Burchfield PM, Gamez DG, Ortiz J (2013) Foraging area fidelity for Kemp's ridleys in the Gulf of Mexico. Ecol Evol 3(7):2002-2012

Snover ML, Hohn AA, Crowder LB, Heppell SS (2007) Age and growth in Kemp's ridley sea turtles: evidence from mark-recapture and skeletochronology. In: Plotkin PT (ed) Biology and Conservation of Ridley Sea Turtles. Johns Hopkins University Press, Baltimore, p 89-105

Spotila JR, Standora EA (1985) Environmental constraints on the thermal energetics of sea turtles. Copeia 3:694-702

Thompson N, Henwood T, Epperly S, Lohoefener R, Gitschlag G, Ogren L, Mysing J, Renaud M (1990) Marine turtle habitat plan. NOAA Tech Mem NMFS-SEFC-255

Tucker AD (2010) Nest site fidelity and clutch frequency of loggerhead turtles are better elucidated by satellite telemetry than by nocturnal tagging efforts: implications for stock estimation. J Exp Marine Biol Ecol 383:45-55

Turtle Expert Working Group (1998) An assessment of the Kemp's ridley (*Lepidochelys kempii*) and loggerhead (*Caretta caretta*) sea turtle populations in the western North Atlantic. U.S. Department of Commerce, NOAA Tech Mem NMFS-SEFSC-409, p 1-96

Turtle Expert Working Group (2000) Assessment update for the Kemp's ridley and loggerhead sea turtle populations in the western North Atlantic. U.S. Department of Commerce, NOAA Tech Mem NMFS-SEFSC-444, p 1-115

Tuxbury SM, Salmon M (2005) Competitive interactions between artificial lighting and natural cues during seafinding by hatchling marine turtles. Biol Conserv 121:311-316

U.S. Fish and Wildlife Service and National Marine Fisheries Service (1992) Recovery plan for the Kemp's ridley sea turtle (*Lepidochelys kempii*). St. Petersburg: National Marine Fisheries Service, p 1-40

Vasquez-Sauceda ML, Aguirre-Guzman G, Perez-Castaneda R, Sanchez-Martinez JG, Martin-del Campo RR, Loredo-Osti J, Rabago-Castro JL (2008) Evaluation of the influence of two transport boxes on the incubation, hatching and emergence of Kemp's ridley turtle (*Lepidochelys kempii*) eggs. Ciencias Marina 34(1):101-105

Vielé TG (1858) 'Following the drum': a glimpse of frontier life. Rudd and Carleton, New York

Watson KP, Granger RA (1998) Hydrodynamic effect of a satellite transmitter on a juvenile green turtle (*Chelonia mydas*). J Exp Biol 201:2497-2505

Werler JE (1951) Miscellaneous notes on the eggs and young of Texan and Mexican reptiles. Zoologica 36(3):37-48

Whitmore CP, Dutton PH (1985) Infertility, embryonic mortality and nest site selection in leatherback and green sea turtles in Suriname. Biol Conserv 34:251-272

Wibbels TR (1984) Orientation characteristics of immature Kemp's ridley sea turtles Lepidochelys kempi. U.S. Department of Commerce, NOAA Tech Mem NMFS-SEFC-131

Wilson C, Tisdell C (2001) Sea turtles as a non-consumptive tourism resource especially in Australia. Tourism Manage 22:279-288

Witherington BE (1992) Behavioral responses of nesting sea turtles to artificial lighting. Herpetologica 48:31-39

Witzell WN, Burchfield PM, Peña LJ, Márquez MR, Ruiz MG (2005a) Nesting success of Kemp's ridley sea turtles, *Lepidochelys kempi*, at Rancho Nuevo, Tamaulipas, Mexico, 1982-2004. Mar Fish Rev 69:46-52

Witzell WN, Salgado-Quintero A, Garduño-Dionte M (2005b) Reproductive parameters of the Kemp's ridley sea turtle (*Lepidochelys kempii*) at Rancho Nuevo, Tamaulipas, Mexico. Chelonian Conserv Biol 4(4):781-787

Woody JB (1989) International efforts in the conservation and management of Kemp's ridley sea turtle (*Lepidochelys kempi*). In: Caillouet CW Jr, Landry AM Jr (eds) Proc 1st International Symposium on Kemp's Ridley Sea Turtle Biology, Conservation and Management. Texas A & M University Sea Grant College Program, Galveston, p 1-3

Woody JB (1990) Is 'headstarting' a reasonable conservation measure? "On the surface, yes; in reality, no. Mar Turtle Newsl 50:8-11

Zbinden JA, Aebischer A, Margaritoulis D, Arlettaz R (2008) Important areas at sea for adult loggerhead sea turtles in the Mediterranean Sea: satellite tracking corroborates findings from potentially biased sources. Mar Biol 153:899-906

Zug GR, Kalb HJ, Luzar SJ (1997) Age and growth in wild ridley seaturtles *Lepidochelys kempii* from skeletochronological data. Biol Conserv 80(3):261-268

APPENDIX A

SEA TURTLE NESTING PATROL EFFORT[1,2] ON GALVESTON ISLAND, TEXAS DURING 2007

	Foot		ATV		Total	
	Effort (h)	**Coverage (km)**	**Effort (h)**	**Coverage (km)**	**Effort (h)**	**Coverage (km)**
April	148.34	393.60	56.71	851.02	205.05	1244.62
May	172.78	467.19	96.52	1321.44	269.30	1788.63
June	158.23	425.09	79.23	1091.62	237.46	1516.71
July	53.00	146.69	31.25	574.54	84.25	721.23
TOTAL	**532.35**	**1432.57**	**263.71**	**3838.62**	**796.06**	**5271.19**

[1] **Effort shown occurred during 102 patrol days between 2 April and 13 July 2007.**

[2] **Patrols were funded by a Texas General Land Office Coastal Management Program grant to TAMUG.**

APPENDIX B

SEA TURTLE NESTING PATROL EFFORT[1,2] ON GALVESTON ISLAND, TEXAS DURING 2008

	Foot		ATV		Total	
	Effort (h)	**Coverage (km)**	**Effort (h)**	**Coverage (km)**	**Effort (h)**	**Coverage (km)**
April	193.08	509.13	92.29	1252.72	285.37	1761.85
May	156.53	436.78	86.16	1134.27	242.69	1571.05
June	160.31	435.49	75.55	1069.41	235.86	1504.90
July	3.00	7.60	41.08	574.54	44.08	582.13
TOTAL	**512.92**	**1389.00**	**295.08**	**4030.94**	**808.00**	**5419.94**

[1] Effort shown occurred during 76 patrol days between 1 April and 15 July 2008.

[2] Patrols were funded by a Texas General Land Office Coastal Management Program grant to TAMUG.

APPENDIX C

SEA TURTLE NESTING PATROL EFFORT[1,2] ON BOLIVAR PENINSULA, TEXAS DURING 2008

	ATV	
	Effort (h)	Coverage (km)
April	64.35	944.11
May	100.71	1388.74
June	97.06	1303.86
July	41.92	712.62
TOTAL	**304.04**	**4349.33**

[1] **Effort shown occurred during 75 patrol days between 2 April and 15 July 2008.**

[2] **Patrols were funded by a Texas General Land Office Coastal Management Program grant to TAMUG.**

APPENDIX D

TOTAL COORDINATED SEA TURTLE NESTING PATROL EFFORT[1,2] ON THE UPPER TEXAS COAST DURING 2008

	Total	
	Effort (h)	**Coverage (km)**
April	349.72	2705.96
May	343.40	2959.79
June	332.92	2808.77
July	86.00	1294.75
TOTAL	**1112.04**	**9769.27**

[1] **Effort shown occurred during 76 patrol days between 1 April and 15 July 2008.**

[2] **Patrols were funded by a Texas General Land Office Coastal Management Program grant to TAMUG.**

APPENDIX E

SEA TURTLE NESTING PATROL EFFORT[1,2] ON GALVESTON ISLAND, TEXAS DURING 2009

	Foot		ATV		Total	
	Effort (h)	**Coverage (km)**	**Effort (h)**	**Coverage (km)**	**Effort (h)**	**Coverage (km)**
April	72.34	210.89	52.40	653.40	124.74	864.29
May	153.29	425.88	130.01	1659.24	283.30	2085.12
June	176.70	483.51	94.58	1263.50	271.28	1747.01
July	68.33	186.56	45.35	574.54	113.68	761.09
TOTAL	**470.66**	**1306.84**	**322.34**	**4150.67**	**793.00**	**5457.52**

[1] **Effort shown occurred during 66 patrol days between 15 April and 15 July 2009.**

[2] **Patrols were partially funded by a Texas General Land Office Coastal Management Program grant to TAMUG.**

APPENDIX F

SEA TURTLE NESTING PATROL EFFORT[1,2] ON BOLIVAR PENINSULA, TEXAS DURING 2009

	ATV	
	Effort (h)	**Coverage (km)**
April	39.47	636.18
May	50.07	668.65
June	98.70	1482.24
July	47.37	746.90
TOTAL	**235.61**	**3533.97**

[1] Effort shown occurred during 51 patrol days between 15 April and 15 July 2009.

[2] Patrols were partially funded by a Texas General Land Office Coastal Management Program grant to TAMUG.

APPENDIX G

SEA TURTLE NESTING PATROL EFFORT[1,2] ON FOLLETS ISLAND, TEXAS DURING 2009

	ATV	
	Effort (h)	**Coverage (km)**
April	35.74	441.35
May	75.21	880.09
June	72.43	925.50
July	36.62	486.31
TOTAL	**220.00**	**2733.26**

[1] **Effort shown occurred during 63 patrol days between 15 April and 15 July 2009.**

[2] **Patrols were partially funded by a Texas General Land Office Coastal Management Program grant to TAMUG.**

APPENDIX H

TOTAL COORDINATED SEA TURTLE NESTING PATROL EFFORT[1,2] ON THE UPPER TEXAS COAST DURING 2009

	Total	
	Effort (h)	**Coverage (km)**
April	199.95	1941.81
May	408.58	3633.86
June	442.41	4154.76
July	197.67	1994.31
TOTAL	**1248.61**	**11724.74**

[1] **Effort shown occurred during 66 patrol days between 15 April and 15 July 2009.**

[2] **Patrols were partially funded by a Texas General Land Office Coastal Management Program grant to TAMUG.**