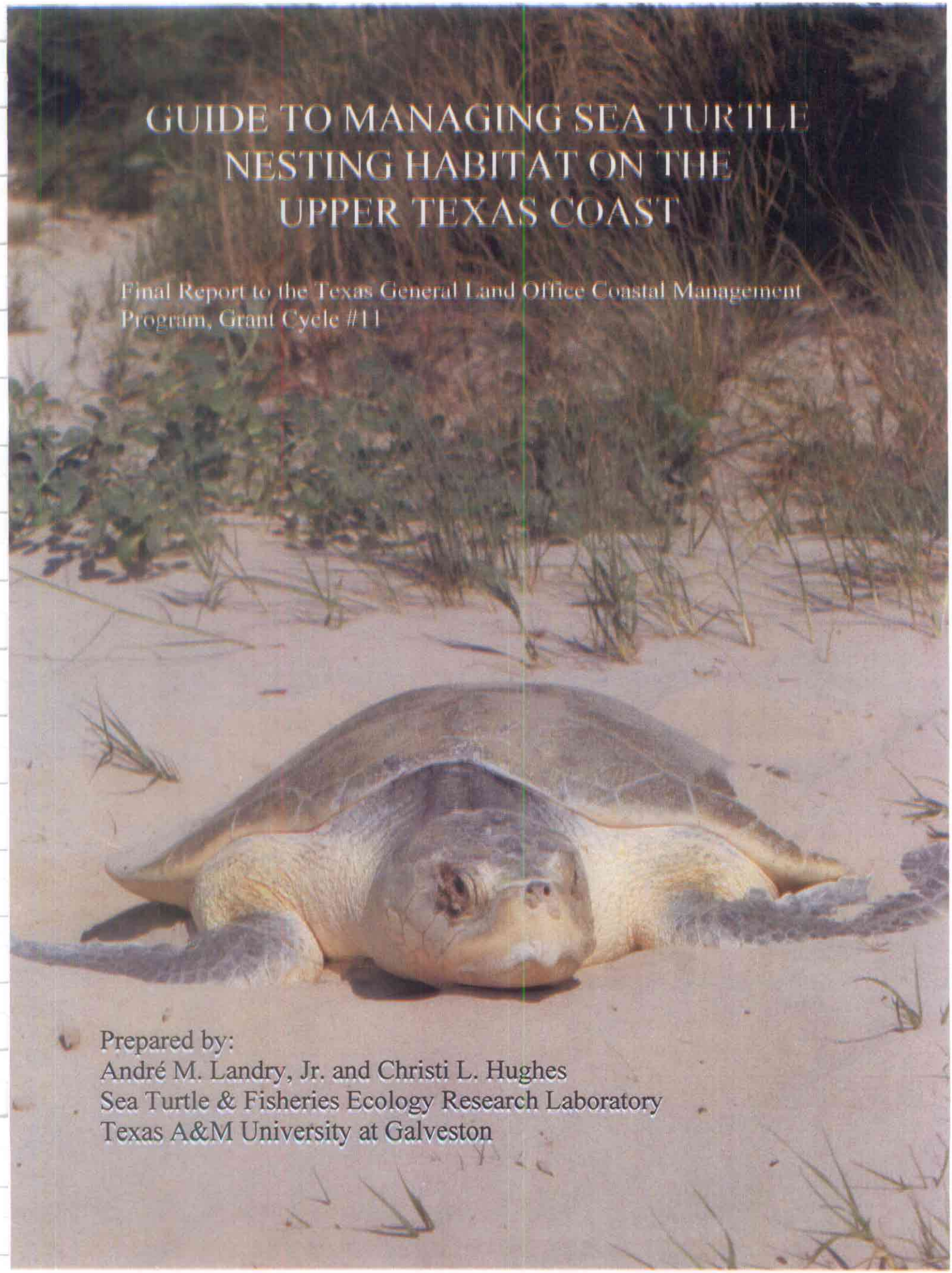
GUIDE TO MANAGING SEA TURTLE NESTING HABITAT ON THE UPPER TEXAS COAST

Final Report to the Texas General Land Office Coastal Management Program, Grant Cycle #11



Prepared by:
André M. Landry, Jr. and Christi L. Hughes
Sea Turtle & Fisheries Ecology Research Laboratory
Texas A&M University at Galveston

GUIDE TO MANAGING SEA TURTLE NESTING HABITAT ON THE UPPER TEXAS COAST

Final Report to the

Texas General Land Office
Coastal Management Program
In Fulfillment of
Contract #07-005-002
P.O. Box 12873
Austin, Texas 78711-2873

Prepared by

André M. Landry, Jr.
Christi L. Hughes

Sea Turtle and Fisheries Ecology Research Laboratory
Texas A&M University at Galveston
5007 Avenue U
Galveston, TX 77550

April 2008

ABSTRACT

Nesting by the critically endangered Kemp's ridley sea turtle (*Lepidochelys kempii*) on the upper Texas coast has increased significantly since nesting was first documented on constituent beaches in 2002; this increase coincides with exponential increases in this species' nesting activity on its primary nesting beach at Rancho Nuevo, Mexico. As such, a need exists for the implementation of upper Texas coast beach management policies designed to meet the needs of a rapidly developing public sector and this proliferating assemblage of nesting sea turtles, particularly on the highly utilized beaches of Galveston Island where the majority of nests have been documented. A multitude of environmental (vegetation coverage, sand compaction, beach slope and width) and anthropogenic (beach nourishment, artificial lighting) variables were identified as affecting the attractiveness of dynamic beach habitats to nesters on Galveston Island. The Island's beaches were divided into three main zones (West End, Seawall, and East End), and further segregated into multiple sections, based on the consistent occurrence of habitat characteristics identified during foot and ATV surveys conducted on these beaches in February and March 2008. Data generated during these surveys were analyzed to categorize constituent beaches as good, fair, or poor nesting habitat. Following the categorization of beach segments, historical Galveston Island nest locations were plotted and examined to assess possible relationships between habitat quality and habitats in which nesting occurred. Historically, 78.6% of nesting has occurred along the West End zone, which is characterized by a shrinking corridor of dune habitat situated between a seaward barrier of coastal erosion and a landward barrier of extensive residential development. A total of 23 sections was identified within this 28.29 km zone, which is comprised of 15.98% poor habitat (6 sections), 15.55% fair habitat (5 sections), and 68.47% good habitat (11 sections). Of 22 nests documented within the West End zone, an average of 0.78 nests per kilometer of available habitat, 17 were located in good habitat, 1 in fair habitat, and 4 in poor habitat. The remaining 21.4% of historical nesting has occurred along the 5.97 km Seawall zone, which is characterized by the presence of a protective seawall barrier that prevents formation of natural vegetated dune habitat. This factor prevented Seawall sections from being classified as good; consequently, this zone consists of 49.58% poor habitat (13 sections) and 50.42% fair habitat (7 sections). Historically, a total of 6 nests has been documented along the Seawall, an average of 1.01 nests per kilometer of available habitat. Four of these nests were located in fair habitat while two were laid in habitat currently classified as poor. No nesting activity has been documented along the 6.14 km East End zone, which is characterized primarily by its lack of recent nourishment activity and beach armor. The East End contains 41.86% poor habitat (5 sections), 1.79% fair nesting habitat (1 section), and 56.37% good habitat (2 sections). Increasing sea turtle nesting activity on the upper Texas coast, particularly that by Kemp's ridleys, accentuates the need for expeditious implementation of beach habitat management strategies to aid recovery of this critically endangered species and ensure availability of quality nesting habitat. Multiple natural and anthropogenic challenges are identified that managers of these dynamic beach environments must face, particularly in habitats heavily utilized by the public or impacted by coastal development. Various options are offered as steps in developing effective strategies for managing sea turtle nesting products.

INTRODUCTION

Recent exponential increases in the reproductively-viable segment of the critically endangered Kemp's ridley sea turtle (*Lepidochelys kempii*) population (Marquez et al., 2005; Shaver, 2005; Seney and Landry, 2008) have coincided with annual increases in the number of conspecific nests laid on the upper Texas coast (herein defined as beaches from Sabine Pass to Matagorda Peninsula) since nesting was first documented on constituent beaches. All 43 sea turtles nests documented on the upper Texas coast since 2002 have been laid by Kemp's ridleys, this planet's most critically endangered sea turtle species (Schmid, 2003; Marquez et al., 2005); 28 of these nests have been laid on Galveston Island.

Continued recovery of the Kemp's ridley population will likely lead to increased nesting on the upper Texas coast, particularly Galveston Island. Increased likelihood for interaction between this growing assemblage of nesters and rapid development of the upper Texas coast mandates implementation of management strategies meeting the needs of these user groups while reducing impact to Kemp's ridleys. This final report, with its emphasis on Galveston Island, is intended as a guide for state and federal agencies responsible for managing sea turtle nesting habitat on the upper Texas coast, where increased levels of human use and beachfront development may mandate a management strategy that differs from that in other areas of Texas currently protected as Kemp's ridley nesting habitat.

Nesting beaches are highly dynamic environments that constantly accrete and erode in response to wind, waves, currents, storms, and alterations in sea level (Peterson and Bishop, 2005). While sea turtles often exhibit strong nest site fidelity to natal beaches (Bjorndal, 1995; Shaver, 2005), a multitude of environmental variables may significantly impact the attractiveness of a specific site to nesters (Santos et al., 2006) and the "seafinding" ability of hatchlings emerging from nests (Salmon et al., 1995; Bertolotti and Salmon, 2005). The recent occurrence of Kemp's ridley females nesting at locations other than this species' primary nesting beach, Rancho Nuevo, Mexico, has precipitated concerns over natal beach fidelity, particularly in light of recent nesting activity along the upper Texas coast . These concerns along with ongoing recovery trends and one of the shortest estimates of age at sexual maturity [11-16 years (Zug et al., 1997)] among sea turtle species mandate that information critical to managing Kemp's ridley's nesting beaches be developed. This need is particularly acute in the case of those environmental variables and human activities that may significantly impact the quality and sustainability of beach habitat on the upper Texas coast. A brief summary of the influence of various environmental factors (vegetation coverage, sand compaction, beach slope and width) and human activities (beach nourishment, artificial lighting) on sea turtle nesting habitat is presented below.

Vegetation Coverage. Vegetation, particularly late successional species like sea oats (*Uniola paniculata*), is critical in reducing beach erosion, binding sediments, and building dunes (Feagin et al., 2005) and, as such, influences a beach's attractiveness and suitability as nesting habitat. In addition, vegetated sites are significantly less compacted than non-vegetated sites (Horrocks and Scott, 1991) as roots may loosen substrate and aid in the natural emergence of hatchlings from nests (Santos et al., 2006). Many late

successional species native to Galveston Island have been confined to isolated beach sections or even lost due to coastal erosion and/or landward barriers associated with housing development. This loss or constriction of natural beach vegetation prevents characteristic successional patterns from occurring (Feagin et al., 2005), which may detrimentally impact the quality of available nesting habitat. Although hawksbill (*Eretmochelys imbricata*) sea turtles have been shown to prefer vegetated nesting sites and hatchling emergence rates are significantly higher on vegetation-covered dunes (Horrocks and Scott, 1991), vegetation can pose a hazard to eggs and hatchlings. Roots can invade nests (Mrosovsky, 2006) and pierce eggs (Whitmore and Dutton, 1985). Additionally, hatchlings emerging where visual "seafinding" cues are lacking or obscured, such as on barren open sandflats devoid of vegetation or in thick undergrowth, may become disoriented and fail to progress seaward (Mrosovsky, 2006).

Sand Compaction. Substrate compaction is nearly twice as influential as all other tested variables influencing nesting habitat suitability for green (*Chelonia mydas*) and hawksbill turtles (Santos et al., 2006). Sand compaction resulting from recreational beach use (Horrocks and Scott, 1991), vehicular traffic, construction, and beach nourishment activities (Santos et al., 2006) negatively impacts nesting habitat. For nesters, it increases the amount of energy required to excavate a nest, and high compaction levels may prevent nest excavation and cause the turtle to return to the sea without depositing eggs (Santos et al., 2006). For hatchlings, hatching and emergence success are negatively correlated with compaction, this due to increasing probability of suffocation and/or exhaustion associated with emergence from compacted substrates (Horrocks and Scott, 1991).

Beach Width and Slope. Beach width and slope, in conjunction with tidal amplitude, influence the suitability of nest sites and the potential for inundation-related embryonic mortality (Whitmore and Dutton, 1985). While nests below the high tide line are not necessarily fully destroyed, they often exhibit lower hatching and emergence rates (Mrosovsky, 2006) as seawater suffocates embryos and elevated salinity disrupts egg metabolism (Whitmore and Dutton, 1985). In Texas, nests documented at laying are located at various positions on the beach; however, all fourteen nests documented at hatching have been located high on the beach in areas protected from tides and beach traffic (Shaver, 2008).

Beach slope may be altered by nourishment activities and vehicular traffic (Santos et al., 2006). Steep slopes may impede nesters and increase the energy required to reach a suitable nesting site, while overly low counterparts increase the distance a nester must crawl to lay her nest safely above the high tide line (Santos et al., 2006). Moderately sloped beaches are advantageous as they provide multiple nest location options at varying distances from the water. As such, they increase the overall probability of hatchlings entering the sea, particularly in a fluctuating beach environment where stochastic events frequently alter the viability of specific nest locations. Years with strong storm events, which may favor nests far from the water, are thus mitigated by years in which nests laid close to the water fare better, especially when terrestrial predator pressures are particularly high (Mrosovsky, 2006).

Beach nourishment. Beach nourishment is a common but temporary remedy for coastal erosion (Peterson and Bishop, 2005) that is accelerated by human-induced disturbance and sea level rise (Feagin et al., 2005). Nourishment is used to combat erosion on Galveston Island, where subsidence and reductions in long-shore sediment transport resulting from the presence of a seawall and associated groins contribute to average shoreline loss rates exceeding several meters per year (Feagin et al., 2005). Uncertainty persists regarding the ecological consequences of beach nourishment despite nearly four decades of national agency-mandated monitoring, this primarily due to widespread flaws in study design and data analysis and interpretation (Peterson and Bishop, 2005). However, it is known that nourishment substantially disturbs and can potentially degrade beach and nearshore habitats (Peterson and Bishop, 2005). While nourishment may create suitable nesting habitat in areas otherwise unavailable (Crain et al., 1995), it may alter a beach's sand density, shear resistance, moisture content, slope, sand color, grain size, sand shape, and sand mineral content, all of which can deleteriously affect sea turtle nesting success (Horrocks and Scott, 1991; Crain et al., 1995; Peterson and Bishop, 2005). Rumbold et al. (2001) reported a significant decrease in loggerhead (*Caretta caretta*) nesting and a significant increase in the incidence of false crawls in the year immediately following beach nourishment. Although reduced, these effects were still apparent during the second nesting season following nourishment.

Artificial Lighting. Two distinct problems arise when artificial lights associated with beachfront development illuminate nesting beaches. First, artificial lighting may repel (Witherington, 1992) or disorient nesting females, disrupt nest site selection, and increase the frequency of nest abandonment (Santos et al., 2006). Second, artificial lights increase hatchling mortality by interfering with sensory and perceptual cues to successful nocturnal seafinding, resulting in either misorientation (hatchlings crawling toward the light source) or disorientation (hatchlings crawling in circuitous paths) (Horrocks and Scott, 1991; Bertolotti and Salmon, 2005; Tuxbury and Salmon, 2005). While seafinding is accurate on dark beaches, allowing hatchlings to enter the sea within minutes, misoriented and disoriented counterparts usually fail to locate the water (Bertolotti and Salmon, 2005) and perish from exhaustion, dehydration or predation (Tuxbury and Salmon, 2005).

Artificial lighting is the least likely factor influencing nesting habitat quality on the upper Texas coast. With the exception of a single loggerhead nest laid in 1996 (NMFS Sea Turtle Stranding and Salvage Network, unpublished data), the diurnally nesting Kemp's ridley (Witzell et al., 2005) is the only species documented nesting on the upper Texas coast. Although a paucity of information exists regarding typical emergence times for Kemp's ridley hatchlings, previous studies suggest that the majority of nest emergences occur between 0200 and 0400 (Jaime Pena, Gladys Porter Zoo, Brownsville, Texas, personal communication). The possibility of nocturnal hatchling emergences, in addition to the potential for nocturnal nesting activity by either Kemp's ridleys or green and loggerhead turtles known to nest on other parts of the Texas coast, mandate consideration of this variable in the determination of nesting habitat quality.

RESEARCH OBJECTIVES

Proper management of upper Texas coast beaches exhibiting increasing signs of use by nesting sea turtles requires up to date information regarding potential impacts of the aforementioned environmental variables and human activities on constituent habitats. Galveston Island, the site of sea turtle nesting patrols funded by a CMP Cycle #11 grant to TAMUG, is the subject of research objectives designed to assess these impacts. These objectives include:

1. To identify beach stretches with the highest sea turtle nesting potential.
2. To identify beach segments whose nesting potential should be improved.
3. To identify beach sections lost to nesting because natural phenomena or man-made alterations have rendered them unattractive to nesting or pose a threat to the survival of a nest and its contents.

METHODS

Galveston Island Beach Surveys. Data detailing specific attributes of all Galveston Island beaches patrolled by TAMUG in 2007 were collected during three separate surveys in February and March 2008. Beaches from San Luis Pass to 8 Mile Road were surveyed via ATV on 13 February from 0745 to 1155, beaches from 61st Street to 12th Street were surveyed on foot on 17 February from 1445 to 1645, and beaches from 12th Street to the South Jetty on East Beach were surveyed on foot on 9 March from 0915 to 1120. Visual observations were made regarding beach width; 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. Pertinent locations were marked with a Garmin GPS 72, converted to decimal degrees (WGS84) format, and mapped with Google Earth.

Data Compilation and Mapping. Galveston Island's beaches were categorized within three main zones consistently demonstrating general characteristics revealed in data generated during the aforementioned nesting habitat surveys. These beach zones include the:

West End (28.29 km): San Luis Pass to 8 Mile Road;
Seawall (5.97 km): 61st Street to just east of 12th Street; and
East End (6.14 km): just east of 12th Street to the South Jetty on East Beach.

Each zone was further partitioned into sections of varying length characterized as good, fair or poor nesting habitat based upon the consistent occurrence of specific positive and negative attributes recorded during surveys. Sections were characterized as:

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

To avoid bias in habitat quality determinations, all 28 historical nesting locations on Galveston Island, obtained from GPS data 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 all beach sections had been formally characterized as either good, fair or poor. Additionally, data regarding documented false crawls (two occurred in 2007) were obtained from the same source and plotted on maps of habitat quality for comparison purposes.

RESULTS

Quality of Sea Turtle Nesting Habitat.

West End Zone: The West End of Galveston Island, where 78.6% of historical nesting has occurred, is characterized by relatively natural beach habitat situated within a shrinking corridor between the seaward barrier of coastal erosion and landward barrier of extensive residential development. While the location of the majority of these residential structures behind natural dune habitat presents no current impediment to nesters, artificial lighting sourced from these homes poses a threat to nocturnally emerging hatchlings. Although numerous vehicle parking areas exist, as these beaches are heavily utilized by the public, vehicular traffic is not allowed on the majority of this segment. Nourishment is a commonly utilized remedy to erosion in this area, although no nourishment projects were apparent or in progress when this zone was surveyed. Twenty-three distinct sections ranging in quality from poor to good were identified along this zone (Table 1, Figure 1).

While moderately wide beaches with well-vegetated, low to moderately high dunes are typical of the West End, six relatively short sections (W5, W7, W9, W11, W13, W19) comprising 15.98% of this zone (Table 2) were rated as poor habitat due to the presence of houses on the beach near the waterline. These sections suffer from reduced or an absence of nesting habitat, particularly in front of residential structures where lack of dunes and vegetation may lead to visual disorientation of nesters and increased risk of nest flooding. Additionally, section W17, which utilizes a geo-tube to protect homes located immediately behind it from beach erosion, is rated as one of the poorest sections in terms of nesting habitat on Galveston Island. Multiple locations within this section are subject to erosive wave action that has exposed bare surfaces of the geo-tube and rendered it submerged during high tide, thus eliminating beach nesting habitat.

Five sections (W1, W4, W16, W21, W22) representing 15.55% of the West End were rated as fair nesting habitat. Dunes within section W1 are located several hundred meters from the waterline and, as such, may lead to visual disorientation among nesters. In addition, high vehicular traffic at this popular fishing destination compacts substrate and may be 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. Section W4 contains three dune crossovers with excessively wide bases constructed in a way that presents an entrapment hazard to nesters and emerging hatchlings; W21 contains two dune crossovers whose expansive bases block nester movement toward dune habitat; and W22 contains sand fences with minimal to no sand accretion placed at an angle to the waterline, which may entrap or disorient hatchlings and nesting females. Finally, section

W16's narrow beach increases the potential for tidal inundation of nests and, thus, is considered fair habitat.

Eleven sections constituting 68.47% of the West End are rated as good nesting habitat, including the two longest sections (W2 and W10). 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) contain sand fences parallel to the water's edge that effectively prevent females from accessing nesting habitat behind the base of the foredunes. In addition, section W15 (Galveston Island State Park) contains sand fences placed diagonally at the base of the foredunes that not only limit nester access to dune habitat but also may disorient or entrap nesters and hatchlings. However, these factors alone did not reduce quality ratings, as certain sections exhibit mitigating factors and historical data for the upper Texas coast indicate the majority of nesters (80%) do not nest behind the base of the foredunes.

Seawall Zone: Historically, 21.4% of nesting on Galveston Island has occurred along beaches armored by a seawall that effectively eliminates nesting habitat at or behind the base of the foredunes. This factor, combined with a lack of natural dunes and associated vegetation plus presence of heavy beach raking, recent nourishment activity (sections S1, S3, S10, S17), and artificial lighting from commercial development eliminated any section within this zone from being classified as good nesting habitat (Table 3, Figure 2). While dunes are absent, occasional mounds of raked *Sargassum* pushed to the foot of the Seawall have formed minimally vegetated surrogates for natural dunes; all references to dunes along the Seawall imply the presence of these raked *Sargassum* piles. The Seawall zone is 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, is prohibited.

No beach nourishment activity was apparent on any of the 13 Seawall sections classified as poor, which comprise 49.58% of this zone (Table 4). Nesting habitat has been completely eliminated on four fully armored sections (S2, S4, S6, S19), and is negatively impacted on four partially armored sections (S7, S9, S13, S20). 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 visually deter nesters and/or present an obstacle to nester and hatchling movement. Four of the five remaining sections classified as poor (S5, S8, S11, S16) consist of narrow beaches with increased risk of tidal inundation of nests; three of these (S5, S8, S16) are also extremely short in length. Dune-like mounds of scraped *Sargassum* with prohibitively steep slopes are present near the base of the Seawall on S11; the irregularity of these mounds represents 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 present a visual deterrent to nesters, while artificial lights located on these piers may increase visual deterrence and pose a hazard to nocturnally emerging hatchlings.

The remaining seven sections, which constitute 50.42% of the Seawall zone, contain fair nesting habitat. Four moderately wide sections (S1, S3, S10, S17) that were recently nourished exhibit an ensuing berm whose steep slope may prevent females from

accessing most of the beach above the high tide line. The three sections lacking nourishment (S12, S15, S18) possess moderately well vegetated dunes, although the slope of these dunes is prohibitive to nesters on S12, and beaches of S15 and S18 are moderately narrow.

East End Zone: No historical nesting activity has been documented on beaches of the East End that collectively range in habitat quality from poor to good (Table 5, Figure 3). This highly variable zone is characterized only by its lack of recent nourishment activity and beach armor. (Note: Section E1, although bordered by the Seawall, is included in this zone as the Seawall has little to no effect on nesting habitat east of 12th Street due to its sharp angle away from the beach.)

All five sections (E2, E3, E4, E6, E8) characterized as poor habitat, collectively comprising 41.86% of this zone (Table 6), have been artificially widened for public use and recreation and contain various configurations of wooden pilings that may hinder turtle movement. While well-vegetated dunes are present on all sections, these dunes are located behind vehicle parking areas and up to several hundred meters from the tideline. Nesters crawling onto these sections would likely become visually disoriented and fail to see and/or utilize dune nesting habitat. In addition, all sections contain 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), are popular tourist destinations where significant pedestrian traffic may deter nesting.

One section (E5) representing 1.79% of the East End zone qualified as fair nesting habitat. While this section contains moderately high, well-vegetated dunes, it is a short, excessively wide stretch located between relatively long sections of poor habitat. The majority (56.37%) of the East End zone is comprised of two sections (E1, E7) of good habitat containing moderately wide beaches with well-vegetated dunes. Section E7 spans 3.23 km and, with the exception of two dune crossover bases that may present an obstacle and/or entrapment hazard to nesters and hatchlings, contains 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 pose a threat to nocturnally emerging hatchlings.

Historical Nesting Patterns

West End Zone: Since 2002, 22 nests and 2 false crawls have been documented within the West End zone (Table 7; Figures 4, 5), an average of 0.78 nests per kilometer of available habitat (Table 2). Although most of this activity has occurred along beaches currently classified as good nesting habitat, four nests have been documented on beaches of poor quality; both habitat types exhibit an average of 0.88 nests per kilometer. Two nests were laid in poor habitat within section W17, a narrow beach lacking dunes and vegetation that is armored by a geo-tube exposed by wave action at multiple locations. On 23 May 2006, a ridley nested at the base of this geo-tube. 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 geo-tube. Section W19 contained the two remaining nests located in poor habitat; this narrow beach lacks dunes and vegetation and exhibits multiple residential structures situated directly on the beach. On 6 May 2006, a nester crawled past one of these homes and on to 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.

One nest and one false crawl were located in fair habitat (0.23 nests/km) within section W1 near San Luis Pass, where dunes are located several hundred meters from the waterline. On 20 June 2005, a turtle nested approximately 45 meters from the waterline on the backbeach; this turtle was previously seen nesting 16 May 2005 on the downslope of the first foredune on section W10. On 17 May 2007, a different female was observed nesting on the backbeach approximately 5 meters from the waterline, an area that is 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 West End zone were located in good habitat.

Seawall Zone: Six nests have been located within the Seawall zone, an average of 1.01 nests per kilometer of available habitat (Table 4), since nesting was first documented on constituent beaches in 2004 (Table 8; Figure 6). Of the two nests in poor habitat (0.68 nests/km), one was located in embryonic dunes on section S11, a narrow beach where moderately vegetated dunes exist at the base of the Seawall. 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 (1.33 nests/km) 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.

East End Zone: No nests have been documented in this zone.

DISCUSSION

Management of Threats to Sea Turtle Nesting Habitat

Beach Erosion and Nourishment: Galveston Island's beaches are vulnerable to negative physical impacts of projected anthropogenic increases in sea level, as extensive coastal development, particularly along the West End and Seawall zones, creates a physical barrier preventing the inland retreat of beach and dune habitat. Historically, Galveston Island has attained relative projected rates of sea level rise; a continuation of this trend will accelerate erosion rates, which already exceed several meters per year (Feagin et al., 2005).

The extent of ecological ramifications from loss of beach habitat to nesting sea turtles is difficult to assess. Accelerated shoreline loss rates will increase the need for remedies, such as beach nourishment, to maintain habitats suitable for both public recreation and sea turtle nesting. Negative effects of nourishment on sea turtle nest site selection and nest hatching and emergence success (Crain et al., 1995; Horrocks and Scott, 1991; Peterson and Bishop, 2005), including sand compaction and alterations in

moisture content and beach slope (Rumbold et al., 2001), are offset by the provision of nesting habitat in areas otherwise rendered unavailable.

Nourishment also may prevent tidal inundation of incubating nests along beaches of adequate width; this, a concern that currently exists at multiple locations along the West End zone (sections W5, W7, W13, W16, W17, W19) and on several unarmored sections of the Seawall zone (S5, S8, S11, S16). The importance of beach width to nest success is highlighted by the fact that, of the fourteen nests successfully incubated *in situ* and detected at hatching in Texas, all have been located high on the beach protected from tidal inundation (Shaver, 2008), including the nest documented in Seawall section S3 on 6 August 2007. The need for remediation of erosion to provide appropriate nesting habitat is further accentuated within the Seawall zone, where four (S1, S3, S10, S17) of seven beaches containing suitable nest incubation habitat show signs of recent nourishment.

Potential negative impacts of nourishment must be given careful consideration before related projects are initiated on upper Texas coast beaches, as previous research suggests nourished beaches provide inferior nesting habitat when compared to that on natural counterparts (Rumbold et al., 2001). Although nourishment has been shown to reduce overall nest numbers and increase the incidence of false crawls for loggerheads nesting in Florida (Rumbold et al., 2001), these impacts have not been documented for Kemp's ridleys nesting on the upper Texas coast. However, at least one of two documented false crawls on Galveston Island during 2007 occurred on a beach showing no signs of nourishment (San Luis Pass).

The timing of nourishment activities also is critical to maintaining suitable nesting beaches along the upper Texas coast. The survey of the Seawall zone documented steeply sloped berms created by recent nourishment projects on four sections (S1, S3, S10, S17) that would prevent females from accessing habitat above the high tide line, thus temporarily eliminating benefits from expanding beach width. Ideally, beach nourishment activities should be completed in time to allow natural processes to eventually transform steeply sloped beaches to a grade that will not constitute a barrier to nester movement. To minimize direct effects on nesters and nests, nourishment activities should be prohibited during nesting season and for subsequent incubation of undetected nests left *in situ*, a period lasting from approximately 1 April to 15 August.

Dune Habitat and Vegetation Coverage: Compounding effects of anthropogenic sea level rise accelerating erosion of beach habitats along with increasing development of landward barriers have spatially constricted native sand dune plant communities and disrupted natural successional processes on the upper Texas coast. This impact is so severe that many areas of Galveston Island contain only remnant dune populations or are completely devoid of vegetation (Feagin et al., 2005). As late-successional sand dune plant communities are critical to reducing erosion and providing habitat for dependent species like nesting sea turtles, restoration of these communities should be prioritized (Feagin et al. 2005).

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 upper Texas coast. While 80% of historically documented nests have been laid no farther landward than the base of the foredunes, the site preferred by 42.5% of upper

Texas coast nesters, it is likely that many of these females were prevented from accessing dune habitat by man-made barriers including the Seawall (Table 8), sand fences, and residential structures. Nests located at the base of these barriers are likely categorized as laid at the base of foredunes, regardless of their relative location on the beach, due to constraints with current nest location options on Texas nesting forms used in reporting these data to the Sea Turtle Stranding and Salvage Network.

The regeneration of dunes and associated plant communities as well as removal of structures limiting nester access to quality nesting habitat is critical to providing females with minimally compacted nest sites protected from tidal inundation. Dunes are also critical in absorbing light and providing a higher, darker landward silhouette that contrasts with the lower, brighter seaward horizon, cues that are critical to seafinding for hatchlings emerging from *in-situ* nests (Bertolotti and Salmon, 2005). Horizontal elevation cues provided by dunes are even more important than light cues in this regard (Salmon et al., 1995). While dune restoration is not a viable option along the Seawall zone, as this protective barrier prevents adequate dune formation, it is recommended for multiple sections along the West End zone. Here, preferred nesting sites at the base of or in natural dunes and vegetation have been partially or wholly eliminated (W5, W7, W9, W13, W17, W19, W21) and/or rendered inaccessible by sand fences (W3, W6, W7, W8, W11).

Various sections along the East End and West End zones (E2, E3, E4, E6, E8, W1) provide inferior nesting habitat due to the relocation of vegetated dunes to behind beaches artificially widened for public use (i.e., up to several hundred meters from the tideline). Females able to visualize preferred dune nesting habitat would expend considerable energy to reach them; furthermore, hatchlings emerging from nests located in the proximity of these dunes may be exposed to increased risk of mortality from exhaustion, predation, and vehicular traffic. More likely, excessively wide beaches would visually disorient females unable to locate dune habitat, thus deterring them from nesting and elevating their risk to increased levels of pedestrian and vehicular traffic, particularly on sections W1, E6, and E8. Evidence of this visual disorientation existed in an atypical backbeach location subject to regular tidal inundation on section W1 with the documentation of one nest and observed nesting activity by a turtle whose emergence was officially reported as a false crawl. Historically, 90% of upper Texas coast nests have been laid in habitats behind this location. Additionally, the female associated with the aforementioned nest was previously observed nesting on the downslope of the first dune, a drastically different location in terms of protection from tidal inundation. While information is scarce regarding consistency of nest site selection by Kemp's ridleys, one may suspect that individual ridley nest location patterns would more closely resemble those of other sea turtles utilizing relatively stable beaches like hawksbills, whose nest sites correlate strongly with each other (Mrosovsky 2006).

Management of artificially widened beaches could incorporate the needs of both public users and nesting sea turtles by reintroducing dunes into a more natural location near the water. Expansive spaces for recreation and vehicle parking mimicking those currently in existence could be located behind a strip of regenerated dunes that would improve nesting habitat, enhance beach aesthetics, and reduce erosion. Public access to these popular beaches could be maintained through the deployment of multiple pedestrian

and vehicular dune crossovers, while relocated dunes could potentially serve to delineate vehicular traffic corridors.

Residential and Commercial Development: Many upper Texas coast beaches are becoming increasing urbanized through rapid residential and commercial development which, if poorly located, constitutes a barrier to landward movement of dunes and vegetation. However, multi-use beaches do not preclude nesting by sea turtles, as evidenced by the majority (65.1%) of upper Texas coast nests being located on heavily developed Galveston Island. The economy of coastal locations, like Galveston Island, depends largely on tourism and, thus, the realization that use and development of constituent beaches is an increasing reality. An in-depth examination of the complexity of this issue and its impact on sea turtles is beyond the scope of this report. Nonetheless, one seemingly compatible first step in addressing this issue is through public education and the strategic development of effective ecotourism initiatives designed to ensure a conservation-oriented approach to coastal development. Sea turtle nesting activity is a tremendous source of ecotourism dollars generated on Florida beaches and a major component of predictive models used in managing habitat, artificial lighting, commercial and residential development, and recreational beach use issues. Duplicating this success along the upper Texas coast will depend on continued recovery of the Kemp's ridley and developing a working partnership between state and federal agencies and the beach-going public to ensure the integrity of nesting habitat available to an increasing population of reproductively-active ridley females.

Other Stressors on Quality Nesting Habitat: Rising gas prices, economic woes and Galveston Island's effort to enhance its "vacation hot spot" image will result in an ever increasing number of tourists that visit the Island's beaches. The Island's proximity to Houston guarantees a steady influx of its neighbors to constituent beaches from late spring through early fall. Galveston also draws additional visitors departing aboard cruise lines operating from the Island's port. Beach-oriented recreation is one venue the Island must grow in order to maximize tourist generated income. To do this, City officials invest considerable time and effort in keeping constituent beaches attractive and safe for its visitors. A large percent of this effort is expended during late spring and summer when mats of *Sargassum* are blown shoreward by southerly winds to strand in massive quantities on Galveston beaches. If left near the water's edge, these aggregations become a smelly nuisance to beach goers who must traverse constituent mounds to reach the Gulf, beach comb or simply view the adjacent surf. The City resolves this user conflict with an intensive beach cleaning program whereby *Sargassum*, entrained debris and the sand covered by this material are raked or scraped by heavy machinery and deposited in large mounds near or on dunes. Researchers at Texas A&M University are currently studying the impact of this beach cleaning protocol on Galveston Island as well as investigating ways in which to beneficially use *Sargassum* in restoring beach habitat integrity. The current protocol removes or displaces sand on the beach, alters the natural beach slope, facilitates the erosion process, and results in *Sargassum* being placed on nesting habitat where it may kill natural dune vegetation, increase sand temperature, prevent hatchling emergence from in situ nests and become an obstruction to nesters and

hatchlings. This source of stress will continue until suitable alternatives to current beach cleaning practices are found.

Management of Sea Turtle Nest Products

Multiple options exist for the management of eggs laid by sea turtles on upper Texas coast beaches, all of which exert a heavy influence on subsequent habitat management decisions. Currently, all sea turtle eggs in Texas, with the exception of those laid on South Padre Island and Boca Chica Beach, are excavated and transported to Padre Island National Seashore (PINS) for subsequent incubation and hatchling release. For eggs laid on Galveston Island, this involves the transfer of eggs from the nest to Styrofoam incubation containers and a subsequent 5 hour vehicle transport to an incubation facility operated by the National Park Service. Hatching success rates for Galveston Island nests transported by this means have been comparable to nests not subjected to the stress of highway driving, a result similar to that presented by Mrosovsky (2006) for sea turtle eggs promptly relocated to higher beach zones and incubated *in situ*. However, previous research on green and loggerhead turtle eggs found that movement of eggs, even a few hours after laying, reduced hatching success (Whitmore and Dutton, 1985), confirming that this method is not without risk. Additionally, consideration must be given to future long-term effects of this transfer of nest products. While the imprinting process is not fully understood, a strong possibility exists that hatchlings sourced from upper Texas coast nests incubated and released at PINS will return to PINS, and not their natal beach, to nest as adults. Continued translocation of eggs laid on upper Texas coast beaches may significantly reduce or eliminate Kemp's ridley nesting in this area, thus undermining the potential for development of an important natal beach and generation of ecotourism dollars. Additionally, this method is physically taxing, especially when turtle tracks are the only means of locating the general area where a nest may have been laid. Careful searching for the nest in this case may require considerable digging in the hot sand with bare hands during very warm and humid conditions. Once the nest is found, there is the financial and time expenses associated with round-trip travel to PINS.

The second option for managing nesting products involves relocation of eggs laid on the upper Texas coast to a protected corral in this area, an option successfully utilized in south Texas (South Padre Island and Boca Chica Beach) as well as on the ridley's primary nesting beach at Rancho Nuevo. This option becomes more viable with a sizeable increase in nesting along the upper Texas coast and at PINS, with the latter site possibly becoming so overwhelmed by nests that incubation of the former site's nests is not practical. Another prerequisite to this option is to ensure temperatures within the egg chamber of nests laid along the upper Texas coast are conducive to high hatching success and hatchling emergence potential and are within the proper range to produce appropriate sex ratios. Temperature information of this kind is not currently available for upper coast beaches. Nonetheless, potential benefits of using protected corrals could include reduced logistic time and travel expenses, less handling of clutches and more time to respond to and excavate nests, expand ecotourism, and involve the public in hatchling releases. This will not lessen the need for 24-hour surveillance and management of nests during the week prior to expected hatching.

A third but unlikely option in managing nesting products along the upper Texas coast is to leave them in situ. While this option is successful in Florida where thousands of sea turtle nests, especially those laid by loggerheads, render use of translocation or protected corrals protocols impractical, it will not be a viable candidate for consideration on the upper Texas coast until nesting levels mirror those on beaches within the Mexican State of Tamaulipas (i.e., the location of Rancho Nuevo and adjacent nesting beaches). Even then, measures must be in place for maintaining healthy beaches suitable for nesting, limiting vehicular traffic to avoid crushing nests, minimizing debris as well as other obstacles to turtle movement, and educating the public as to the importance of in situ nests. Currently, the only nests left in situ along the upper Texas coast are those that go undetected.

CONCLUSIONS

Care must be taken in the interpretation and specific application of data presented in this study, as the information presented herein represents only a snapshot in time of dynamic beach habitats on the upper Texas coast. Further examination of the specific attributes affecting the suitability of these beaches as sea turtle nesting habitat, particularly in light of the environmental and anthropogenic variables discussed, is required in generating information adequate to the long-term management of sea turtle nesting habitat on the upper Texas coast. Consideration must be given to the life history strategy of sea turtles, whose long lives and late maturation mean it may take decades for results of management decisions to be apparent.

Certain questions, adapted from those originally posed by Santos et al. (2006), merit continued research in the management of sea turtle nesting habitat on the upper Texas coast. First, what additional steps can be taken to improve nesting habitat for turtles, particularly in areas with extensive coastal development? Second, if current nest product management procedures are altered to allow eggs laid on the upper Texas coast to remain for subsequent incubation and release, how will surrogate incubation habitat be identified? Finally, how much and what kinds of disturbances can turtles tolerate?

Population recovery of the Kemp's ridley, Texas' dominant nester, is well underway but far removed from achieving historical abundances known for conspecifics using Gulf waters as recent as the 1940s. This ongoing recovery and the fact that nesting in Texas, especially along the upper Texas coast, is a recent phenomena that necessitates generation of long-term data sets describing the level of sea turtle nesting activity, the role of Texas beaches in this activity, conflicts between nesters and other beach user-groups, and the Kemp's ridley's role in promoting ecotourism as well as serving as an essential component in the conservation and management plans for beach habitat.

ACKNOWLEDGEMENTS

This report is a final requirement of a Texas General Land Office Coastal Management Program Cycle #11 grant (Contract #07-005-002) to Texas A&M University at Galveston. Work described herein could not have been accomplished

without the patrol efforts of graduate and undergraduate students in residence at TAMUG as well as volunteers from Master Naturalist Chapters and the general public. NOAA Fisheries staff in Galveston assisted with many elements of work accomplished during this grant, especially the staff of the NOAA Sea Turtle Facility. Additional assistance with patrol equipment was provided by Texas Parks and Wildlife's Galveston Island State Park. Administrators and other personnel with the City of Galveston, Galveston County, and Parks Board facilitated access to Galveston Island beaches and assisted in deploying sea turtle signage. The Department of Marine Biology at TAMUG provided various in-kind support functions to this study.

LITERATURE CITED

Bertolotti, L. and Salmon, M. 2005. Do embedded roadway lights protect sea turtles? Environmental Management 36:702-710.

Bjorndal, K.A. 1995. Biology and conservation of sea turtles. Smithsonian Institution Press, Washington, D.C. 615 pp.

Crain, D.A., Bolten, A.B., and Bjorndal, K.A. 1995. Effects of beach nourishment on sea turtles: review and research initiatives. Restoration Ecology 3:95-104.

Feagin, R.A., Sherman, D.J., and Grant, W.E. 2005. Coastal erosion, global sea-level rise, and the loss of sand dune plant habitats. Frontiers in Ecology and the Environment 3:359-364.

Horrocks, J.A. and Scott, N.McA. 1991. Nest site location and nest success in the hawksbill turtle *Eretmochelys imbricata* in Barbados, West Indies. Marine Ecology Progress Series 69:1-8.

Marquez, R.M., Burchfield, P.M., Diaz, J.F., Sanchez, M.P., Carrasco, M.A., Jimenez, C.Q., Leo, A.P., Bravo, R.G., and Pena, J.V. 2005. Status of the Kemp's ridley sea turtle, *Lepidochelys kempii*. Chelonian Conservation and Biology 4(4):761-766.

Mrosovsky, N. 2006. Distorting gene pools by conservation: assessing the case of doomed turtle eggs. Environmental Management 38:523-531.

Peterson, C.H. and Bishop, M.J. 2005. Assessing the environmental impacts of beach nourishment. BioScience 55:887-896.

Rumbold, D.G., Davis, P.W., and Perretta, C. 2001. Estimating the effect of beach nourishment on *Caretta caretta* (loggerhead sea turtle) nesting. Society for Ecological Restoration 9:304-310.

Salmon, M., Tolbert, M.G., Painter, D.P., Goff, M., and Reiners, R. 1995. Behavior of loggerhead sea turtles on an urban beach. II. Hatchling orientation. Journal of Herpetology 29:568-576.

Santos, K.C., Tague, C., Alberts, A.C., and Franklin, J. 2006. Sea turtle nesting habitat on the US naval station, Guantanamo Bay, Cuba: a comparison of habitat suitability index models. Chelonian Conservation and Biology 5:175-187.

Schmid, J.R., Bolten, A.B., Bjorndal, K.A., Lindberg, W.J., Percival, H.F., and Zwick, P.D. 2003. Home range and habitat use by Kemp's ridley turtles in west-central Florida. Journal of Wildlife Management 67:196-206.

Seney, E.E. and Landry, A.M. 2008. Movements of Kemp's ridley sea turtles nesting on the upper Texas coast: implications for management. Endangered Species Research 4:73-84.

Shaver, D.J. 2005. 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 Conservation and Biology 4(4):846-859.

Shaver, D.J. 2008. Kemp's ridley sea turtle project at Padre Island National Seashore and Texas sea turtle nesting and stranding 2007 report. U.S. Department of the Interior, 33 pp.

Tuxbury, S.M. and Salmon, M. 2005. Competitive interactions between artificial lighting and natural cues during seafinding by hatchling marine turtles. Biological Conservation 121:311-316.

Whitmore, C.P. and Dutton, P.H. 1985. Infertility, embryonic mortality and nest site selection in leatherback and green sea turtles in Suriname. Biological Conservation 34:251-272.

Witherington, B.E. 1992. Behavioral responses of nesting sea turtles to artificial lighting. Herpetologica 48:31-39.

Witzell, W.N., Salgado-Quintero, A., Garduno-Dionte, M. 2005. Reproductive parameters of the Kemp's ridley sea turtle (Lepidochelys kempii) at Rancho Nuevo, Tamaulipas, Mexico. Chelonian Conservation and Biology 4(4):781-787.

Zug, G.R., Kalb, H.J., and Luzar, S.J. 1997. Age and growth in wild Kemp's ridley sea turtles Lepidochelys kempii from skeletochronological data. Biological Conservation 80:261-268.

Table 1. Characterization of Sea Turtle Nesting Habitat Quality within the West End Zone of Galveston Island, Texas.

SECTION	LENGTH (km)	SECTION BEGINNING Latitude	SECTION BEGINNING Longitude	SECTION END Latitude	SECTION END Longitude	NESTING HABITAT CHARACTERISTICS
W1	1.31	29.08397	-95.11488	29.09103	-95.10525	- Beach potentially visually disorienting for nesters as dunes located several hundred meters from tideline. - High vehicle traffic results in sand compaction and is potentially hazardous to nests, nesters, and hatchlings.
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 meters, 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 meters, present major obstacle to nester and hatchling movement.
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. - Sand fences (diagonal to water, spaced ~2 m apart) present obstacle to nester and hatchling movement, limit access to dune habitat. + Lack of vehicular traffic reduces sand compaction and risk of injury to turtles and nests.

HABITAT QUALITY KEY		
GOOD	FAIR	POOR

Table 1. Cont'd.

SECTION	LENGTH (km)	SECTION BEGINNING Latitude	SECTION BEGINNING Longitude	SECTION END Latitude	SECTION END Longitude	NESTING HABITAT CHARACTERISTICS
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 directly on beach present entrapment hazard as 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 nester and hatchling movement, limit 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

Table 2. Analysis of West End Zone Habitat Quality Composition and Number of Nests per Kilometer.

SECTION QUALITY	PERCENTAGE OF ZONE	TOTAL LENGTH (km)	NUMBER OF NESTS	NUMBER OF NESTS/KM
Good	68.47	19.37	17	0.88
Fair	15.55	4.40	1	0.23
Poor	15.98	4.52	4	0.88
Zone Total	**100.00**	**28.29**	**22**	**0.78**

Table 3. Characterization of Sea Turtle Nesting Habitat Quality within the Seawall Zone of Galveston Island, Texas.

SECTION	LENGTH (km)	SECTION BEGINNING Latitude	SECTION BEGINNING Longitude	SECTION END Latitude	SECTION END Longitude	NESTING HABITAT CHARACTERISTICS
S1	0.29	29.26635	-94.82613	29.26773	-94.82365	Nourishment: Yes. + Moderately wide beach. - No dunes or vegetation. - Fishing pier at 61st Street presents potential danger to turtles from increased pedestrian traffic and 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 dunes (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 moderately well-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.
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.

HABITAT QUALITY KEY		
GOOD	FAIR	POOR

Table 3. Cont'd.

SECTION	LENGTH (km)	SECTION BEGINNING Latitude	SECTION BEGINNING Longitude	SECTION END Latitude	SECTION END Longitude	NESTING HABITAT CHARACTERISTICS
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 4. Analysis of Seawall Zone Habitat Quality Composition and Number of Nests per Kilometer.

SECTION QUALITY	PERCENTAGE OF ZONE	TOTAL LENGTH (km)	NUMBER OF NESTS	NUMBER OF NESTS/KM
Good	0.00	0.00	0	0.00
Fair	50.42	3.01	4	1.33
Poor	49.58	2.96	2	0.68
Zone Total	**100.00**	**5.97**	**6**	**1.01**

Table 5. Characterization of Sea Turtle Nesting Habitat Quality within the East End Zone of Galveston Island, Texas.

SECTION	LENGTH (km)	SECTION BEGINNING Latitude	SECTION BEGINNING Longitude	SECTION END Latitude	SECTION END Longitude	NESTING 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 nester and hatchling 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 nester and hatchling 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 nester and hatchling 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

Table 6. Analysis of East End Zone Habitat Quality Composition and Number of Nests per Kilometer.

SECTION QUALITY	PERCENTAGE OF ZONE	TOTAL LENGTH (km)	NUMBER OF NESTS	NUMBER OF NESTS/KM
Good	56.35	3.46	0	0.00
Fair	1.79	0.11	0	0.00
Poor	41.86	2.57	0	0.00
Zone Total	**100.00**	**6.14**	**0**	**0.00**

Table 7. Historical Kemp's Ridley Sea Turtle Nesting Activity in the West End Zone of Galveston, Texas.

NESTING DATE	TIME	LOCATION (WGS84) Latitude	Longitude	NESTING LOCATION	BEACH SECTION	NEST HABITAT	NESTER WILD OR HEADSTART	NESTER SCL [4] (cm)	NESTER PRIMARY TAG
06/09/02	1630	29.12300	-95.06683	West End of Galveston Island	W3 / Good	Base of Foredunes	1992 Headstart [2]	N/R	N/R
06/10/02	0930	29.13472	-95.04583	Sea Isle	W8 / Good	Top of First Foredune	Unknown [3]	N/A	N/A
05/16/03	1008	29.20552	-94.93158	Pirate's Beach East	W17 / Poor	Top of First Foredune	Unknown [3]	N/A	N/A
04/17/04	1700	29.17597	-94.98207	Jamaica Beach	W12 / Good	Base of Foredunes	1991 Headstart [2]	62.5	RRV317
05/16/05	1000	29.15393	-95.01765	Sandhill Shores - West Indian Beach	W10 / Good	Downslope of First Foredune	1992 Headstart [2]	65.8	SSD127
05/29/05	0800	29.18860	-94.96038	Galveston Island State Park	W15 / Good	Base of Foredunes	Wild [2]	62.5	RRV251
05/29/05	1000	29.13392	-95.05003	Sea Isle	W8 / Good	Upslope of First Foredune	Unknown [3]	N/A	N/A
06/04/05	0630	29.19363	-94.95168	Galveston Island State Park	W15 / Good	Base of Foredunes	Unknown [3]	N/A	N/A
06/20/05	0830	29.08635	-95.11085	San Luis Pass	W1 / Fair	Backbeach	1992 Headstart [2]	65.5	SSD127
05/06/06	1500	29.21595	-94.91393	Bermuda Beach	W19 / Poor	Base of Foredunes	1991 Headstart [2]	62.1	RRV255
05/06/06	1500	29.20873	-94.92597	Galveston Island Pocket Park #3	W18 / Good	Base of Foredunes	1989 Headstart [2]	61.5	RRV315
05/20/06	0800	29.23485	-94.88268	8 Mile Road	W23 / Good	Base of Foredunes	Unknown [3]	N/A	N/A
05/23/06	0700	29.20452	-94.93290	Pirates Beach	W17 / Poor	Embryonic Dunes	Unknown [3]	N/A	N/A
05/26/06	1200	29.21238	-94.92007	Bermuda Beach	W18 / Good	Base of Foredunes	1989 Headstart [2]	61.5	RRV315
05/27/06	0900	29.11948	-95.07153	Miramar Beach	W3 / Good	Embryonic Dunes	Unknown [3]	N/A	N/A
06/14/06	0500	29.21262	-94.91943	Bermuda Beach	W19 / Poor	Embryonic Dunes	Unknown [3]	N/A	N/A
05/01/07	0845	29.16768	-94.99545	Near Beach Access #18	W10 / Good	Base of Foredunes	Unknown [3]	N/A	N/A
05/03/07	1045	29.14700	-95.02910	Sandhill Shores	W10 / Good	Base of Foredunes	Unknown [3]	N/A	N/A
05/17/07	1000	29.13660	-95.04558	Sea Isle	W8 / Good	Embryonic Dunes	1991 Headstart [2]	64.0	RRV235 [5]
5/17/2007 [1]	1230	29.08403	-95.11390	San Luis Pass	W1 / Fair	Backbeach	1989 Headstart [2]	62.4	RRV237 [5]
05/18/07	0955	29.23443	-94.88368	8 Mile Road	W23 / Good	Base of Foredunes	1995 Headstart [2]	59.7	SSH496 [5]
5/26/2007 [1]	1000	29.22250	-94.90325	Hershey Beach	W20 / Good	Base of Foredunes	1992 Headstart [2]	61.0	RRV371 [5]
06/08/07	0945	29.16132	-95.00595	Kahala Beach	W10 / Good	Top of First Foredune	Unknown [3]	N/A	N/A
06/20/07	1010	29.16627	-94.99767	Indian Beach	W10 / Good	Embryonic Dunes	Unknown [3]	N/A	N/A

[1] Turtle engaged in false crawl (emerged onto nesting beach but did not lay nest).

[2] Nesting female identified by biologists as Kemp's ridley.

[3] Nesting female not seen, but hatchlings were Kemp's ridleys (D. Shaver, NPS, pers. comm.)

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

[5] Outfitted with satellite transmitter in 2007.

Table 8. Historical Kemp's Ridley Sea Turtle Nesting Activity in the Seawall Zone of Galveston, Texas.

NESTING DATE	TIME	LOCATION (WGS84) Latitude	Longitude	NESTING LOCATION	BEACH SECTION	NEST HABITAT	NESTER Wild or Headstart	NESTER SCL [4] (cm)	NESTER Primary Tag
04/05/04	1100	29.27405	-94.81637	30th St. & Seawall Blvd.	S11 / Poor	Embryonic Dunes	1989 Headstart [2]	58.5	RRV313
05/30/05	0700	29.28277	-94.79860	33rd St. & Seawall Blvd.	S12 / Fair	Upslope of First Foredune	1992 Headstart [2]	63.0	RRV253
06/04/05	1000	29.28583	-94.79345	28th St. & Seawall Blvd.	S10 / Fair	Upslope of First Foredune	1992 Headstart [2]	60.0	RRV371
04/28/06	1330	29.29533	-94.78107	16th St. & Seawall Blvd.	S19 / Poor	Embryonic Dunes	Wild [2]	67.2	RRV232
05/28/06	0600	29.27132	-94.81762	51st St. & Seawall Blvd.	S3 / Fair	Backbeach	Unknown [3]	N/A	N/A
8/6/2007 [1]	0900	29.27090	-94.81837	52nd St. & Seawall Blvd.	S3 / Fair	Embryonic Dunes	Unknown [3]	N/A	N/A

[1] **Date biologists documented nest hatching. Actual nesting date unknown.**

[2] **Nesting female identified by biologists as Kemp's ridley.**

[3] **Nesting female not seen, but hatchlings were Kemp's ridleys (D. Shaver, NPS, pers. comm.)**

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

Figure 1. Characterization of Sea Turtle Nesting Habitat Quality within the West End Zone of Galveston Island, Texas.

Figure 2. Characterization of Sea Turtle Nesting Habitat Quality within the Seawall Zone of Galveston Island, Texas.

Figure 3. Characterization of Sea Turtle Nesting Habitat Quality within the East End Zone of Galveston Island, Texas.

Figure 4. Historical Nest Locations versus Current Nesting Habitat Quality within the Western Half of the West End Zone of Galveston Island, Texas.

Figure 5. Historical Nest Locations versus Current Nesting Habitat Quality within the Eastern Half of the West End Zone of Galveston Island, Texas.

Figure 6. Historical Nest Locations versus Current Nesting Habitat Quality along the Seawall Zone of Galveston Island, Texas.

PROGRESS REPORT

Project Name: Characterization of Sea Turtle Nesting Activity along the Upper Texas Coast

GLO Contract No.: Contract #07-005-002

Reporting Period: January - March 2008

Task 1: Historical Review of Sea Turtle Nesting Activity on the Upper Texas Coast

- Description of the status of the task: **Task Finished (Completed)**. A copy of the historical review was formally submitted in the January-March 2007 Progress Report. **There are no more deliverables associated with this task.**

Task 2: Monitoring of Sea Turtle Nesting Activity on Galveston Island in 2007

- Description of the status of the task: **Task Finished (Completed)**. Data detailing the monitoring of sea turtle nesting activity on Galveston Island in 2007 were formally submitted in the July-September 2007 Progress Report. **There are no more deliverables associated with this task.**

Task 3: Implementation of a Volunteer Nesting Survey Force

- Description of the status of the task: **Task Finished (Completed)**. Information detailing the efforts of the volunteer nesting survey force was formally submitted in the July-September 2007 Progress Report. **There are no more deliverables associated with this task.**

Task 4. Satellite Tracking of Selected Nesters

- Description of the status of the task: **Task Finished (Completed)**. Four satellite transmitters purchased by TAMUG were applied to Kemp's ridley females discovered nesting on Galveston Island during the April through mid-July 2007 nesting season. These satellite transmitters were integral to tracking post-nesting movements of nesters, assessing the potential for their renesting on the upper Texas coast, specifically Galveston Island, and identifying general beach locations where subsequent nesting takes place.

- List of the major accomplishments for the reporting period: The four satellite transmitters attached to Kemp's ridley females continued to yield information regarding post-nesting movement and habitat fidelity during the last milestone reporting period (October-December 2007). Maps detailing each turtle's migration route since satellite tracking was initiated were provided in Figure 1 of the progress report for the aforementioned reporting period. Tracking data were uploaded daily to the Seaturtle.org website, allowing the public continuous access to real-time tracks of these satellite tagged nesters. Analysis of satellite tracking data continued throughout the October-December 2007 reporting period to facilitate further characterization of nesting turtles' use of the upper Texas coast, as well as their behavior and post-nesting movement while doing so.

- Identification of any problems or obstacles encountered: No problems were encountered.
- Description of the plans for the next reporting period, including deliverables due and their delivery dates: All four transmitters attached to Kemp's ridley sea turtles have continued to provide tracking information through the end of this the last required reporting period. Although all funds awarded for this task have been exhausted, tracking data continue to be uploaded to Seaturtle.org until these transmitters are no longer operational. Excurricular funds are being used to support the continuation of this public reporting. **There are no more deliverables associated with this task.**

Task 5. Guide to Managing Sea Turtle Nesting Habitat on the Upper Texas Coast

- Description of the status of the task: **Task Finished (Completed).** TAMUG personnel have developed a working guide to sea turtle nesting on Galveston Island during 2007. This guide identifies beach stretches: 1) with highest sea turtle nesting potential; 2) those whose nesting potential should be improved; and 3) those lost to nesting because natural phenomena or man-made alterations have rendered them unattractive to nesting or pose a threat to survival of the nest and its contents.

- List of the major accomplishments for the reporting period: The aforementioned working guide to sea turtle nesting on Galveston Island is attached as a final report in meeting the last contractual requirement of a CMP Cycle #11 grant to TAMUG. This final report is included as an attachment to this progress report.

- Description of the plans for the next reporting period, including deliverables due and their delivery dates: All contractual requirements of this grant have been met; **there are no additional deliverables due.**