Nesting Trends of Sea Turtles in National Seashores along Atlantic and Gulf Coast Waters of the United States

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Abstract

National Seashores provide important nesting and foraging habitats for endangered and threatened sea turtles inhabiting the Atlantic and Gulf coast waters of the United States. Successful recovery of these species depends on effective monitoring and protection. We examined protocols and efforts of sea turtle nest monitoring programs at six National Seashores and eight states in the southeastern U.S. National Seashores included Cape Hatteras, Cape Lookout, Cumberland Island, Canaveral, Gulf Islands, and Padre Island. States included North Carolina, South Carolina, Georgia, Florida, Alabama, Mississippi, Louisiana, and Texas. We compared annual fluctuations in sea turtle nesting levels among National Seashores and between seashores and surrounding states for years 1989 through 1997 or 1998. We investigated influences on sea turtle nesting activities. Data and information presented were provided by researchers and officials at National Seashores, various state agencies, regional fishery councils, and the U.S. Fish and Wildlife Service.

In most cases, annual fluctuations in documented sea turtle nesting at National Seashores generally reflected annual fluctuations in nesting in the surrounding state. In most areas and for most species, the numbers of documented nests remained stable or increased slightly during the study period. Primary influences on nesting activity documented at National Seashores were similar to influences noted in surrounding states, and included tidal inundation, erosion, commercial fishing, vehicle use, human disturbance, predation, and artificial lighting.

Maximizing consistency in monitoring protocols between organizations involved in sea turtle recovery enables researchers to more accurately determine the impact of

conservation efforts and to devise more effective strategies for achieving recovery goals. Consistency in monitoring programs at most seashores and states and coordination of monitoring activities between the seashores and states had improved by 1989. Index Nesting Beach Survey (INBS) programs, utilizing standardized monitoring techniques to assess nesting trends, have been in place at most nesting beaches in Florida, Georgia, and North Carolina for the last 10 years. With the exception of the Mississippi District of Gulf Islands National Seashore, patrols for sea turtle nests are now conducted daily throughout the monitoring season at the six National Seashores in the southeastern U.S. However, there are minor differences in monitoring methods outside of INBS areas and differences in methods for measuring reproductive success both among National Seashores and between seashores and surrounding states. We recommend standardized measures and calculations of reproductive success, centralized documentation of survey effort, and long-term consistency in monitoring across locations and years. We also recommend that the National Seashores continue to conduct nest protection measures authorized by state and federal permits that take into consideration National Park Service mandates and policies, meet local needs, and have been deemed effective through research or monitoring results. However, these recommendations are contingent on adequate and consistent funding of sea turtle nest monitoring and protection programs.

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Problem Statement and Introduction

National Seashores, under the administration of the National Park Service, play a crucial role in sea turtle conservation efforts. Five species of marine turtles found in U.S. Atlantic and Gulf coast waters utilize these areas. National Seashores allow for perpetual, comprehensive protection of nesting beaches and provide an opportunity for long-term research. The National Park Service can develop and implement conservation strategies on multiple levels, with objectives tailored for one population, one species, one region, or all seashores.

Six National Seashores located along the Atlantic and Gulf coast waters of the southeastern U.S. serve as the focus of this study (Appendix A). The six National Seashores include Cape Hatteras, Cape Lookout, Cumberland Island, Canaveral, Gulf Islands, and Padre Island. Considering these six areas collectively, loggerhead sea turtles (*Caretta caretta*) nest more frequently than any other sea turtle species. These National Seashores encompass nesting grounds for at least three demographically independent cohorts of loggerhead sea turtles. The Northern Nesting Subpopulation ranges from North Carolina south to northeastern Florida, the South Florida Nesting Subpopulation is located in southern Florida, and the Florida Panhandle Nesting Subpopulation is found in northwestern Florida (Encalada et al., 1998; Turtle Expert Working Group, 1998).

Cape Hatteras, Cape Lookout, and Cumberland Island National Seashores provide protection for the Northern Nesting Subpopulation of loggerhead sea turtles (Encalada et al., 1998; Turtle Expert Working Group, 1998). This smaller nesting group is extremely important as a source of male hatchlings since, due to temperature-dependent sex determination, the warmer temperatures of Florida result in a majority of female hatchlings (Ackerman, 1997). Canaveral National Seashore is located within the second largest nesting assemblage of loggerhead sea turtles in the world and provides important nesting habitat for members of the South Florida Nesting Subpopulation (Turtle Expert Working Group, 1998). Both the Florida and Mississippi districts of Gulf Islands National Seashore provide nesting habitat for loggerhead turtles. Although fewer nests are found at Gulf Islands than at some of the other National Seashores, the Florida district (and perhaps Mississippi district) serves as a nesting refuge for loggerheads from the

Florida Panhandle Nesting Subpopulation. Although loggerhead turtles nest at Padre Island National Seashore, very few nests are found each year and the Nesting Subpopulation for these turtles is currently unknown.

Considering the six National Seashores collectively, green sea turtles (*Chelonia mydas*) nest in second greatest abundance. Canaveral National Seashore provides important nesting habitat for green turtles. Green turtle nests have also been recorded at Cape Hatteras, Cape Lookout, Gulf Islands Florida District, and Padre Island National Seashore.

Of the six National Seashores, Kemp's ridley sea turtle (*Lepidochelys kempi*) nests have only been documented at Padre Island. Also, Padre Island National Seashore is the only site in the United States where Kemp's ridleys nest on a regular basis. A few leatherback sea turtle (*Dermochelys coriacea*) nests are found at Canaveral National Seashore each year. Leatherback nesting was also recorded at Cape Hatteras National Seashore in 1998 and at Padre Island National Seashore in the 1930's and 1940's. The first hawksbill sea turtle (*Eretmochelys imbricata*) nest documented in the state of Texas was found at Padre Island National Seashore in 1998. During the 1998 monitoring season, four sea turtle species—Kemp's ridley, green, loggerhead, and hawksbill—were documented nesting at Padre Island National Seashore. Diversity of nesting sea turtle species is greater at Padre Island National Seashore than at the five other National Seashores.

Together, these six National Seashores provide valuable nesting and foraging habitat for all sea turtle species found in the Atlantic and Gulf coast waters of the U.S. Monitoring and protection of sea turtles, their nests, and their habitats have long been priorities for these areas. All National Seashores operate under the policies and mandates of the National Park Service, but individual seashores may implement different protocols and develop specific objectives. However, monitoring and protection programs undertaken by the National Seashores must be conducted in accordance with appropriate state and U.S. Fish and Wildlife Service permits.

Currently, changes in the number of sea turtle nests found each year provide the most reliable and widely-used index of population size and status for most sea turtle species (National Research Council, 1990; Turtle Expert Working Group, 1998).

Comparisons of nesting, hatching, and other monitoring information are critical for measuring the impact of conservation efforts on species recovery. Additionally, analysis of monitoring information on regional, population, and species levels can help identify any changing or emerging factors that may threaten marine turtle populations already at risk. However, the accuracy and value of these analyses are greatly influenced by the quality of information gathered from different areas by different organizations on a long-term basis.

Survey methods (including survey frequency and the dates that surveys begin and end each season) greatly influence the numbers of nests that are enumerated for various sea turtle species. Monitoring and protection efforts within the National Seashores and states have been conducted by various private and public organizations. The intensity and scope of these efforts have varied between areas and years, largely due to budget and time constraints, but the efforts have become increasingly effective and coordinated at the state and federal levels. Index Nesting Beach Survey (INBS) programs, utilizing standardized monitoring techniques to assess nesting trends, have been in place in Florida, Georgia, and North Carolina since 1989. Implementation of INBS programs has greatly increased the compatibility of monitoring programs among the participating seashores and surrounding states. However, there continues to be differences in monitoring protocols for areas not participating in INBS programs, spatial and temporal differences in the amounts of monitoring effort, and differences in measures of reproductive success. Continued efforts to maximize the compatibility of information gathered in different areas and by different organizations over multiple years will further improve the effectiveness of recovery efforts and provide the best chance for monitoring and protecting sea turtle populations.

A variety of nest protection measures are conducted at the six National Seashores and in the eight states. Nest protection activities undertaken at the National Seashores depend largely on activities authorized by state and federal permits, National Park Service mandates and policies, local/regional needs, and funding availability.

We examined general monitoring procedures used at six National Seashores along the U.S. Atlantic and Gulf coasts, comparing procedures among seashores and between seashores and states involved in sea turtle recovery efforts. We assessed annual

fluctuations in nesting levels, comparing each seashore to the state in which it is located. Trends in nesting levels were examined. We investigated influences on sea turtle nesting and hatching success. Finally, we used the results of these analyses to prepare a series of recommendations. Information gained thorough this study will be provided to the National Park Service to help enhance their monitoring and protection strategies so that the limited funds and resources allotted to each program can be targeted toward activities that offer the best chance to aid with recovery efforts.

Objectives

1. Assess annual fluctuations in sea turtle nest counts and hatchling emergence at the six National Seashores.
2. Compare annual trends in sea turtle nest counts at the six National Seashores with overall trends from the states in which they are located.
3. Identify and evaluate factors affecting trends in nest counts, distributions, and hatchling emergence in the six National Seashores. Among the factors that will be investigated are beach lighting, changes in nesting habitat, vehicular traffic, nighttime beach usage, commercial fishing, and predation.

Methods

We examined general procedures used and results of monitoring efforts at six National Seashores and in the states surrounding those seashores. National Seashores included were Cape Hatteras (CAHA), Cape Lookout (CALO), Cumberland Island (CUIS), Canaveral (CANA), Gulf Islands (GUIS), and Padre Island (PAIS). States included were North Carolina, South Carolina, Georgia, Florida, Alabama, Mississippi, Louisiana, and Texas.

Researchers and officials at each of six seashores and four states were contacted by phone, fax, or e-mail and asked to complete a Southeast Nesting Project questionnaire (Appendix B). These biologists provided information on number of nests found,

reproductive success, nest monitoring procedures, and influences on sea turtle nesting activities. The U.S. Fish and Wildlife Service's National Sea Turtle Coordinator also provided information for these states, as well as documentation on nesting recorded in Alabama, Mississippi, and Louisiana. Personnel at Bon Secour National Wildlife Refuge, Alabama provided additional information on sea turtle nesting at their refuge.

Officials at marine fishery management agencies in eight states were contacted regarding shrimp fishery regulations. Information was provided on the duration of shrimp fishery seasons and on specific area closures within state waters. Officials at the South Atlantic and Gulf of Mexico Fishery Management Councils were also contacted, and provided information on shrimp fishing seasons in federal waters.

Prior to 1989, monitoring of sea turtle nesting in the southeastern U.S. was generally fragmented and inconsistent. However, by 1989, monitoring efforts and methods improved substantially in most areas involved in this study. Accordingly, documentation of sea turtle nesting prior to 1989 was not included in comparisons among seashores and between seashores and states.

Nesting information for years 1989-1998 was compiled and analyzed. Turtle nests found at National Seashores were separated and removed from state records to allow comparisons between the seashores and the remainders of each state (Appendices C and D). Annual changes in the number of nests found at each seashore were compared to changes in the remainder of the state, excluding National Seashores. Any emerging trends in annual fluctuations of nest counts were examined.

Researchers at each National Seashore and within each state provided anecdotal information on factors influencing nesting and hatching success. Some quantitative information on nests affected by these factors was also provided. This information was compiled and compared within seashores and between seashores and states.

All qualitative and quantitative results presented in this report are derived directly from information provided by researchers and officials completing the Southeast Nesting Project questionnaire, unless otherwise indicated. Information presented on sea turtle nesting at Bon Secour National Wildlife Refuge was provided by the U.S. Fish and Wildlife Service's National Sea Turtle Coordinator and Bon Secour National Wildlife Refuge personnel. Information presented regarding shrimp fishery regulations was

provided by the South Atlantic Fishery Management Council, Gulf of Mexico Fishery Management Council, North Carolina Division of Fisheries, South Carolina Department of Natural Resources, Georgia Department of Natural Resources, Florida Marine Fisheries Commission, Alabama Department of Conservation and Natural Resources, Mississippi Department of Marine Resources, Louisiana Department of Wildlife and Fisheries, and Texas Parks and Wildlife Department.

Project Personnel/Cooperators and Partners

This project was completed by Jody L. Mays, Biological Technician, National Park Service, and Donna J. Shaver, Research Biologist, U.S. Geological Survey. Data were provided by Sandra L. MacPherson, National Sea Turtle Coordinator, U.S. Fish and Wildlife Service; Ruth Boettcher, North Carolina Sea Turtle Coordinator, North Carolina Wildlife Resources Commission; Marcia Lyons, Natural Resource Specialist, Cape Hatteras National Seashore, National Park Service; Jeff Cordes, Resource Management Specialist, Cape Lookout National Seashore, National Park Service; Sally Murphy, South Carolina Sea Turtle Coordinator, South Carolina Department of Natural Resources; Adam MacKinnon, State Sea Turtle Technician, Georgia Department of Natural Resources; Jennifer Bjork, Resource Management Specialist, Cumberland Island National Seashore, National Park Service; Dr. Robbin Trindell, Florida Sea Turtle Coordinator, Florida Department of Environmental Protection; John Stiner, Resource Management Specialist, Canaveral National Seashore, National Park Service; Mark Nicholas, Resource Management Specialist, Gulf Islands National Seashore, Florida District, National Park Service; Gary Hopkins, Resource Management Specialist, Gulf Islands National Seashore, Mississippi District, National Park Service; Bon Secour National Wildlife Refuge; South Atlantic Fishery Management Council; Gulf of Mexico Fishery Management Council; North Carolina Division of Fisheries; South Carolina Department of Natural Resources; Georgia Department of Natural Resources; Florida Marine Fisheries Commission; Alabama Department of Conservation and Natural Resources; Mississippi Department of Marine Resources; Louisiana Department of Wildlife and Fisheries; and, Texas Parks and Wildlife Department.

Project Facilities/Equipment and Study Areas

No field sampling was undertaken for this project by the authors. Data provided by others were analyzed at Padre Island National Seashore. Areas for which nesting and reproductive success data were compared include six National Seashores (Cape Hatteras, Cape Lookout, Cumberland Island, Canaveral, Gulf Islands, and Padre Island) and eight states (North Carolina, South Carolina, Georgia, Florida, Alabama, Mississippi, Louisiana, and Texas).

Results and Discussion

Monitoring Efforts and Protocol

The need to regularly monitor sea turtle nesting in the southeastern U.S. was realized by 1964, when Jim Richardson began monitoring Little Cumberland Island in Georgia. However, widespread monitoring on a regular basis did not begin until the late 1970's. By 1989, most nesting beaches in the southeastern U.S. were included in monitoring efforts (Turtle Expert Working Group, 1998). Due in large part to budget constraints, amounts of monitoring effort and monitoring protocols have varied spatially and temporally at many nesting beaches. However, the intensity and consistency of methods for monitoring sea turtle nesting in the U.S. have improved substantially in recent years, particularly since the Index Nesting Beach Survey (INBS) program was instituted for major nesting beaches in Florida, Georgia, and North Carolina in 1989.

Cape Hatteras (CAHA), Cape Lookout (CALO), and North Carolina

In 1986, North Carolina began monitoring sea turtle nests on a statewide basis under the direction of the Nongame and Endangered Wildlife Program of the North Carolina Wildlife Resources Commission. At CAHA, nest monitoring began in 1978. CALO initiated a nest monitoring program in 1976.

North Carolina, CAHA, and CALO currently participate in, and follow, INBS protocols. In North Carolina, daily patrols are conducted generally from May through August. All-terrain vehicles (ATVs) are used for surveys on most beaches, although patrols are also conducted on foot or by truck in some areas. Protocol has changed little since monitoring began, although the amount of effort has increased. The number of hours spent monitoring sea turtle nesting activities is recorded by individual volunteer projects, but no centralized documentation of survey effort is maintained. At CAHA, patrols are now conducted each morning from June through August using an ATV or a truck. Effort, measured as the number of hours spent and the distance traveled during nesting patrols, has increased every year. However, annual levels of patrol effort have not been calculated. A variety of methods were used for sea turtle nest monitoring at CALO between 1976 and 1989. Since 1990, CALO has conducted daily patrols from June through mid-August using an ATV. No documentation of the amount of effort has been maintained.

At CAHA, CALO, and in the rest of North Carolina, most nests are left *in situ* (untouched where deposited on the beach), with no environmental conditions monitored. However, at times, a large percentage of the nests located in North Carolina are moved to increase protection for them. Nests found at CAHA may be moved if deposited in areas below the debris line marking the typical high tide or in areas with heavy artificial lighting, erosion, or vehicle traffic. At CALO, nests in danger of repeated inundation are relocated to higher ground. In the remainder of North Carolina, nests may be relocated if deposited in areas where high levels of inundation, erosion, or vehicle and foot traffic occurs (North Carolina Wildlife Resources Commission, unpubl. guide).

Flat wire screens are placed over some nest sites found both at CALO and in North Carolina. Wire cages may also be placed over some nest sites in North Carolina (North Carolina Wildlife Resources Commission, unpubl. guide). Both of these devices, which are designed to protect nests from predation, are self-releasing, with openings large enough to allow turtle hatchlings to emerge and escape. Nests found at CAHA may be cordoned off to divert vehicle traffic, but no enclosures are used to protect nests from predation. No trapping or hunting to control nest predators is conducted at CAHA, at CALO, or on a statewide basis in North Carolina.

South Carolina

No National Seashores are located in South Carolina. Sea turtle nesting has been monitored in South Carolina since the mid-1970's. South Carolina's Department of Natural Resources has monitored sea turtle nesting using aerial surveys, beginning in 1980. These aerial surveys are done on a 5-year schedule. Twelve surveys are conducted each year for 3 consecutive years, then four surveys are conducted each year for 2 consecutive years (Hopkins-Murphy et al., in press). Approximately half of the state's coastline is also surveyed on the ground by numerous volunteer projects. These ground surveys are performed daily by foot, ATV, or truck. No documentation of the amount of survey effort has been maintained for ground surveys. However, aerial survey effort has been consistent, following a 5-year schedule, since 1980.

Surveyed areas encompass about 70% of sea turtle nests laid in the state. Most of these nests are left *in situ*. However, many of these nests are relocated if found in areas of heavy development or tidal inundation. In 1997, approximately 41% of all nests found were relocated. Others may be protected from predation using a flat, self-releasing screen or a self-releasing hatchery fence. In most areas, no trapping or hunting for nest predators is conducted.

Cumberland Island (CUIS) and Georgia

Efforts to monitor and protect sea turtle nesting in Georgia are coordinated by the Georgia Department of Natural Resources, Nongame/Endangered Wildlife Program. Surveys for nests have been conducted by a variety of agencies, beginning in 1964. Since 1989, when Georgia (including CUIS) began participation in the Index Nesting Beach Survey (INBS) program, surveys have covered 84% of the Georgia coast. Ten of the fifteen areas monitored are patrolled every day (seven daily, three nightly); four areas are patrolled bi-weekly; and one is patrolled on an irregular basis. Patrols are conducted by truck, airplane, Honda Mule, ATV, bicycle, or on foot. The amount of time spent conducting nesting surveys has been recorded, but annual levels of survey effort have not been determined. At CUIS, complete surveys of the entire island began in 1994. Patrols are conducted daily during the monitoring season, primarily using an ATV. Annual

levels of survey effort are not calculated, although survey effort has been consistent since 1994.

Most nests found at CUIS are left *in situ*. Specific nests at risk of tidal inundation and nests that have been partially depredated may be relocated. Self-releasing wire screens are placed over some nests in areas with a high frequency of raccoon predation. Predators are also controlled by trapping or hunting as needed. Nest protection measures vary in the remainder of Georgia. On some Georgia beaches, self-releasing protective screens are secured over the nest site. Some nests are relocated if deposited in areas prone to heavy tidal inundation, erosion, or predation. In other areas, no protection measures are implemented. Raccoons and feral hogs are trapped and shot year-round in Georgia with varying intensity, while ghost crabs are sometimes trapped if they become a problem during the sea turtle nesting season.

Canaveral (CANA), Gulf Islands - Florida District (GUIS-FL), and Florida

In 1979, the Florida Marine Research Institute (FMRI), within the Florida Department of Environmental Protection, implemented a statewide monitoring program for sea turtles. CANA began surveying for sea turtle nests in 1984. GUIS-FL implemented a monitoring program in 1989.

When sea turtle monitoring began in Florida, methodologies and survey efforts varied considerably both between areas surveyed and between years. Due to these variations, information collected prior to 1989 may not be viable for examining changes in sea turtle populations (Meylan et al., 1995). Beginning in 1989, when the Index Nesting Beach Survey (INBS) program was initiated, monitoring efforts increased and became more consistent. The program is designed to collect information viable for analyzing population trends, and focuses on consistent, long-term monitoring efforts (Meylan et al., 1995). The INBS program in Florida now involves 32 nesting beaches (total shoreline length 392 km), representing over 80% of sea turtle nesting in the state. Statewide monitoring seasons run from mid-May through August for Index Beaches, but can begin anywhere from January to August and end anywhere from May to December on other beaches. Although surveys are conducted daily on Index Beaches, survey effort on other beaches ranges from 7 days per week to 1 day per year (Meylan et al. 1995,

Florida Marine Research Institute, unpubl. data). Surveys on most Florida beaches are conducted each morning on foot or using an ATV, although some areas may conduct patrols by truck. Survey effort is measured as the amount of beach monitored each year.

At CANA, the same general protocol has been followed since nest monitoring began. This seashore follows the INBS survey protocol from mid-May through August, conducting ATV patrols on a daily basis. But CANA also monitors before and after this period, resulting in ATV patrols on most days between 8 May and 30 September in most years. Annual totals of survey effort, measured in terms of the number of hours spent surveying for nests, have not been calculated. However, survey effort has been consistent each year since 1990.

At GUIS-FL, only aerial surveys were conducted in 1989. From 1990-1993, surveys were conducted every 2-3 days using an ATV. Since 1994, ATV surveys have been conducted daily. Patrols were conducted from May through August between 1989 and 1993. Beginning in 1994, patrols have been conducted from May until October or November. Effort has been relatively consistent since 1994.

Most of the nests found at CANA, GUIS-FL, and in the rest of Florida are left *in situ*, with no environmental conditions monitored. At both seashores, a flat, self-releasing mesh screen is secured over the nest site as soon as it is identified. In the remainder of Florida, nests at high risk for tidal inundation may be relocated, while nests at high risk for predation are protected with wire screens or cages (Florida Department of Environmental Protection, unpubl. guide). At CANA, limited trapping is also conducted in problem areas for predators that learn to dig underneath the protective nest screen; predators are live trapped and released elsewhere at CANA. At GUIS-FL, trapping and hunting of canine predators is done intensively but on a seasonal basis. Limited use of chemical controls for fire ants near nest sites is practiced in the remainder of Florida (Florida Department of Environmental Protection, unpubl. guide).

Gulf Islands - Mississippi District (GUIS-MS), Alabama, Mississippi, and Louisiana

Sea turtle nesting at GUIS-MS has been monitored on a systematic basis since 1990. It is apparently the only sea turtle nest monitoring project currently conducted in Mississippi. At GUIS-MS, aerial surveys are conducted once per week from May through September each year. If tracks are observed, then nesting is verified on the ground. No documentation of the amount of survey effort is maintained, although effort has remained relatively consistent.

All nests found at GUIS-MS are left *in situ*, with no environmental conditions monitored. Nests are not relocated and no protective measures are implemented. No trapping for predators is conducted. Nests are checked 10 days and 75 days after being identified. If eggshells are seen at the surface of a nest site, then the nest is excavated and predation or hatching is verified. However, many nests are inaccessible after hatching due to tropical storms and hurricanes.

No National Seashores are located in Alabama or Louisiana. Little information is available on sea turtle nesting in these states. In 1989 and 1990, biologists conducted limited sea turtle nesting surveys of Louisiana's Breton and Delta National Wildlife Refuges by air and on foot. Eight loggerhead nests were found in 1989 and one loggerhead nest was found in 1990 at Breton and Delta National Wildlife Refuges (Fuller, unpubl. report; Fuller and Lohoefener, 1990).

In Alabama, two to three loggerhead nests were found at Dauphin Island each year between 1995 and 1997. Sea turtle nesting has been monitored at Bon Secour National Wildlife Refuge since 1994. Surveys are conducted 3 days per week from early June through mid- to late August. Most nests are left *in situ*, with no environmental conditions monitored. Nests deposited in areas at high risk for inundation or human disturbance are relocated. Some nests are protected from predation using flat, self-releasing screens. Nests found at Bon Secour National Wildlife Refuge in Alabama are checked for hatching 75 days after the lay date.

Padre Island (PAIS) and Texas

PAIS began patrols for sea turtle nests in 1986. Currently, PAIS conducts the only monitoring project specifically for sea turtle nesting in Texas. However, biologists conducting patrols (once or twice a week) for stranded turtles elsewhere in Texas remain observant for nesting. Additionally, beach visitors report a large percentage of the sea turtle nestings documented on the Texas coast, within and outside of PAIS.

Patrol effort has increased significantly since monitoring began in 1986. Both the number of hours spent patrolling and the number of kilometers traveled during patrols have been documented each year since 1986 and have increased since that time. In 1990, the area patrolled by PAIS staff and volunteers expanded from the 104 km length of PAIS to include the remaining 24 km of Gulf beach shoreline on North Padre Island, north of PAIS. Since that time, PAIS patrols have covered the entire 128 km length of North Padre Island. From 1986 through 1990, patrols at PAIS were conducted 2-3 days per week using a variety of methods, including trucks, military HUM-Vs, and airplanes. Beginning in 1991, patrols were done daily, using ATVs, military surplus Mules, and trucks (Shaver, unpubl. report). Since 1993, ATVs have been either the primary or only vehicle type used for patrols.

PAIS patrols are conducted primarily to detect nesting by Kemp's ridley sea turtles, the sea turtle species found nesting most frequently on the Texas coast. The PAIS patrol strategy and data parameters collected are patterned after monitoring efforts on-going for Kemp's ridley turtles at their primary nesting beach in Rancho Nuevo, Mexico. Because one of the primary objectives of the PAIS monitoring program is to actually examine nesting Kemp's ridley turtles for tags (in an attempt to determine if they are part of the experimental project to establish a secondary nesting colony) and because Kemp's ridley tracks disappear much more quickly than do tracks of other sea turtle species that nest in the U.S., PAIS and Rancho Nuevo patrols repeatedly traverse the target area on patrol days.

A comparison of the number of kilometers traveled during nesting patrols to the number of nests found at PAIS each year indicates that, in general, documented nesting has increased with increasing patrol effort (Figure 1). Nests found per hour patrolled

have increased from 0.0006 in 1990 to 0.0018 in 1998. In 1996, success per unit effort peaked at 0.0029 nests found per hour patrolled.

Due to the critically endangered status of Kemp's ridley, a variety of threats to nests (beach driving, predators, tidal inundation, etc.), and the large geographic dispersion of the limited number of nests found, virtually all sea turtle nests found in south Texas (including at PAIS) are retrieved, placed in styrofoam containers, and incubated in a controlled environment at PAIS. Temperatures are monitored and controlled for each clutch of eggs throughout the incubation period. Predators, including insects, are excluded from the incubation facility. No trapping or hunting for predators is conducted at the seashore. Most nests found by visitors in south Texas, outside North Padre Island, are reported to the University of Texas at Pan American Coastal Studies Laboratory or to the University of Texas at Austin Marine Sciences Institute and the eggs are retrieved and incubated in styrofoam containers at PAIS. Hatchlings born at the incubation facility are weighed, measured, and released at PAIS. Potential predators, including ghost crabs and birds, are excluded from release sites during hatchling releases.

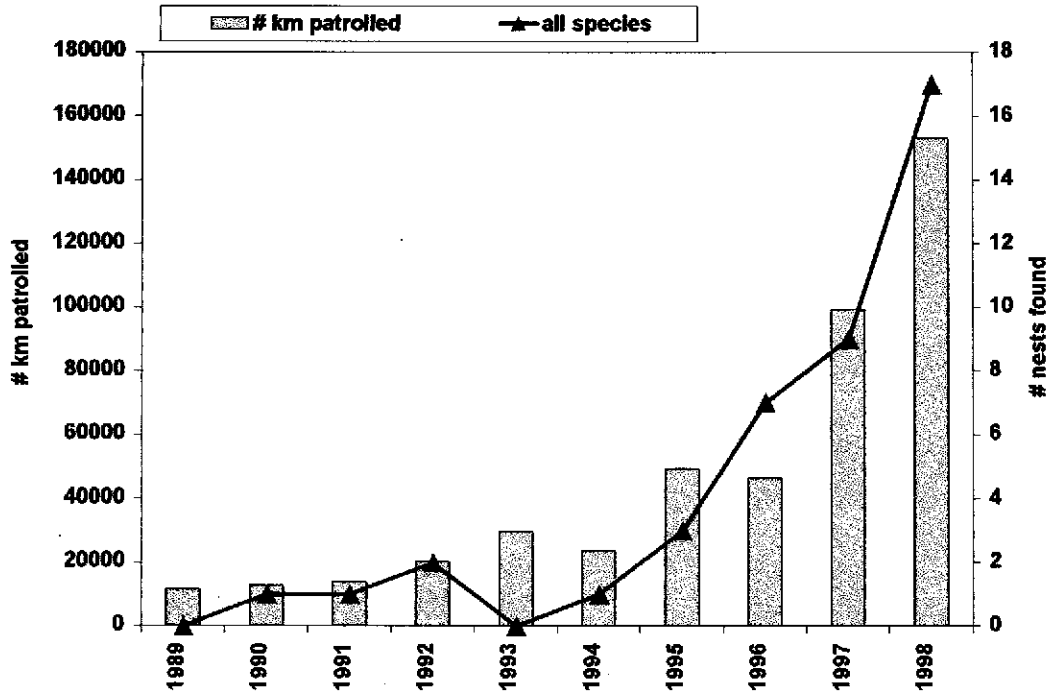

Figure 1. Sea turtle nests (all species) found at Padre Island National Seashore compared to patrol effort, measured as the number of kilometers patrolled, for 1989-1998.

Measures of Reproductive Success

Annual changes in sea turtle reproductive success can provide valuable information on the status of sea turtle populations. Without a standardized means of measuring sea turtle reproductive success, the impact of conservation measures on sea turtle nesting activities cannot be accurately determined.

Measures of reproductive success differed considerably among National Seashores, and between seashores and surrounding states. The definition of terms used for describing reproductive success was not consistent. Methods for determining reproductive success also varied. However, recent refinement of methods used in measuring reproductive success has improved the accuracy of these measures in several areas incorporated in this study.

At CAHA, CALO, and in the remainder of North Carolina, hatching success is defined as the proportion of turtle hatchlings that emerged from the nest. Hatchlings that emerged from the egg but died in the nest are not considered successfully hatched. Hatching success is calculated by subtracting the number of dead hatchlings from the number of hatched eggs, then dividing that number by the number of eggs deposited (North Carolina Wildlife Resources Commission, unpubl. guide).

In South Carolina, hatching success is defined as the proportion of hatchlings that make it out to sea out of the total number of eggs laid. However, hatchlings are not witnessed as they emerge and reach the water. Rather, the number of hatched eggs are counted, and all hatchlings that emerged from the nest are assumed to have made it out to sea. Hatchlings that emerged from the egg but died in the nest are not considered successfully hatched. Hatching success is estimated from information provided by various volunteer projects. In 1997, hatching success for nests that hatched ranged from 46% to 87% for various sites in South Carolina. Nesting success, defined as the proportion of nests that produce hatchlings, is also estimated from information provided by various volunteer projects. Currently, overall nesting success for South Carolina is estimated at 80%. However, the accuracy of these measures is difficult to determine due to differences between volunteer monitoring projects.

Hatching success in Georgia is defined as the proportion of eggs that hatched from each nest. Hatchlings that emerged from the egg but died in the nest are considered

successfully hatched in this calculation. CUIS and other areas in Georgia calculate hatching success by dividing the number of hatched eggs by the total number of eggs in the nest. Hatching success is not determined separately for predated nests at CUIS but is determined separately for undisturbed nests and for predated nests for other areas in Georgia. Emergence success, defined as the proportion of eggs yielding hatchlings that made it out of the nest, is also calculated. Hatchlings that emerged from the egg but died in the nest are not considered successfully emerged in the calculation of emergence success. Emergence success at CUIS is calculated as the number of hatchlings that emerged from eggs minus the number of dead hatchlings in the nest, divided by the total number of eggs. This measurement of emergence success is equivalent to the number of hatched eggs minus the number of dead hatchlings, divided by the number of eggs, which is the calculation used for hatching success at CAHA, CALO, and North Carolina.

Hatching and emergence success are not determined for many areas monitored in Florida. However, some areas voluntarily collect data on hatching and emergence success. Nesting success, defined as the proportion of adult emergences from the water that result in a nest, is estimated by comparing the total number of sea turtle tracks found to the total number of nests deposited each year. During a typical year on a Florida nesting beach, a deposited nest was found for approximately half of all sea turtle tracks located. The rest were false crawls. Prior to 1996, two methods for measuring hatching success were used at CANA. All nests found were investigated, and a nest was defined as successful if any hatchlings emerged. In addition, a portion of nests found each season were excavated after hatching to calculate an average hatching rate, defined as the percentage of eggs that hatched in each nest. These methods did not accurately account for the effects of predation, since predated nests were gone before excavation took place. Beginning in 1996, CANA began marking 10% of all nests found as index nests. These index nests are excavated to count the number of hatched eggs and to determine predation levels. At GUIS-FL, a detaining enclosure may be temporarily placed over some nests to prevent disorientation of hatchlings. Witnessed hatching success, defined as the number of turtle hatchlings actually seen entering the water, is determined for each nest. Hatching success, defined as the proportion of turtles that hatch from the egg, is also

calculated. Hatchlings that emerged from the egg but died in the nest are included as successfully hatched in this calculation.

Hatching success at GUIS-MS is investigated only for those nests where eggshells are visible at the nest site. If predation is not verified for a nest found at GUIS-MS, then it is considered successfully hatched. However, many nests are inaccessible for verification at hatching due to tropical storms or hurricanes.

Hatching success at PAIS, defined as all turtle hatchlings that emerge from the egg, is calculated by dividing the number of hatchlings by the number of eggs incubated. Hatchlings that emerge from the egg but die before release are considered successfully hatched in this calculation. The numbers of hatchlings that die prior to release, number of hatchlings released, and number of hatchlings that are too weak for release (transported to rehabilitation facilities) are also enumerated at PAIS.

Annual rates of reproductive success up to 1997 were available for CAHA, CALO, the remainder of North Carolina, CUIS, CANA, and PAIS/Texas (Table 1). Reproductive success was not determined for every nest found, nor for a consistent proportion of nests found, at all locations in all years, due to tropical storms, hurricanes, and other factors. Consequently, measured reproductive success may not reflect true reproductive success on an annual basis at a given location. A single success rate was calculated for all nests incubated at PAIS, which include all nests found in Texas. Although the method for calculating reproductive success is not the same at all locations, the definition and calculation of reproductive success at each locality has remained consistent for those years and locations listed in Table 1.

In general, measured reproductive success at these six locations has remained above 50% for most years included. Reproductive success rates in these areas have ranged from a low of 31.78% in North Carolina (excluding National Seashores) in 1996 to a high of 100% at PAIS in 1990.

Hatching success at CALO and at CAHA followed the same general pattern for most years between 1989 and 1997 (Figure 2). However, CALO documented a low in hatching success in 1995 not observed at CAHA. Neither National Seashore reflects the precise patterns in hatching success documented in the remainder of North Carolina. In addition, a low in sea turtle hatching success recorded in North Carolina (excluding

Table 1. Annual rates of reproductive success, measured as hatching success[1,3,4] or emergence success[3], at Cape Hatteras National Seashore (CAHA), Cape Lookout National Seashore (CALO), North Carolina (excluding National Seashores), Cumberland Island National Seashore (CUIS), Canaveral National Seashore (CANA), and Padre Island National Seashore (PAIS) combined with Texas.

Year	CAHA[1]	CALO[1]	North Carolina[1]	CUIS[2]	CANA[3]	PAIS/Texas[4]
1989	68.56	Not determined	63.48	Not determined	Not determined	No nests found
1990	63.94	71.00	75.78	Not determined	Not determined	100.00
1991	51.50	62.00	61.12	Not determined	Not determined	94.00
1992	58.03	73.00	67.53	45.10	Not determined	69.00
1993	50.33	74.00	82.53	52.20	Not determined	No nests found
1994	56.18	85.00	76.66	63.30	Not determined	90.00
1995	63.87	51.00	67.35	56.10	Not determined	88.80
1996	51.90	75.50	31.78	67.50	50.13	63.36
1997	60.51	73.00	75.15	64.70	43.07	82.46

[1] Measured as hatching success = (# hatched eggs – # dead hatchlings) / (# eggs deposited) x 100.
[2] Measured as emergence success = (# hatched eggs – # dead hatchlings in nest) / (total # eggs) x 100.
[3] Measured as hatching success = (# hatched eggs) / (# eggs deposited) x 100
[4] Measured as hatching success = (# hatchlings) / (# eggs incubated) x 100

National Seashores) in 1996, when a hurricane struck the North Carolina coast, was not documented at CAHA or CALO.

Hatching success at CAHA and CALO and emergence success at CUIS are defined and calculated in comparable manners. CUIS and CAHA recorded similar levels of success during the 1992-1997 period (Figure 3), ranging from 45.10% to 68.56%. However, annual emergence success at CUIS increased slightly during this period, while annual hatching success remaining relatively stable at CAHA. With the exception of 1995, hatching success at CALO was consistently higher in comparison to hatching success at CAHA and emergence success at CUIS during the 1989-1997 period.

Hatching success is monitored at CANA and at PAIS. However, due to changes in protocol, accurate hatching success rates at CANA were only available since 1996. Hatching success at PAIS, which reflects hatching levels for nearly all nests found in Texas, was generally higher in comparison to other locations during the 1990-1997 period. However, hatching levels at PAIS are measures of the success of incubation in a controlled environment, a situation unique to PAIS.

Annual Fluctuations and Trends in Loggerhead Nesting

Genetic evidence shows that adult female loggerheads return to nest in the same general area where they first entered the water as hatchlings, and are highly unlikely to nest outside this natal area (Bowen and Karl, 1997; Lohmann et al., 1997; Encalada et al., 1998; Turtle Expert Working Group, 1998). As a result, distinct nesting assemblages, or subpopulations, have developed. Due to extremely low maternal gene flow between such colonies, the extirpation of a nesting subpopulation represents a significant loss of genetic variability for the species. Documented losses of loggerhead nesting colonies demonstrate that regional dispersal will not replace that lost colony in the foreseeable future. Based on this information, the Turtle Expert Working Group (1998) recommended that each nesting subpopulation be considered independently in terms of conservation and status.

Six major extant nesting assemblages of loggerhead sea turtles in the Atlantic and Mediterranean have been identified using mitochondrial DNA, which is inherited from the mother. Three of these nesting colonies occur in the southeastern U.S. The Northern

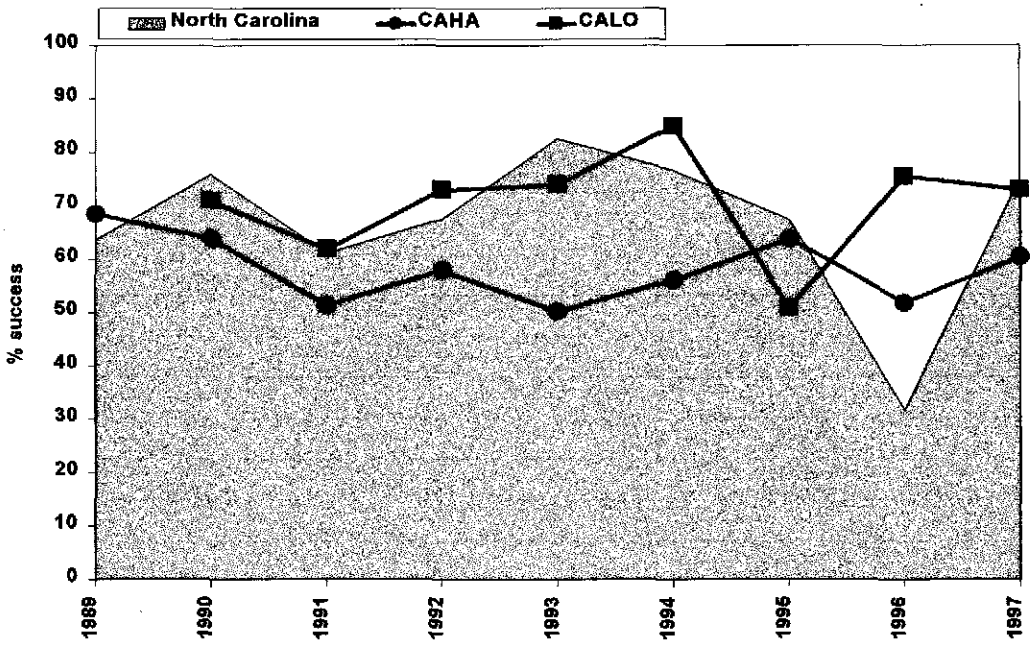

Figure 2. Annual fluctuations in hatching success documented at Cape Hatteras National Seashore (CAHA), at Cape Lookout National Seashore (CALO), and in the remainder of North Carolina, 1989-1997.

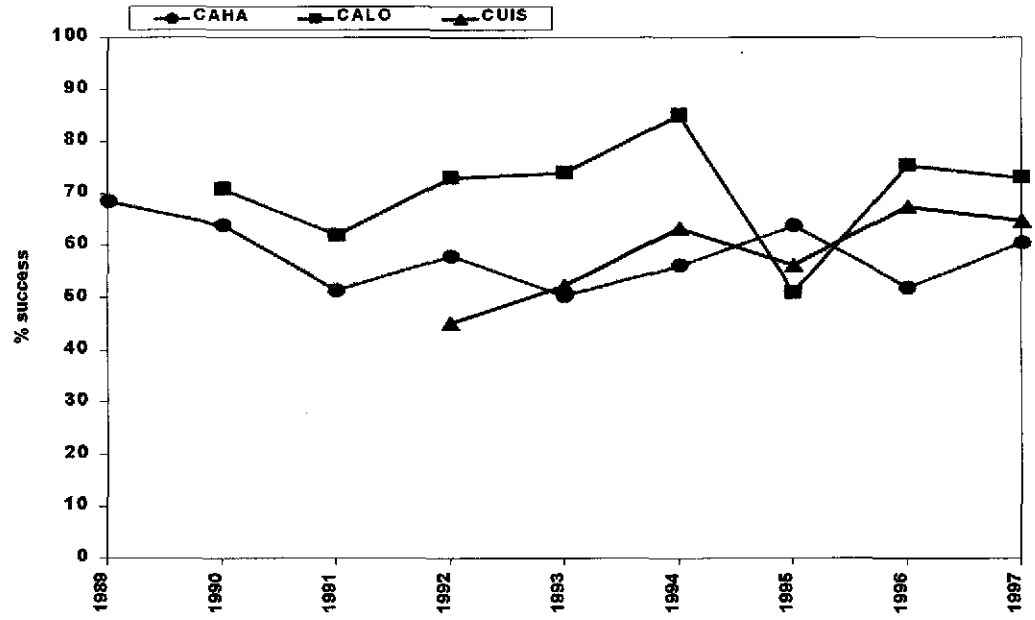

Figure 3. Annual fluctuations in hatching success documented at Cape Hatteras National Seashore (CAHA) and Cape Lookout National Seashore (CALO) and emergence success documented at Cumberland Island National Seashore (CUIS), 1989-1997.

Nesting Subpopulation occurs from North Carolina south to northeast Florida, the South Florida Nesting Subpopulation occurs in southern Florida (from 29 degrees N latitude on the east coast to Sarasota on the west coast), and the Florida Panhandle Nesting Subpopulation occurs solely in northwestern Florida (Encalada et al., 1998; Turtle Expert Working Group, 1998). Loggerhead nesting at five of six National Seashores included in this study occurs as part of these three nesting subpopulations. Loggerhead nesting at PAIS is currently being investigated to determine which nesting subpopulation they are associated with.

Cape Hatteras (CAHA), Cape Lookout (CALO), and North Carolina

At CAHA, an average of 55 loggerhead nests was found each year during the 1989-1998 period. The number of loggerhead nests found ranged from 26 in 1989 to 101 in 1998. Documented loggerhead nesting at CALO since 1989 varied from 80 in 1989 to 193 in 1998, with an average of 110 nests found each year during the 1989-1998 period. Between 1989 and 1998, the number of loggerhead nests found in the remainder of North Carolina ranged from 340 in 1993 to 772 in 1994. On average, 557 loggerhead nests were found each year.

Annual fluctuations in documented loggerhead nesting at CAHA and in North Carolina (excluding National Seashores) were examined for patterns and consistency (Figure 4). Due to differences in the magnitude of nests found, the two areas were plotted on separate axes. CAHA, charted as a line on the right axis, generally follows the same pattern of changes as the remainder of North Carolina, charted as an area on the left axis. Both show a peak in loggerhead nesting in 1991 and again in 1994. However, a third peak in nesting evident in 1996 in North Carolina was not documented at CAHA. In addition, the second nesting peak is proportionally higher than the first peak at CAHA, but not in the remainder of the state. Both areas record lows in loggerhead nesting in 1989, 1992-1993, and 1997.

Annual fluctuations in documented loggerhead nesting at CALO and in the remainder of North Carolina were also compared (Figure 5). Again, due to differences in magnitude, the two areas are plotted on separate scales. CALO, charted as a line on the

right axis, follows less closely the same general pattern as the state. CALO shows a peak in nesting in 1990 and 1994, and a low in nesting in 1989, 1991-1992, and 1996. Like CAHA, CALO shows a relatively higher second peak in nesting. However, CALO also records an increase in nesting in 1997 not documented by CAHA or North Carolina. This increase continues in 1998 at CALO, at CAHA, and in the rest of North Carolina.

The Northern Nesting Subpopulation includes loggerheads that nest in North Carolina, South Carolina, Georgia, and northeast Florida; current trends indicate this subpopulation has declined since the 1980's (Encalada et al., 1998; Turtle Expert Working Group, 1998). From 1989-1998, loggerhead nest numbers documented at CALO appear to have remained stable or increased slightly, at CALO appear to have increased slightly, and in the remainder of North Carolina appear to have remained stable or decreased slightly. However, trends in all these areas may be influenced by changes in survey efforts between years.

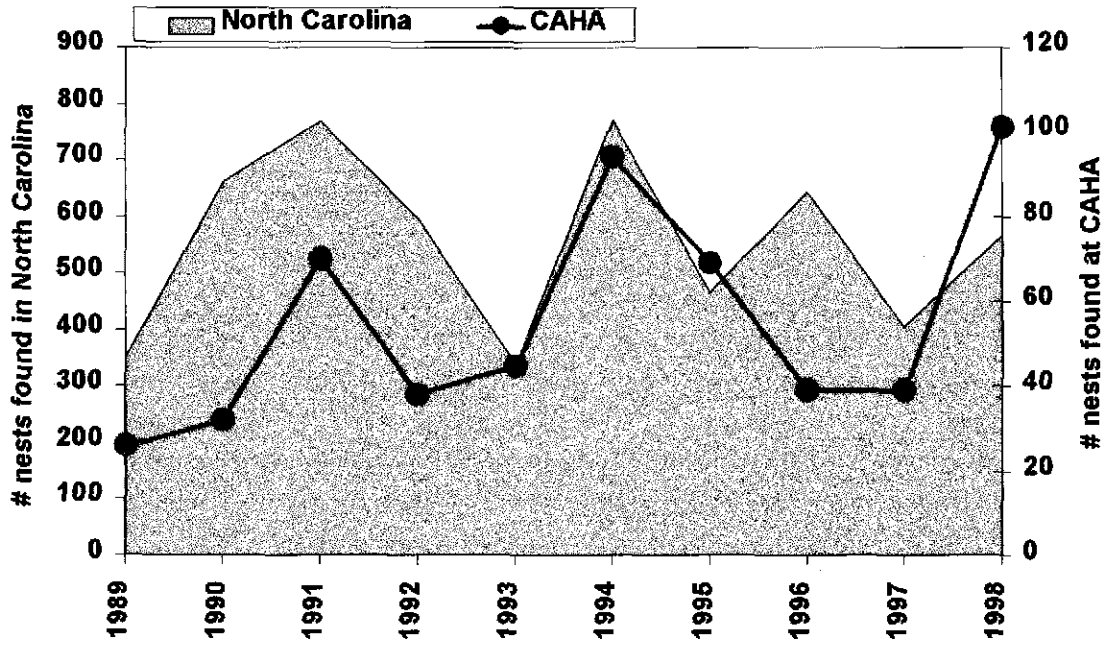

Figure 4. Annual fluctuations in loggerhead nests found at Cape Hatteras National Seashore (CAHA) and in North Carolina (excluding National Seashores), 1989-1998.

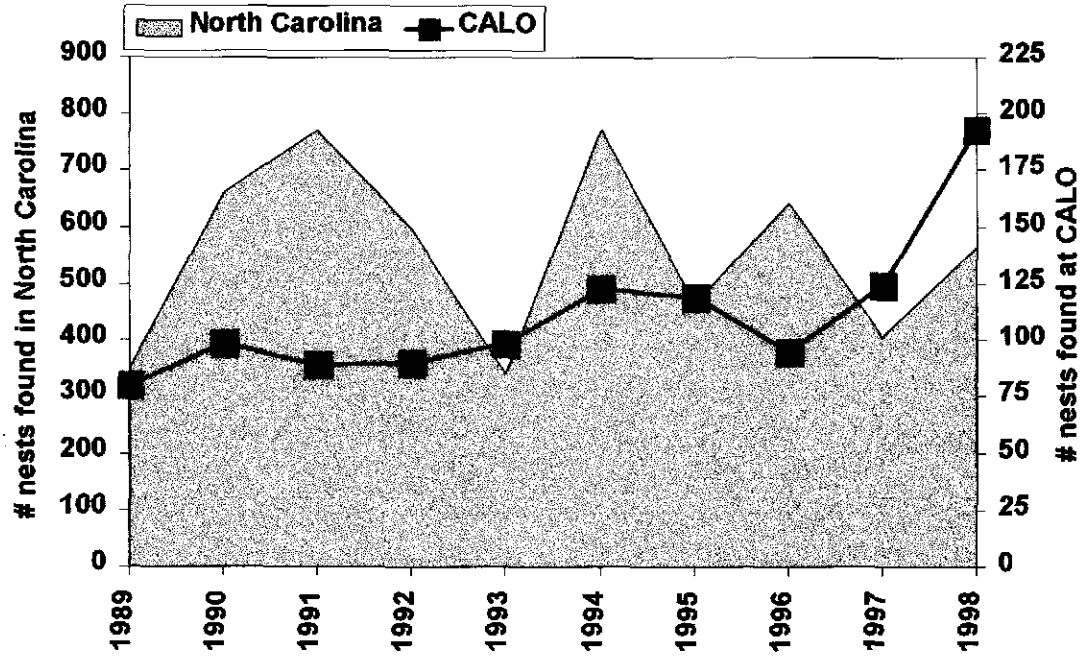

Figure 5. Annual fluctuations in loggerhead nests found at Cape Lookout National Seashore (CALO) and in North Carolina (excluding National Seashores), 1989-1998.

South Carolina

Although no National Seashores are located in South Carolina, annual fluctuations in loggerhead nesting in the state are presented here (Figure 6) for general comparison to loggerhead nesting elsewhere in the study area.

Between 1989 and 1997, the number of loggerhead nests found in South Carolina ranged from 2,444 in 1989 to 4,491 in 1990. On average, about 3,470 loggerhead nests were found each year during this period (Hopkins-Murphy et al., in press). Loggerhead nesting in the state seems to fluctuate on a biannual basis, with peaks in nesting occurring in 1990, 1992, 1994, and 1996. North Carolina also recorded peaks in loggerhead nesting in 1994 and 1996. The Northern Nesting Subpopulation includes loggerheads that nest in North Carolina, South Carolina, Georgia, and northeast Florida; current trends indicate this subpopulation has declined since the 1980's (Turtle Expert Working Group, 1998). Documented loggerhead nesting in South Carolina appears to have remained stable or declined slightly from 1989-1998.

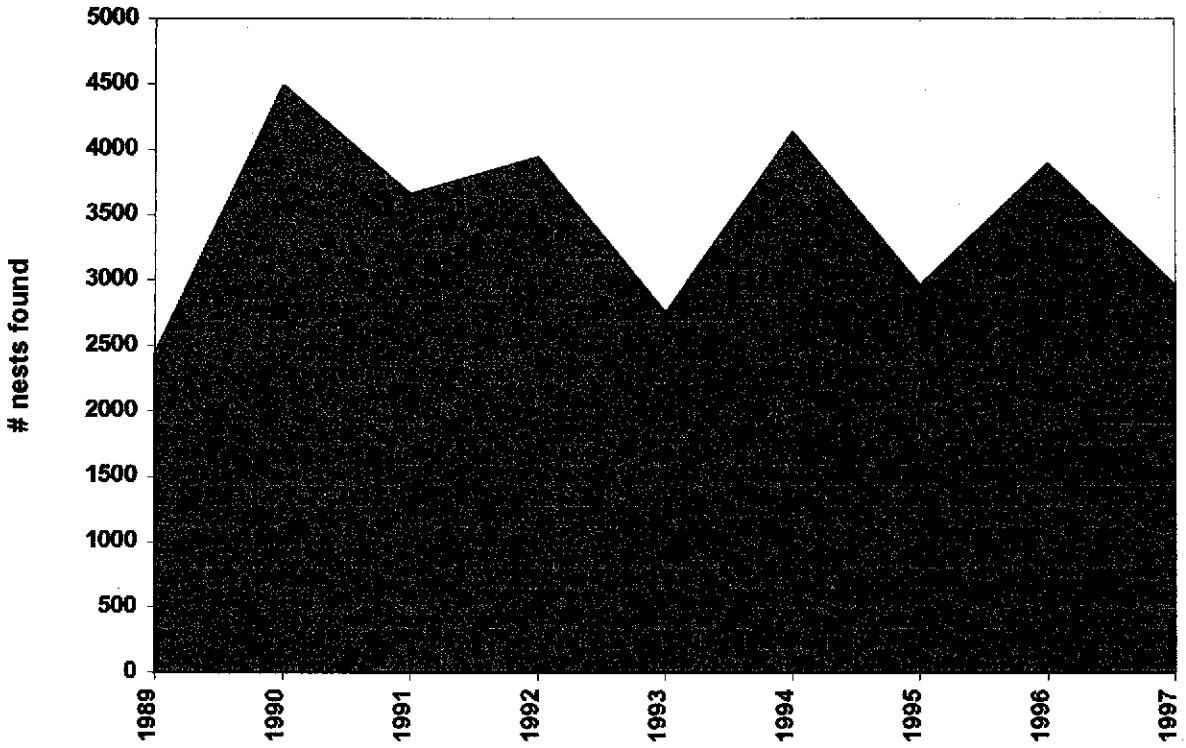

Figure 6. Annual fluctuations in loggerhead nests found in South Carolina, 1989-1997.

Cumberland Island (CUIS) and Georgia

Although monitoring of loggerhead sea turtle nesting in Georgia began in 1964, consistent, annual surveys were not coordinated on a statewide basis until 1989. Between 1989 and 1998, the number of loggerhead nests found in Georgia, excluding CUIS, ranged from 383 nests in 1993 to 1,120 nests in 1994. An average of 789 loggerhead nests were found each year during the 1989-1998 period.

CUIS has been monitored in its entirety since 1992. Since that time, the number of loggerhead nests found at CUIS has ranged from 92 nests in 1993 to 248 nests in 1994. On average, about 189 loggerhead nests were found at CUIS each year between 1992 and 1998. When compared to the remainder of the state, CUIS follows a similar pattern (Figure 7). Lows in loggerhead nesting are recorded in both areas in 1993. Peaks in nesting activity are noted in the state in 1991 and 1994; the peak for 1994 is also recorded for CUIS. The Northern Nesting Subpopulation includes loggerheads that nest in North Carolina, South Carolina, Georgia, and northeast Florida; current trends indicate this subpopulation has declined since the 1980's (Encalada et al., 1998; Turtle Expert Working Group, 1998). Since 1989, loggerhead nesting at CUIS and in Georgia (outside CUIS) appears to have remained relatively stable or increased slightly.

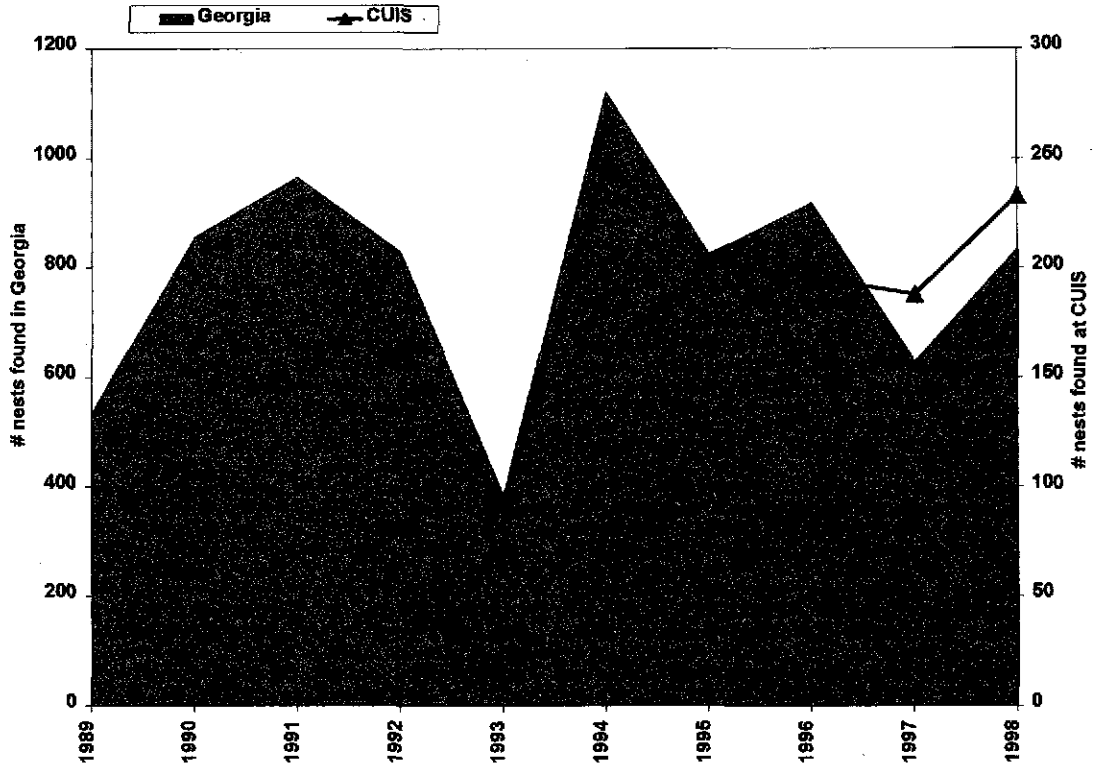

Figure 7. Annual fluctuations in loggerhead nests found at Cumberland Island National Seashore (CUIS) and in the remainder of Georgia, 1989-1998.

Canaveral (CANA), Gulf Islands - Florida District (GUIS-FL), and Florida

Since 1989, the number of loggerhead nests found on CANA has ranged from 2,702 in 1997 to 4,121 in 1995. On average, 3,545 nests were found on CANA each year between 1989 and 1998. At GUIS-FL, the number of loggerhead nests found since 1989 has ranged from 10 in 1991 to 42 in 1996. On average, about 28 nests are found at GUIS-FL each year. For the remainder of Florida, the number of loggerhead nests found between 1989 and 1997 varied from 46,376 in 1989 to 77,161 in 1995. On average, about 63,963 nests are found in Florida (excluding National Seashores) each year (Meylan et al., 1995; Florida Marine Research Institute, unpubl. data).

Figure 8 shows annual fluctuations in loggerhead nests found at CANA and in the remainder of Florida. The pattern of changes in the number of nests found at CANA, charted on the right axis, closely reflects the pattern of changes in the number of nests found in the remainder of Florida (excluding National Seashores), charted on the left axis. Both the state and CANA record two 4-5 year cyclic patterns in loggerhead nesting

between 1989 and 1997. Both areas documented two broad nesting peaks culminating in 1991 and 1995, although the second peak documented in the state is proportionally higher than the first. Both show low nesting periods occurring in 1989, 1993, and 1997. Although CANA documented an increase in nesting during the 1998 season, the number of loggerhead nests recorded in the remainder of Florida for 1998 is not yet available.

Nesting by the South Florida Nesting Subpopulation accounts for about 95% of loggerhead nesting in Florida each year (Meylan et al., 1995; Florida Marine Research Institute, unpubl. data). As a result, the overall pattern of loggerhead nesting in Florida is largely reflective of annual fluctuations in nesting in this single subpopulation. Loggerheads nesting at CANA are part of the South Florida Nesting Subpopulation, which is stable and may be increasing (Turtle Expert Working Group, 1998). From 1989-1997, loggerhead nesting at CANA appears to have remained relatively stable, while nesting in the remainder of the state appears to have increased. Loggerheads nesting at GUIS-FL are part of the Florida Panhandle Nesting Subpopulation; the status of this subpopulation is unknown (Turtle Expert Working Group, 1998). Figure 9 shows annual fluctuations in the number of loggerhead nests found at GUIS-FL and in the remainder of Florida. Loggerhead nesting at GUIS-FL appears to be erratic and annual fluctuations do not follow the pattern of the state. However, it appears that the overall numbers of loggerhead nests documented at both GUIS-FL and in the remainder of Florida increased from 1989-1997.

When compared to annual fluctuations in nesting only in the South Florida Nesting Subpopulation, nesting at CANA still follows the same pattern of changes during the 1989-1997 period (Figure 10). Overall, from 1989-1997, loggerhead nesting at CANA appears to have remained relatively stable, while nesting by the South Florida Nesting Subpopulation appears to have increased. When compared to annual fluctuations in nesting only in the Florida Panhandle Nesting Subpopulation, nesting at GUIS-FL still does not follow the same pattern of changes during the 1989-1997 period (Figure 11). Although nesting documented at GUIS-FL appears to be erratic, overall nesting both at GUIS-FL and by the Florida Panhandle Nesting Subpopulation appears to have increased from 1989-1997. However, the trend detected for the Florida Panhandle Nesting Subpopulation is likely due to an increase in survey effort in the Florida Panhandle.

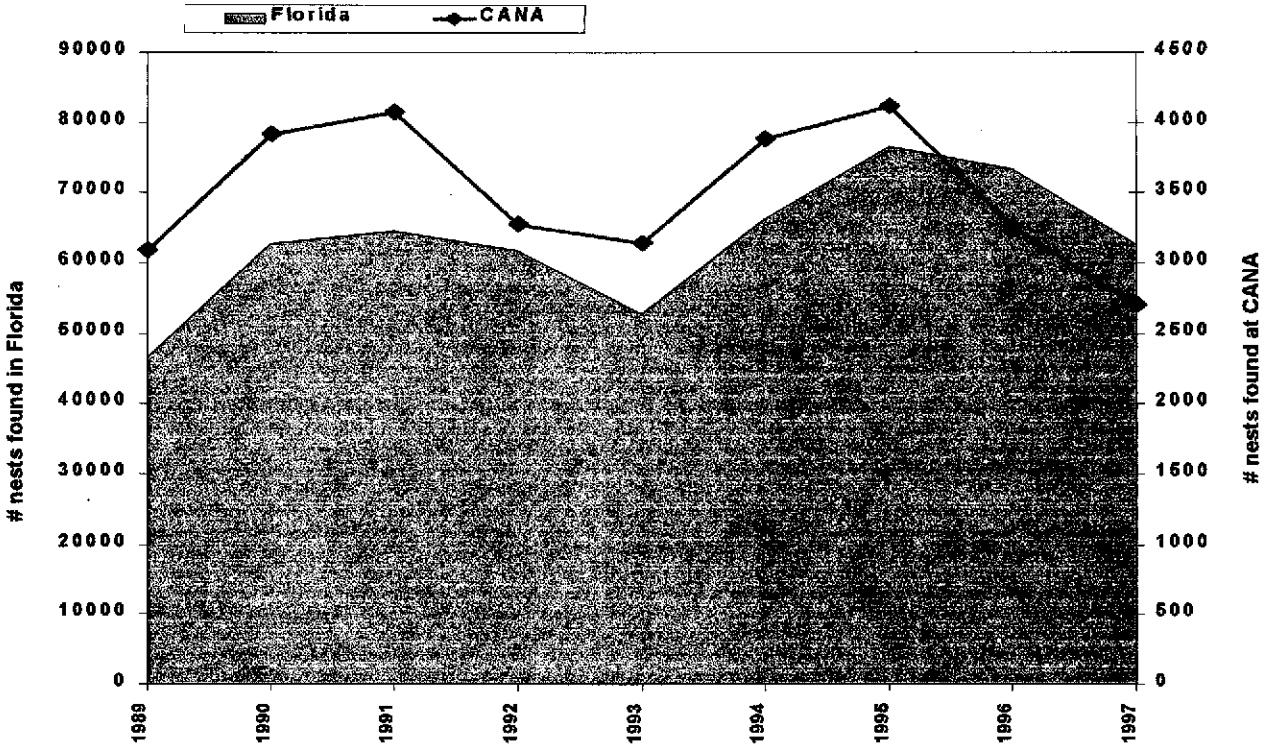

Figure 8. Annual fluctuations in loggerhead nests found at Canaveral National Seashore (CANA) and in Florida (excluding National Seashores), 1989-1997.

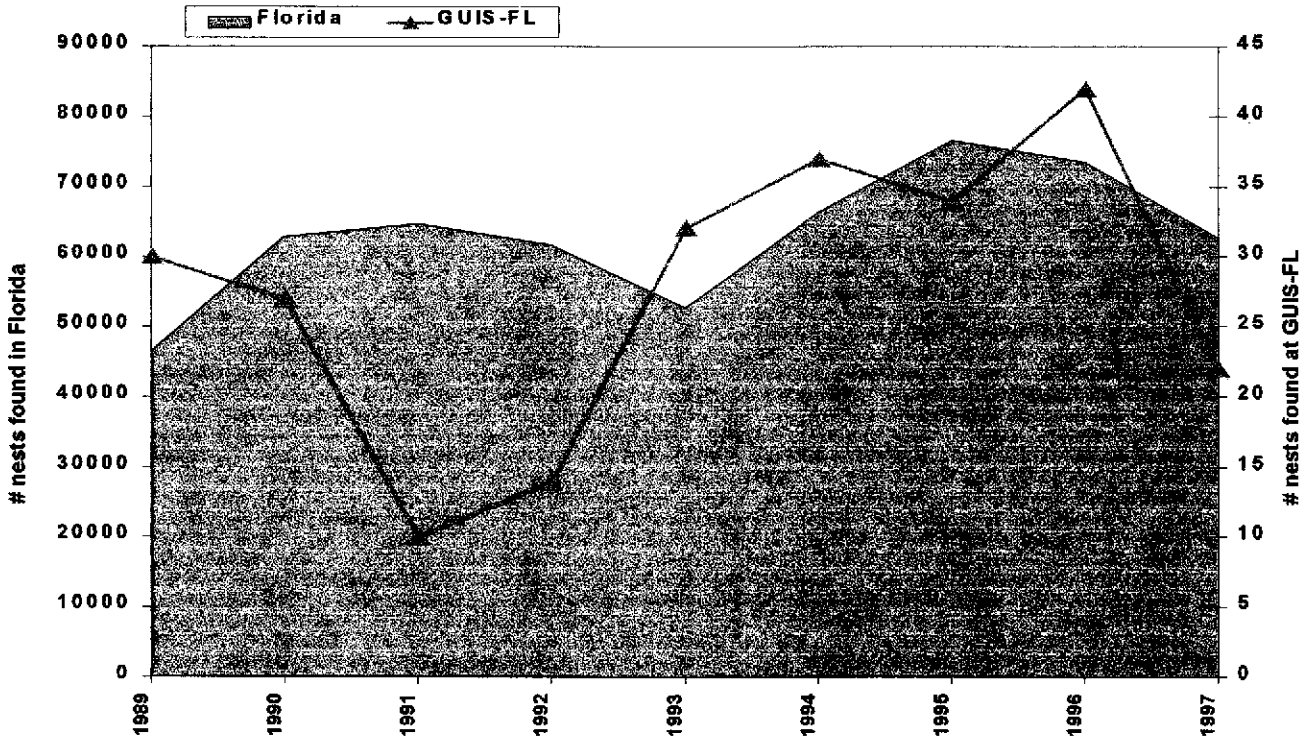

Figure 9. Annual fluctuations in loggerhead nests found at Gulf Islands National Seashore, Florida District (GUIS-FL) and in Florida (excluding National Seashores), 1989-1997.

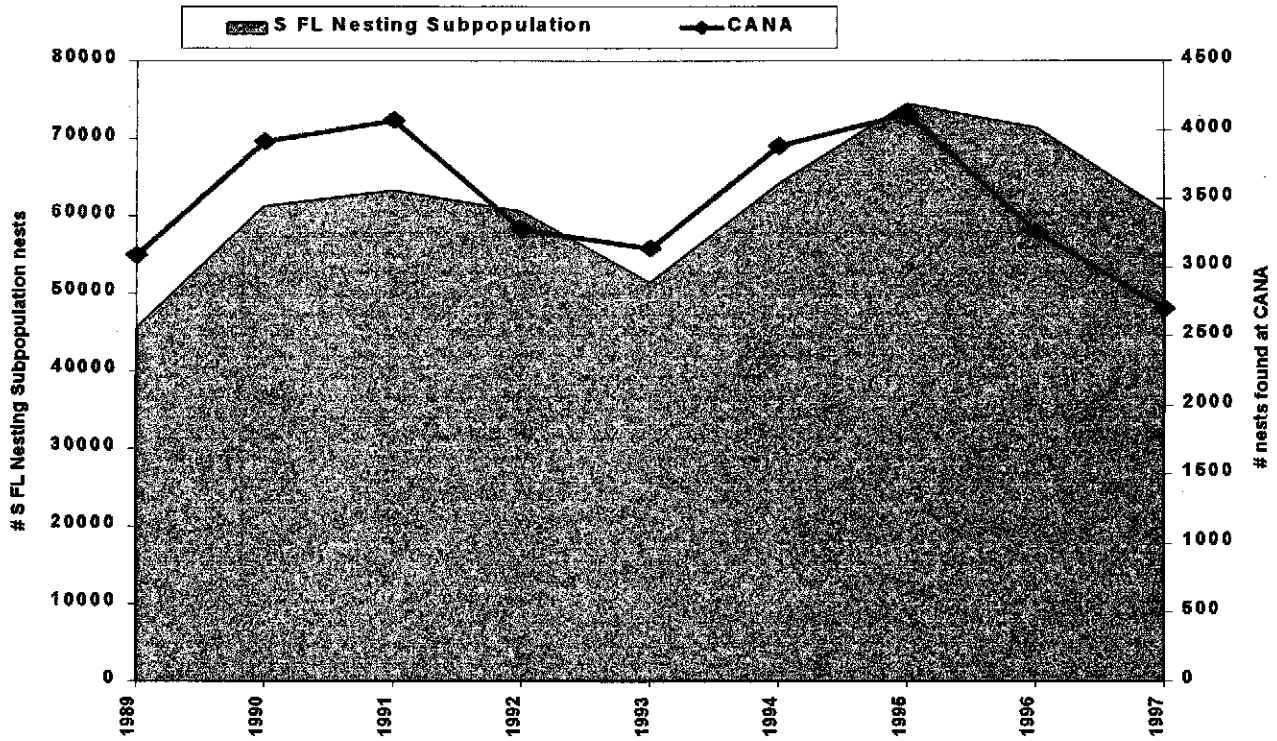

Figure 10. Annual fluctuations in loggerhead nests found at Canaveral National Seashore (CANA) and the remainder of the South Florida Nesting Subpopulation, 1989-1997.

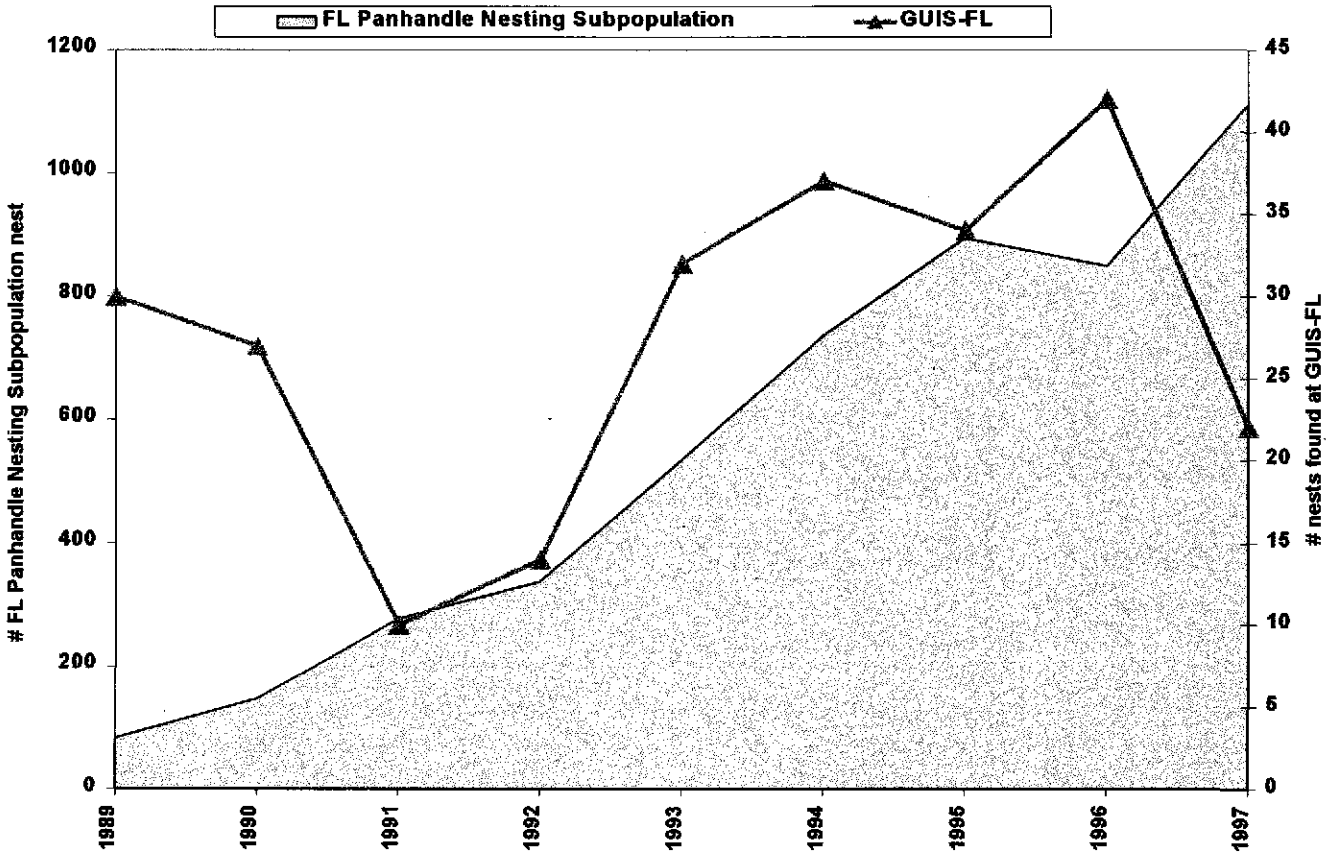

Figure 11. Annual fluctuations in loggerhead nests found at Gulf Islands National Seashore, Florida District (GUIS-FL) and the remainder of the Florida Panhandle Nesting Subpopulation, 1989-1997.

Gulf Islands - Mississippi District (GUIS-MS), Alabama, Mississippi, and Louisiana

Sea turtle nests were found 7 of 9 years at GUIS-MS during the 1990-1998 period. All nests found were loggerheads. The number of nests found during a single monitoring season ranged from zero to nine, with an average of three nests found each year. In 1998, all documented nests at the seashore were lost to Hurricane Georges. Apparently, GUIS-MS conducts the only regular sea turtle nest monitoring program in Mississippi. Sea turtle nesting is not monitored on a statewide basis in Louisiana or Alabama. However, nine loggerhead nests were reported for Louisiana from 1989-1998, including eight in 1989 and one in 1990.

Documented loggerhead nesting at GUIS-MS was erratic during the 1989-1998 period, with no discernible pattern. Although GUIS-FL also recorded erratic annual fluctuations in loggerhead nesting, the two districts of this National Seashore did not document the same annual changes in nesting levels (Figure 12).

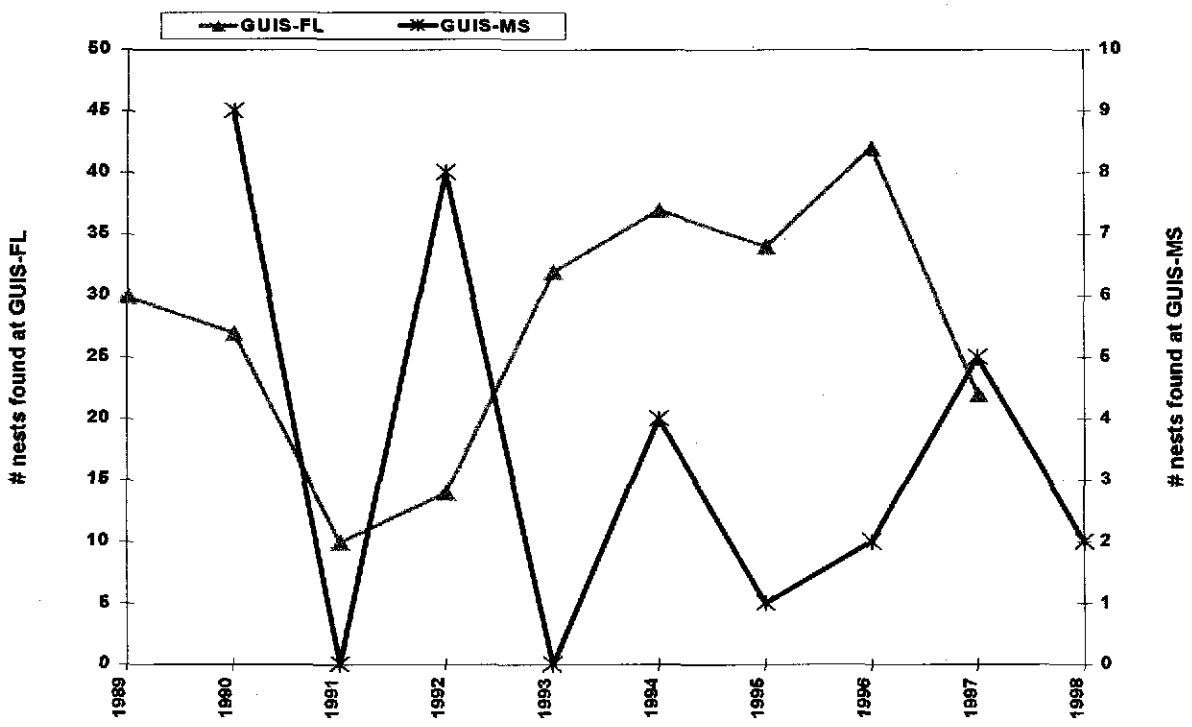

Figure 12. Annual fluctuations in loggerhead nests found at Gulf Islands National Seashore, Mississippi District (GUIS-MS) and at Gulf Islands National Seashore, Florida District (GUIS-FL), 1989-1998.

Padre Island (PAIS) and Texas

Loggerhead nests were found at PAIS in 6 of 10 years during the 1989-1998 period. The number of nests found during a single monitoring season ranged from zero to four, with an average of one nest found each year. PAIS conducts the only regular sea turtle nest monitoring program in Texas. Two loggerhead nests were found on other Texas beaches (outside PAIS) in 1996.

Comparisons among National Seashores

Loggerhead nesting activity varies considerably among National Seashores included in this study. For the four National Seashores located along the Atlantic coast (Appendix A), loggerhead nesting reported generally decreased the further north the National Seashore was located. CANA, part of the South Florida Nesting Subpopulation of loggerheads, documents substantially higher levels of loggerhead nesting activity than any other seashore in the southeastern U.S., with an average of 3,545 loggerhead nests found each year during the 1989-1998 period. CUIS, located in the Northern Nesting Subpopulation range, recorded an average of 189 loggerhead nests each year between 1989 and 1998. At CALO, which is also part of the Northern Nesting Subpopulation, an average of about 110 nests per year were documented between 1989 and 1998. At CAHA, the National Seashore located the furthest north, an average of 55 loggerhead nests were found each year between 1989 and 1997.

About 28 loggerhead nests were found each year between 1989 and 1997 at GUIS-FL, which is part of the Florida Panhandle Nesting Subpopulation. Between 1989 and 1998, about three loggerhead nests were found each year at GUIS-MS and about one loggerhead nest was found each year at PAIS.

The three distinct loggerhead nesting subpopulations in the U.S. may not follow the same trends in nesting activity. Consequently, comparisons of annual fluctuations in loggerhead nesting among seashores are confined to National Seashores located in the same nesting region. CANA is the only National Seashore located in the South Florida Nesting Subpopulation region. GUIS-FL is the only National Seashore located in the Florida Panhandle Nesting Subpopulation region. Therefore, no comparisons are made

of loggerhead nesting involving these two seashores. In addition, documented loggerhead nesting at PAIS is too sporadic for comparisons to other seashores.

Loggerhead nesting activity at CAHA, CALO, and CUIS occurs as part of the Northern Nesting Subpopulation of loggerheads. Nesting levels at these seashores are compared in Figure 13. All three seashores document a peak in loggerhead nesting in 1994. Trends in nesting numbers for CAHA and CALO correspond well, showing two cycles of peaks in nesting between 1989 and 1997. CAHA, CALO, and CUIS also show a rise in nesting levels in 1998. CUIS seems to follow a different pattern in 1992 and 1993 when compared to CAHA and CALO. However, CUIS is located much further south in comparison to CALO and CAHA. Additionally, all three seashores generally follow the same nesting pattern as the state in which they are located. Differences between CUIS and the other two seashores may result at least in part from regional variations in nesting among the Northern Nesting Subpopulation of loggerheads.

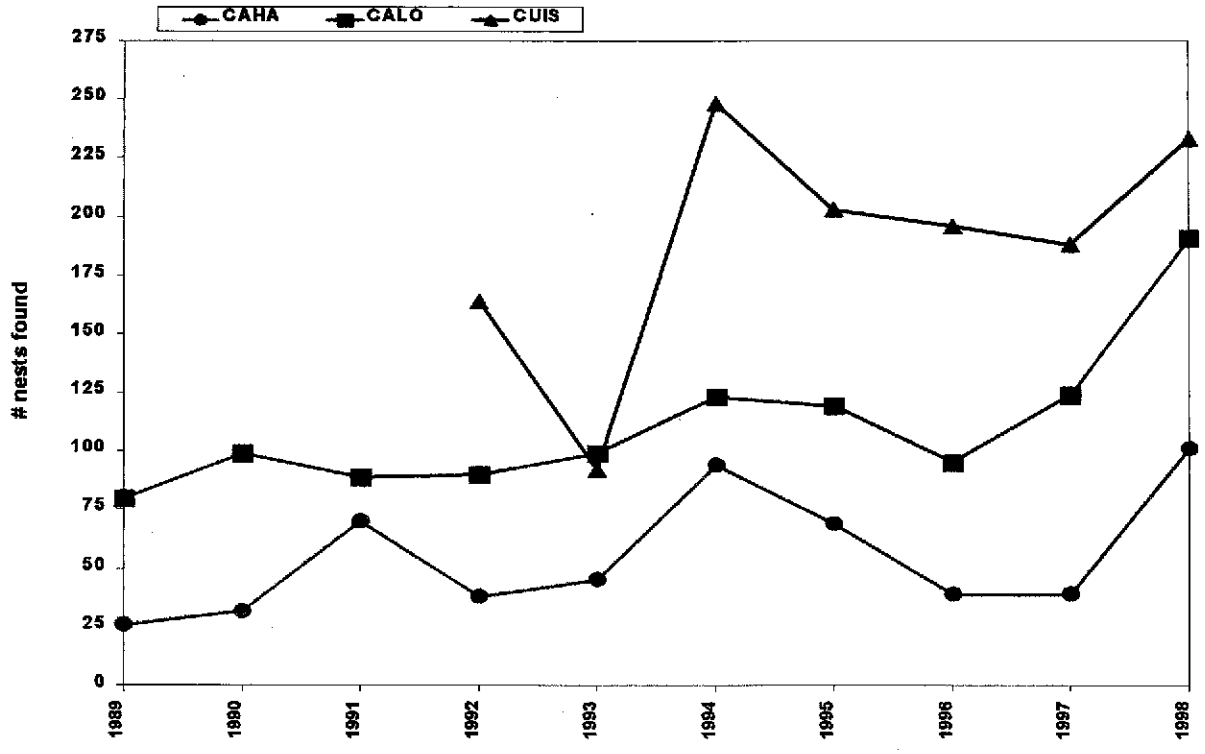

Figure 13. Annual fluctuations in loggerhead nests found at Cape Hatteras National Seashore (CAHA), Cape Lookout National Seashore (CALO), and Cumberland Island National Seashore (CUIS), 1989-1998.

Annual Fluctuations and Trends in Green Nesting

Genetic evidence suggests that, like loggerheads, green sea turtles return to nest on their natal beach (Bowen and Karl, 1997). To date, no genetically distinct nesting assemblages of green sea turtles have been recognized in the United States. In comparison to loggerheads, green sea turtles deposit far fewer nests in the southeastern U.S. However, most monitoring programs do not conduct surveys for sea turtle nests for the entire green sea turtle nesting season (Meylan et al., 1995; Florida Marine Research Institute, unpubl. data). Accordingly, the number of green turtle nests reported is likely underrepresented.

Regular nesting of this species does occur in the southeastern U.S., primarily in Florida. Regular nesting activity of green sea turtles also occurs in North Carolina, but at much lower numbers than in Florida. During the study period (1989-1998), five green sea turtle nests were documented in South Carolina. No green sea turtle nests were documented in Georgia from 1989-1998, although a few were recorded there prior to 1989 and a false crawl was reported in 1998. In Alabama, green turtle nests were reported in 1994 and 1995, but were not confirmed. No green sea turtle nesting was documented in Mississippi or Louisiana. In Texas, one green nest was found in 1987 and five nests were found in 1998, all at PAIS. Because regular nesting has been documented only in North Carolina and Florida, green sea turtle nesting patterns were examined only in North Carolina, Florida, and the National Seashores located in those states.

Cape Hatteras (CAHA), Cape Lookout (CALO), and North Carolina

Green sea turtle nests have been found at CAHA during five monitoring seasons between 1989 and 1998, with a maximum of five nests found in one season. At CALO, green sea turtle nests were found during three monitoring seasons between 1989 and 1998, with a maximum of six nests found in one season. In the remainder of North Carolina, green sea turtle nests were found 8 of 10 years between 1989 and 1998, with a maximum of nine nests found in a single monitoring season.

Although very few green sea turtle nests were found, a distinct nesting pattern emerges (Figure 14). Green sea turtle nesting activity appears to alternate each year between no nesting or nesting in very low numbers and peak nesting. Both National

Seashores follow the pattern documented in the remainder of the state very closely, albeit in lower numbers. This alternating pattern continued at CAHA, at CALO, and in the rest of North Carolina in 1998.

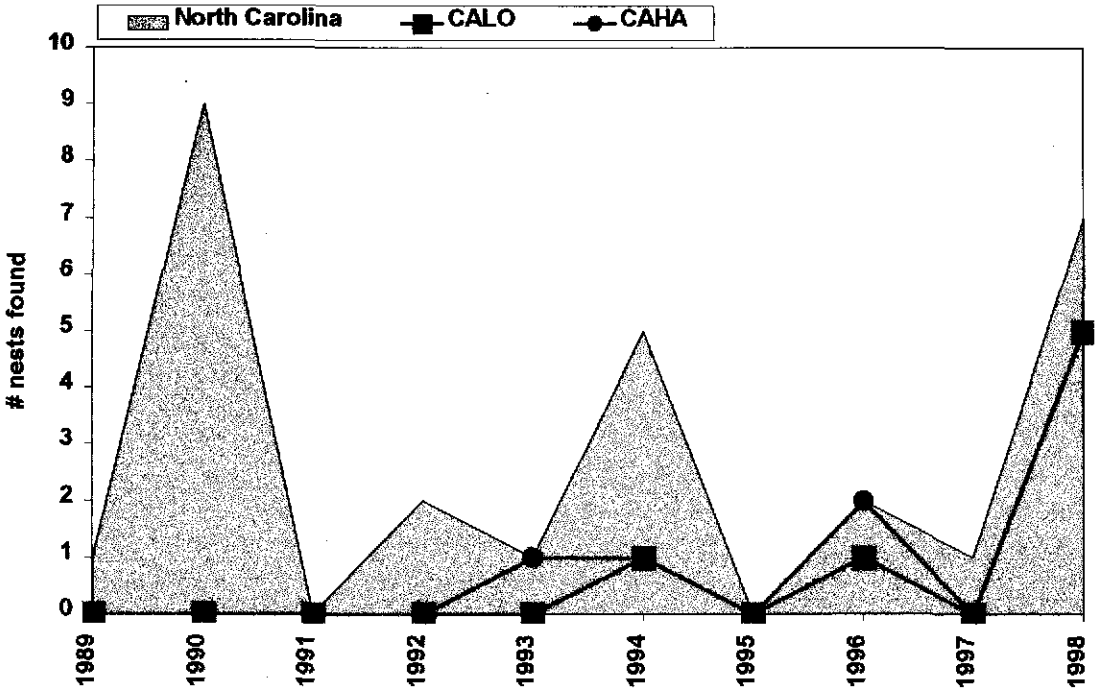

Figure 14. Annual fluctuations in green turtle nests found at Cape Hatteras National Seashore (CAHA), at Cape Lookout National Seashore (CALO), and in the rest North Carolina, 1989-1998.

Canaveral (CANA), Gulf Islands - Florida District (GUIS-FL), and Florida

Most documented green sea turtle nesting in the southeastern U.S. occurs in Florida, the only state where green turtle nests are found every year. The number of green sea turtle nests found (1989-1997) on Florida beaches, excluding National Seashores, varied from 407 in 1993 to 3,305 in 1994 (Meylan et al., 1995; Florida Marine Research Institute, unpubl. data). Excluding National Seashores, an average of 1,457 green sea turtle nests were found statewide each year between 1989 and 1997. The vast majority of these nests were found in the southeast region of the state, where most loggerhead nests were also found. In fact, green turtle nests found in this region accounted for 94-100% of all nests found for this species in Florida each year.

Between 1989 and 1998, the number of green sea turtle nests found at CANA during a season varied from 21 in 1997 to 426 in 1998. On average, 166 nests were found each year. When compared, annual nesting levels at CANA and in the remainder of Florida closely follow the same alternating pattern (Figure 15). In both areas, green sea turtle nesting fluctuated between relatively high numbers and relatively low numbers. Both areas show an increase in peak nesting levels every other year up to 1994, followed by a decline in peak nesting levels in 1996. Overall, from 1989-1997, green sea turtle nesting appears to have increased slightly both at CANA and in the remainder of Florida.

CANA is located within the region where most green sea turtle nesting occurs. GUIS-FL, however, is located in the northwest region of the state, where much lower numbers of green turtle nests are found. Between 1989 and 1997, GUIS-FL documented green sea turtle nesting only in 1994, 1995, and 1996. A maximum of three green sea turtle nests was found in one season. Despite the substantial difference in the magnitude of green turtle nests found, GUIS-FL still follows the same alternating pattern documented in the remainder of Florida (Figure 16).

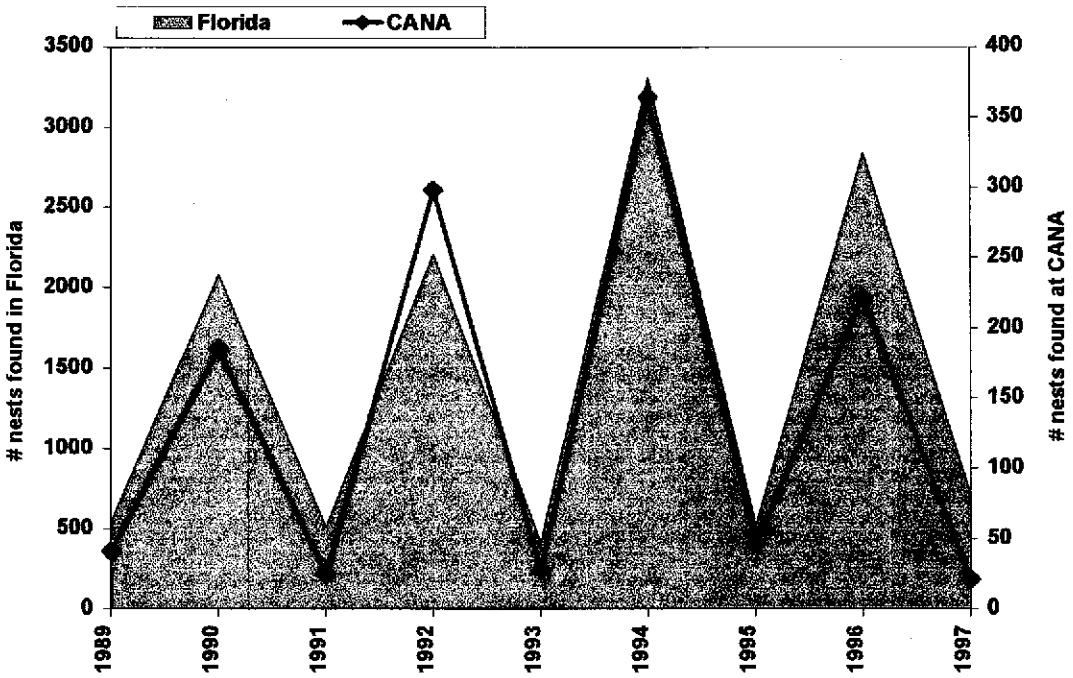

Figure 15. Annual fluctuations in green turtle nests found at Canaveral National Seashore (CANA) and in Florida (excluding National Seashores), 1989-1997.

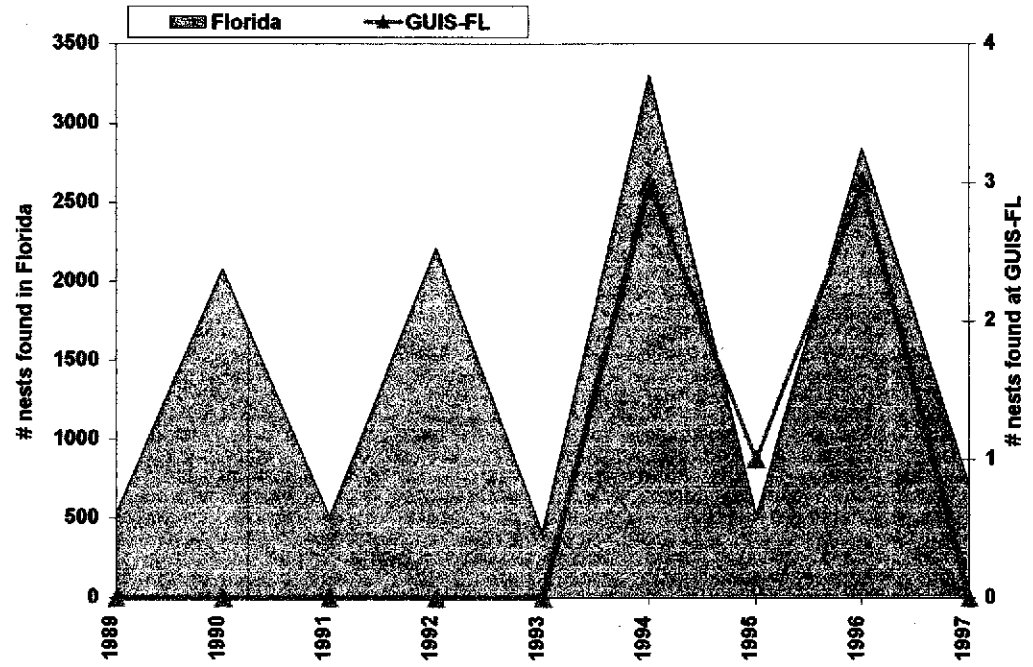

Figure 16. Annual fluctuations in green turtle nests found at Gulf Islands National Seashore, Florida District (GUIS-FL) and in Florida (excluding National Seashores), 1989-1997.

Comparisons among National Seashores

The distinct alternating pattern of green sea turtle nesting is apparent at all seashores where green turtle nests are found, in both North Carolina and Florida. Even when the numbers of nests found differ substantially in magnitude, the pattern is consistent (Figure 17). All four seashores documented peaks in green turtle nesting in 1994 and 1996. At all seashores, peaks in nesting were followed by markedly lower nesting levels the next year. At CAHA, nesting levels remained stable in 1993-1994. However, this may be a result of the small number of nests found at this seashore. In 1998, the alternating pattern continued at CANA, at CALO, and at CAHA. Nesting information for 1998 for GUIS-FL is not yet available.

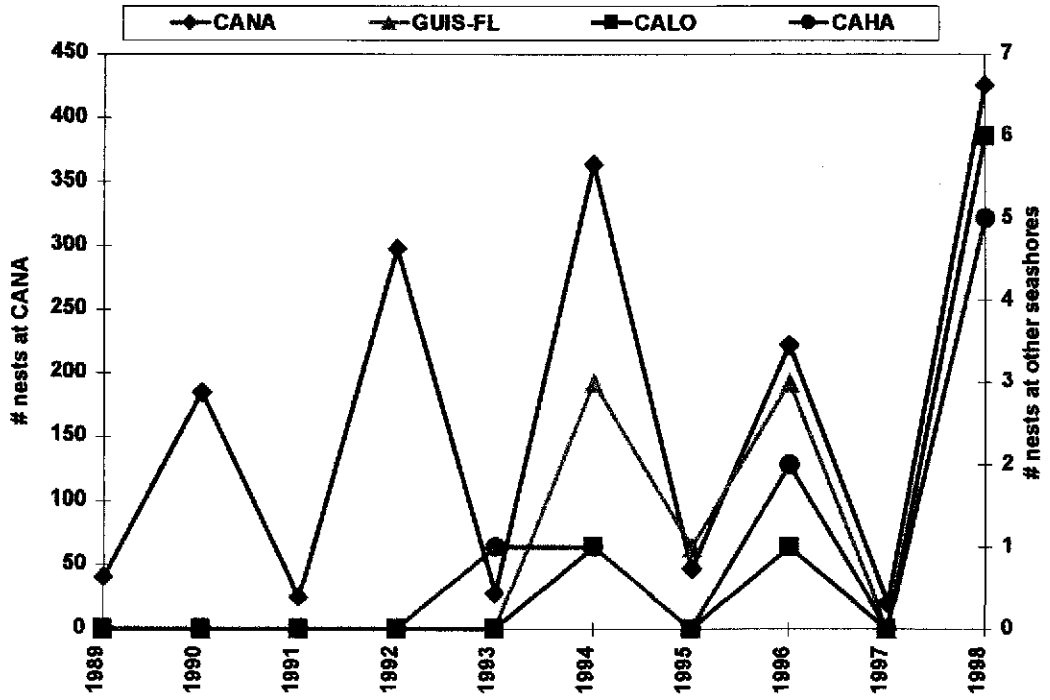

Figure 17. Annual fluctuations in green turtle nests found at Canaveral National Seashore (CANA), Gulf Islands National Seashore, Florida District (GUIS-FL), Cape Hatteras National Seashore (CAHA), and Cape Lookout National Seashore (CALO), 1989-1998.

Annual Fluctuations and Trends in Other Sea Turtle Nesting

Other sea turtle species are known to return to the same beaches each year to nest (National Research Council, 1990; Miller, 1997). Like loggerheads and greens, hawksbill sea turtles apparently return to their natal beach as adult nesters (Bowen and Karl, 1997). The numbers of hawksbill, leatherback, and Kemp's ridley nests found in the southeastern U.S. each year is much lower than the numbers of loggerhead and green sea turtle nests found. However, it is important to note that the nesting seasons for these other species do not coincide precisely with the nesting seasons for loggerhead and green turtles. Most monitoring efforts are designed to detect nesting by loggerheads and are conducted during the loggerhead nesting season, although a few programs extend their monitoring season in an attempt to also detect green turtle nesting. Nests laid by hawksbill, leatherback, and Kemp's ridley turtles, either before or after the loggerhead nesting season, may never be found or documented. Additionally, beach workers are less experienced at encountering nesting by the other species and hence crawls and hatchlings of these other species could be misidentified. Hence, numbers of hawksbill, leatherback, and Kemp's ridley nests reported here should be considered minimum estimates of nesting by them.

Considering the eight states and six National Seashores collectively, the descending order of abundance for the other nests found is leatherbacks, Kemp's ridleys, and hawksbills. However, considering just the six National Seashores collectively, Kemp's ridley nests were documented more frequently than were leatherback or hawksbill nests (Appendix C).

Between one and three hawksbill sea turtle nests were found in Florida during 6 of 9 years between 1989 and 1997 (Meylan et al., 1995; Florida Marine Research Institute, unpubl. data). However, no hawksbill nests were found at CANA or GUIS-FL during this period. One hawksbill nest was found in Texas, at PAIS, in 1998. No other National Seashores in the region have documented nesting by hawksbills.

Florida is the only state where leatherback sea turtles nest on a regular basis. The number of leatherback nests found each year between 1989 and 1997 varied from 98 in 1989 to 397 in 1997. An average of 201 leatherback nests were found each monitoring

season (Meylan et al., 1995; Florida Marine Research Institute, unpubl. data). At CANA, zero to five leatherback nests were found each year between 1989 and 1998. To date, no leatherback nests have been documented at GUIS-FL. Leatherback nesting elsewhere in the southeastern U.S. is irregular. One leatherback nest was documented in 1998 at CAHA in North Carolina. Three leatherback nests were reported for Georgia for 1996. Leatherback nests were documented at PAIS in the 1930's and 1940's, but none have been found since that time.

Leatherback nesting at CANA generally follows the same pattern as leatherback nesting in the remainder of the state (Figure 18). Both areas document a drop in nesting levels during 1992-1993, followed by an increase in nesting levels in 1994. Both areas show peaks in leatherback nesting in 1991, 1994 and 1997. Overall, both CANA and the remainder of Florida show an apparent increase in nesting levels of leatherback sea turtles during the 1989-1997 period.

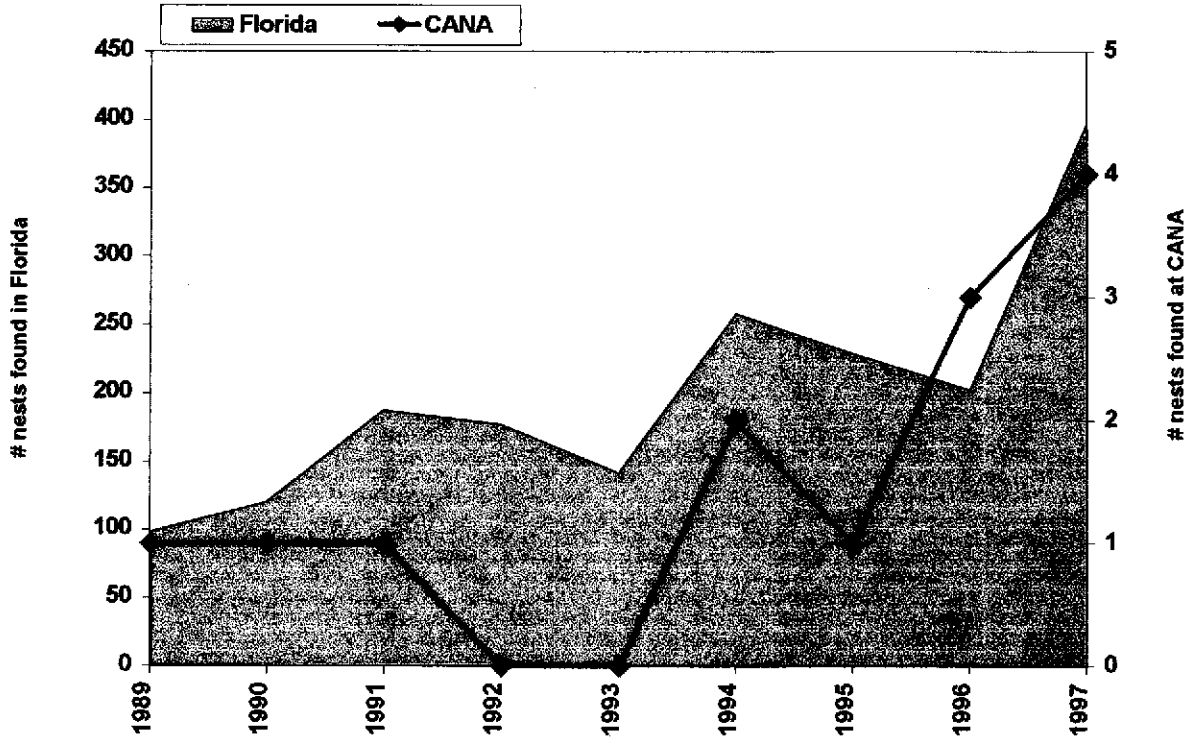

Figure 18. Annual fluctuations in leatherback turtle nests found at Canaveral National Seashore (CANA) and in the remainder of Florida, 1989-1997.

Kemp's ridley sea turtle nesting in the southeastern U.S. is limited almost entirely to south Texas. From 1989-1998, and during the previous 40 years, more confirmed Kemp's ridley nests were located at PAIS than at any other location in the U.S. (Shaver and Caillouet, 1998). One Kemp's ridley nest was reported in North Carolina in 1991, one in South Carolina in 1992, and five in Florida from 1989 to 1998. No other Kemp's ridley nests have been documented in the U.S. outside of Texas.

During the period of this study (1989-1998) the number of Kemp's ridley nests detected at both PAIS and elsewhere in Texas increased, beginning in about 1994-1995 (Figure 19) (Shaver and Caillouet, 1998). The annual maximum number of Kemp's ridley nests found at PAIS was nine, recorded in 1998. The annual maximum number of Kemp's ridley nests found in the remainder of Texas was four, recorded in 1998. However, additional Kemp's ridley nests probably went undetected at PAIS and elsewhere in Texas. PAIS monitoring coverage has increased in very recent years but is still insufficient to ensure detection of all nesting. Additionally, no state-coordinated monitoring program for nesting is conducted in Texas. Virtually all nests found outside of PAIS were initially reported by and then investigated and confirmed by biologists.

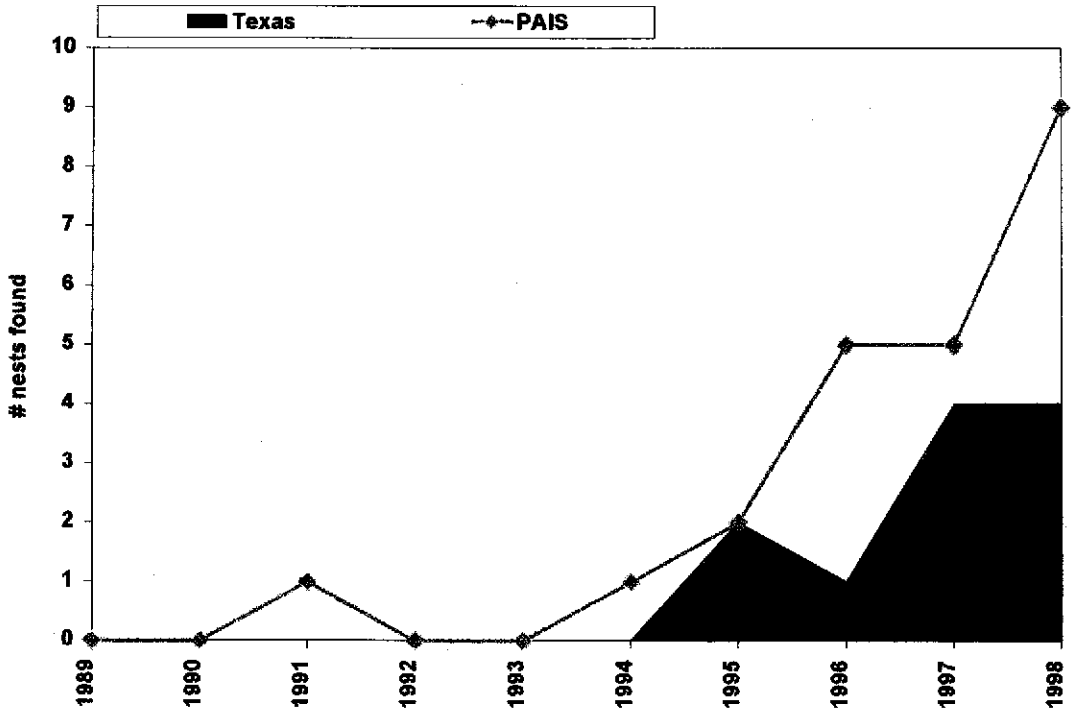

Figure 19. Annual fluctuations in Kemp's ridley turtle nests found at Padre Island National Seashore (PAIS) and in the remainder of Texas, 1989-1998.

From 1978-1988, a joint Mexico-U.S. endeavor transported 22,507 Kemp's ridley eggs from Rancho Nuevo, Mexico, to PAIS, Texas. These eggs were incubated and the hatchlings were released at PAIS in the hope of establishing a secondary nesting colony of Kemp's ridley sea turtles at PAIS, as a safeguard against extinction. Through 1998, five turtles released at PAIS through this experimental project have been documented as adults returning to southern Texas to nest.

Kemp's ridley turtles currently found nesting in south Texas are likely a mixture of turtles from the project to establish a secondary nesting colony and turtles from the wild stock. The recent increase in the number of Kemp's ridley nests detected on the Texas coast could be a result of increased nesting, increased detection efforts by PAIS staff, increased awareness and reporting by the public, or a combination of these factors.

Influences on Sea Turtle Nesting

Sea turtles face a wide array of challenges to their survival and reproduction. Human activities impact every stage of their life cycle, including nesting (National Research Council, 1990; National Marine Fisheries Service and U.S. Fish and Wildlife Service, 1991a; National Marine Fisheries Service and U.S. Fish and Wildlife Service, 1991b; U.S. Fish and Wildlife Service and National Marine Fisheries Service, 1992; Lutcavage et al., 1997; Turtle Expert Working Group, 1998). A thorough treatment of factors impacting sea turtle populations is beyond the scope of this project. Influences examined in this report are limited to those factors impacting reproductive success. These factors include impacts on adult females, impacts on incubating eggs, and impacts on emerging hatchlings. Information on the relative impact and importance of these factors was provided directly by the biologists working on sea turtle monitoring projects incorporated in this study.

Impacts on adult females

Changes in nesting habitat can hinder or prevent adult female nesting attempts. Nesting habitat can disappear or become inaccessible as erosion occurs. Dredging can kill adult females. Armoring can disrupt natural flows of sand between nesting beaches,

resulting in depletion of or disturbance to nesting habitat (National Research Council, 1990; National Marine Fisheries Service and U.S. Fish and Wildlife Service, 1991a; National Marine Fisheries Service and U.S. Fish and Wildlife Service, 1991b; Lutcavage et al., 1997; Turtle Expert Working Group, 1998).

Erosion of nesting beaches – Erosion of nesting beach habitat is a serious threat at many locations in the southeastern United States and may be an important factor in the decline of nesting at some locales. At CAHA, erosion is an increasing problem. An artificial dune line created in the 1930's has formed a barrier that is no longer moving with the island. The result is an increasingly narrow beach and disappearing nesting habitat. Beach renourishment occurs on nesting beaches in North Carolina, South Carolina, Georgia, Florida, and Alabama. In these areas, beach bulldozing, sand bagging, and sand fencing have an influence on sea turtle nesting activities. Sand fences in some areas of North Carolina are constructed in front of the primary dune line, preventing access by nesting females. Sand fences constructed using long sections with few openings can result in a higher incidence of false crawls, and can trap adult nesting females. In South Carolina, some nesting beaches are erosional, resulting in inadequate dune lines. At CUIS, eroding dunes have formed escarpments that have reduced nesting in some areas. Erosion is a special concern throughout Georgia, where nesting habitat is highly variable. Armoring is also a problem on some beaches. Beach erosion also occurs at CANA, and can be a problem in some years. Sea walls are a significant problem in Florida.

Human development and recreation on nesting beaches - Human development and recreation on nesting beaches can have an adverse effect on adults coming in to nest. Shoreline development can deter adults coming in to nest. Artificial lighting disrupts nesting behavior and can reduce nesting activity. Vehicle use on the beach can disturb nesting females. Night use of the beach can result in aborted nesting attempts. Additionally, adult turtles can be caught on recreational fishing lines or hit by boats (National Marine Fisheries Service and U.S. Fish and Wildlife Service, 1991a; National Marine Fisheries Service and U.S. Fish and Wildlife Service, 1991b; Lutcavage et al., 1997).

At CAHA, artificial lighting has become a major problem as increasing development in nearby areas has caused indirect lighting of nesting beaches. In South Carolina, some beaches have been developed, although many of these areas still have adequate nesting habitat. Lights are also a problem in some areas in South Carolina. At CUIS, indirect lighting from adjacent islands may affect nesting activities, particularly on the south end of the island. In Georgia, many false crawls can be directly attributed to hotel lighting. Adult nesters have become disoriented by artificial lighting on some Georgia beaches. Night use of the beach can be heavy in some areas, and has been shown to be detrimental to sea turtle nesting activities in Georgia. At CANA, nearby lighting from Cape Canaveral's space program can be intense, although no impacts on nesting adults have been documented. GUIS-FL has a developed shoreline, with a road constructed very close to some nesting beaches. This road prevents natural development of a primary dune line in some areas at GUIS-FL. Lighting from the park and the mainland has a noticeable influence on nesting activities at GUIS-FL. Adult injury and mortality from boat hits is also a concern at GUIS-FL. In 1997, eight adult female loggerheads were found dead at GUIS-FL with boat injuries, from the propeller or the hull. Stranded adults have also been found at GUIS-FL with fishing line. Artificial lighting is a major problem in Florida as well, where shoreline development is extensive. Indirect lighting from nearby development and night use of nesting beaches also occurs at GUIS-MS, but the impact of these activities on nesting has not been documented.

Vehicles on the beach are an increasing problem where allowed at CAHA and, to a lesser extent, at CALO. Vehicles are allowed at CUIS throughout the seashore and can interrupt nesting activities. However, driving on the beach after dark has been eliminated at CUIS beginning in 1998. Vehicles on the beach are a problem where allowed in Florida although potential negative impacts have been minimized and/or mitigated in Volusia and Gulf counties through implementation of protective measures required or recommended by the U.S. Fish and Wildlife Service, respectively. In addition, an increasing number of visitors drive Florida's beaches at night, specifically looking for and intentionally shining lights on nesting sea turtles. Vehicles are permitted access to nearly the entire Gulf shoreline of PAIS at all times. Although PAIS staff documented one loggerhead sea turtle that emerged at night and was deterred from nesting due to the

presence of a nearby vehicle, vehicle impacts to daytime-nesting Kemp's ridley sea turtles have not been documented at PAIS. However, if Kemp's ridley nesting continues to increase, then the significance of this threat could also increase.

Dredging - Dredging is a concern along the entire Georgia coast, although sea turtle monitors have been placed on every dredge. A recent proposal to deepen the Savannah River has prompted concern for the impacts of channelization, as well.

Commercial fishing - Commercial fishing can have a major impact on adult sea turtles, including females. Shrimp trawling accounts for more sea turtle mortality than all other human sources combined (National Research Council, 1990; National Marine Fisheries Service and U.S. Fish and Wildlife Service, 1991a; National Marine Fisheries Service and U.S. Fish and Wildlife Service, 1991b; U.S. Fish and Wildlife Service and National Marine Fisheries Service, 1992; Lutcavage et al., 1997; Turtle Expert Working Group, 1998). Shrimp trawling can have a significant impact on adult females as they move toward shore during the nesting season.

The implementation of mandatory turtle excluder devices (TEDs), begun in 1987 and fully enacted in 1994, has apparently reduced loggerhead mortality in South Carolina (Lutcavage et al., 1997). However, despite mandatory use of TEDs in Texas, there continues to be an association between shrimping effort in Gulf waters and strandings of turtles on Gulf beaches. The mortality of adult Kemp's ridleys in waters off southern Texas nesting beaches, likely due primarily to incidental capture in shrimp trawls, is a significant threat to the success of efforts to increase Kemp's ridley nesting at PAIS (Shaver and Caillouet, 1998). Repeated captures of sea turtles during periods of intense shrimping effort can result in mortality even when TEDs are used (Lutcavage et al., 1997). Recent proposals to mandate use of bycatch reduction devices (BRDs) to reduce incidental capture of other marine species may also reduce sea turtle mortality by reducing bycatch, which is consumed by sea turtles.

Currently, shrimp trawling is allowed year-round in federal waters along U.S. Atlantic and Gulf coast waters. Commercial food shrimp trawling in state waters is regulated on a state-by-state basis (Appendix E). With the exception of Mississippi and Texas, shrimp trawling in inshore state waters, which include bays, sounds, channels, and estuaries, is not allowed or is very restricted. Shrimp trawling in offshore or nearshore

state waters, which include Atlantic and Gulf coast waters from 0-9 nautical miles in Texas and on the western coast of Florida and from 0-3 miles in other southeastern states, is regulated generally on a seasonal basis.

Commercial food shrimp trawling is generally prohibited during a 2-3 month period in the summer in portions of or all of nearshore state waters in most states included in this study. Exceptions include North Carolina and Louisiana, which are open to shrimp trawling year-round, and South Carolina, which is closed to shrimp trawling approximately from January through June of each year.

The short summer closure of shrimp trawling in most southeastern states is designed to benefit the shrimp fishery itself, allowing small shrimp to mature and grow. Because this closure generally occurs during part of the sea turtle nesting season, adult females returning to mate and nest during this period are afforded protection from incidental capture. However, this summer closure encompasses only a small portion of the sea turtle nesting season.

Impacts on incubating eggs

Inundation of sea turtle nests is a consistent source of loss in the southeastern U.S. Hurricanes and tropical storms cause tidal surges that flood incubating eggs and drown developing embryos. At CAHA, many nests from 1998 were washed out by Hurricane Bonnie. At CALO, flooding is currently the greatest threat to sea turtle nesting success. In North Carolina, at least 315 loggerhead nests documented during the 1996 monitoring season were lost to hurricane tidal surges and flooding. Tidal inundation affected at least 478 nests documented in North Carolina during the 1989-1997 period. In South Carolina, inundation is a problem in many areas. At CANA, high tides from storm surges have caused problems in some years. At GUIS-FL, sea turtle nests have been lost to tropical storms and hurricanes nearly every year, at least since 1994. More than half of all nests found at GUIS-FL in 1998 were lost to Hurricanes Earl and Georges. In Alabama, Bon Secour National Wildlife Refuge documented approximately eleven nests lost to inundation between 1994 and 1996 and, in 1997, all but two nests were lost to hurricanes (U.S. Fish and Wildlife Service, unpubl. data). At GUIS-MS, all sea turtle

nests documented during the 1998 season have apparently been lost to Hurricane Georges.

Sea turtle nest predators include mammalian, crustacean, and insect species. At CALO, raccoon predation is quite variable but can be a problem in some areas. Between 1989 and 1997 in North Carolina, at least 126 nests were predated by ghost crabs, at least 115 nests were predated by raccoons, and at least 137 nests were predated by other animals. Feral hogs, raccoons, and ghost crabs predate nests in some areas at CUIS. These animals are also the primary nest predators of concern in the remainder of Georgia. Red fox and coyote are predators of major concern at GUIS-FL. Numerous predators, including raccoons, fire ants, feral dogs, and others, are a significant problem in the remainder of Florida, as well. Fox, coyote, crabs, and fire ants have predated nests at Bon Secour National Wildlife Refuge in Alabama (U.S. Fish and Wildlife Service, unpubl. data). Coyotes, crabs, and fire ants have predated nests in Texas, as well. Poaching by humans has become a concern on Jekyll Island in Georgia and remains a problem at a few locations in Florida. In addition, isolated cases of vandalism that may subsequently increase the likelihood of predation has been documented both in Georgia and at Bon Secour National Wildlife Refuge in Alabama.

Measures designed to protect incubating sea turtle nests from predation and other impacts have been effective where implemented in areas included in this study. A variety of protective measures, including wire screens, cages, and fencing, have reduced nest predation by foxes on several North Carolina beaches, particularly since 1993. In the late 1970's in South Carolina, sea turtle nesting success, measured as the proportion of deposited nests that produce any hatchlings, was estimated at below 10% due to a combination of predation, poaching, inundation, and other factors. Since nest monitoring and protection measures have been implemented, nesting success in South Carolina has increased to over 80%. In 1992, on one nesting beach in Georgia, nearly 100% of sea turtle nests found were predated by feral hogs. Subsequent to the implementation of nest protection measures, feral hog predation levels in that area have dropped to about 10%. At CANA, over 90% of sea turtle nests were predated during the early 1980's. However, protective measures and predator controls have reduced current predation levels to less than 20%.

Erosion can also expose deposited eggs and cause nest failure. Tidal erosion was noted as an impact on at least 192 loggerhead nests found in North Carolina between 1989 and 1997. Sand accumulation affected at least 41 loggerhead nests in North Carolina during the same period, while at least 67 nests were invaded by plant roots. Bon Secour National Wildlife Refuge in Alabama has also documented nests lost to root invasion and entanglement (U.S. Fish and Wildlife Service, unpubl. data). Notable levels of erosion that may influence nest success are also occurring in some areas of CUIS and throughout Georgia.

Impacts on emerging hatchlings

Eroding sand dunes can bury incubating nests to a depth from which hatchlings are unable to escape. Exotic vegetation can invade nest cavities, forming root mats that entangle hatchlings as they try to emerge from the nest.

Sea turtle hatchlings can become disoriented by artificial lighting as they emerge from the nest. As a result, hatchlings experience increased exposure to predation, exhaustion, and desiccation and may become entangled in vegetation. Artificial lighting can result in high hatchling mortality (National Research Council, 1990; Lutcavage et al., 1997). Impacts from artificial lighting have been documented in North Carolina, where hatchlings have been seen crossing roads and gathering around artificial light sources. Hatchling disorientation in areas with artificial lighting has been documented on nesting beaches in South Carolina, Georgia, and Florida. Artificial lighting has been noted as a potential problem at CAHA, CUIS, GUIS-FL, and GUIS-MS, although its impact on hatchlings has not been documented. The documented impact of artificial lighting on emerging hatchlings at CANA has been minimal.

Vehicles on the beach can cause problems for emerging hatchlings. Ruts left by vehicles can interfere with a hatchling's ability to reach the water, and may increase the risk of predation, exhaustion, and desiccation. Hatchlings can also be crushed by vehicles after they emerge. Vehicles have driven over nests and crushed hatchlings at CUIS. In Florida, vehicles are a problem for hatchlings where beach driving is not regulated to protect sea turtles. Vehicle use can also compact the sand covering nest sites, making it difficult for hatchlings to emerge.

Conclusion and Recommendations

In recent decades, efforts to monitor and protect endangered and threatened sea turtles have increased dramatically. Researchers have improved knowledge of marine turtle biology. Influences on population size, structure, and distribution have been identified with increasing precision. Strategies to aid with the recovery of each species have been devised and implemented.

The National Seashores of the U.S. National Park Service provide important nesting habitat for all five sea turtle species found in the Atlantic and Gulf coast waters of the United States. These National Seashores encompass several important loggerhead sea turtle nesting beaches and include the most important nesting area in the United States for Kemp's ridley sea turtles.

Reproductive success is crucial to the recovery of these species. Conservation strategies targeted toward the protection of sea turtle nests and nesting adults have been implemented in the last few decades. Monitoring annual fluctuations in the number of nests deposited and the ultimate fate of those nests provide an important means of determining the success of recovery efforts and the current status of sea turtle populations.

Maximizing consistency in monitoring protocols between organizations involved in sea turtle recovery enables researchers to more accurately determine the impact of conservation efforts and to devise more effective strategies for achieving recovery goals. Consistency in monitoring programs at most seashores and states and coordination of monitoring activities between the seashores and states had improved by 1989 and techniques for monitoring and protecting sea turtles and their nests continue to be refined. Index Nesting Beach Survey (INBS) programs, utilizing standardized monitoring techniques to assess nesting trends, have been in place at most nesting beaches in Florida, Georgia, and North Carolina for the last 10 years. With the exception of the Mississippi District of Gulf Islands National Seashore, patrols for sea turtle nests are now conducted daily throughout the monitoring season at the six National Seashores in the southeastern U.S. Survey effort has increased at Cape Hatteras and Padre Island National Seashores, in North Carolina, and in Florida since the INBS program was instituted. Survey effort

has remained relatively consistent at Cumberland Island National Seashore since complete surveys of the island began in 1994. Survey effort has remained relatively consistent at Canaveral and Gulf Islands National Seashores and in South Carolina since the implementation of current protocols. Measures of reproductive success differed both among seashores and between seashores and states. Definitions and calculations of these measures varied. However, reproductive measures were compatible between Cape Hatteras, Cape Lookout, and North Carolina.

In most cases, annual fluctuations in sea turtle nesting documented at National Seashores generally reflected annual fluctuations in nesting in the surrounding state. Overall, nesting appeared to remain stable or increase at most areas and nesting appeared to increase by most species, from 1989 through 1997 or 1998. However, there were some exceptions and effort to detect nesting increased in some areas.

With the exception of Gulf Islands National Seashore, annual fluctuations in loggerhead nesting documented at National Seashores generally reflected annual fluctuations in loggerhead nesting documented in the surrounding state (excluding National Seashores). Loggerhead nesting levels followed a 4-5 year cyclic pattern at Cape Hatteras, Cape Lookout, and Canaveral National Seashores, as well as in Florida. This cyclic pattern was less evident at Cumberland Island, in North Carolina, and in Georgia. Loggerhead nesting in South Carolina generally fluctuated on a bi-annual basis. Documented loggerhead nesting in both the Florida and the Mississippi Districts of Gulf Islands National Seashore was erratic.

During the 1989-1998 period, loggerhead nesting appears to have remained stable or increased slightly at Cape Hatteras, increased at Cape Lookout, and remained stable or decreased slightly in the remainder of North Carolina. The number of loggerhead nests documented in South Carolina appears to have remained stable or decreased slightly. Loggerhead nests recorded at Cumberland Island and in the remainder of Georgia remained stable or increased slightly. Loggerhead nesting at Canaveral appears to have remained stable, while nesting in Gulf Islands Florida District and in the remainder of Florida (excluding National Seashores) remained stable or increased slightly.

Green sea turtle nesting followed a distinct, alternating pattern at all National Seashores and in all states where documented nesting was documented on a regular basis

between 1989 and 1998. Overall, from 1989-1997, green sea turtle nesting appears to have increased slightly both at CANA and in the remainder of Florida. Leatherback nesting followed similar annual patterns and increased at both Canaveral National Seashore and in the rest of Florida during the 1989-1997 period. Documented Kemp's ridley nesting increased during the 1989-1998 period both at Padre Island National Seashore and in the rest of Texas, the only area where regular nesting occurs for this species in the United States.

A myriad of factors, including erosion, tidal inundation, development, artificial lighting, shrimp trawling, predation, and human disturbance, have influenced sea turtle nesting at one or more locations included in this study. Factors influencing nesting at National Seashores generally corresponded to factors influencing nesting in the surrounding state. Nest inundation, artificial lighting, and shrimp trawling are currently the primary influences on sea turtle nesting activities at one or more of the six National Seashores, although impacts from these factors were not documented at all seashores.

Nest protection measures, authorized by state and federal permits, have varied at all locations as needed to address specific protection concerns and management policies at each nesting beach. Protective measures designed to reduce the impact of nest predation have been effective in many areas included in this study.

Recommendations are described in this section for maximizing the value of information gathered through sea turtle nest monitoring programs. These recommendations focus on long-term consistency, documentation, and the establishment of minimum standards. However, all recommendations are contingent on adequate, consistent funding.

- Minimum standards need to be established for nesting data collection and monitoring protocols. Many aspects of sea turtle nest monitoring programs can remain flexible, addressing specific needs and circumstances at different locations. However, minimum standards for nesting data collection and monitoring protocols should be followed across locations to allow meaningful analysis of the information gathered. The Index Nesting Beach Survey (INBS) program provides the most comprehensive protocol for monitoring sea turtle nesting activities using compatible techniques with consistent

effort over multiple years. CAHA, CALO, CUIS, North Carolina, Georgia, and Florida currently follow this protocol. CANA also follows this protocol, but expands monitoring efforts beyond INBS requirements. We recommend the nesting data collection and monitoring protocols used in this INBS program as a minimum standard for sea turtle nest monitoring programs. This would maximize the compatibility and allow for more accurate and thorough analysis of information gathered on nesting activity. Individual programs could implement measures and efforts beyond this minimum as appropriate for their situation if funding affords the opportunity.

- Terms, definitions, and calculations used to describe reproductive success should be standardized. Definitions of reproductive success differ among National Seashores and between seashores and surrounding states. Such differences largely result from variations in the intensity of monitoring efforts and in the level of nesting activity in the area. However, success must be defined and calculated consistently in order to measure the impact of nest protection efforts on regional or population levels. Nesting success, hatching success, and emergence success are not interchangeable terms and comparisons between these types of measures may not be appropriate. Measures of reproductive success need to be defined and calculated in a manner compatible across locations. CANA may provide an effective method for monitoring reproductive success for most nesting beaches, regardless of variations in nesting activity. In each area, a portion of nests could be marked as index nests each year, ranging from all nests found in areas with low nesting activity to 10% of nests found in areas with high nesting activity. The proportion of nests marked in an area could be decreased in subsequent years if nesting levels increase. Complete documentation of hatching and emergence success for these nests could then provide a consistent and analytically viable reflection of sea turtle reproductive success across locations and across years. In addition, influences on incubating eggs and emerging hatchlings could be quantified and evaluated much more accurately through documentation of these index nests.
- Documentation of survey effort should be maintained. Without maintaining a record of survey effort, apparent changes in nesting activity cannot be verified. At PAIS, the number of sea turtle nests found during a monitoring season has increased for the past four consecutive years. However, careful documentation of the annual number of

kilometers traveled during nesting patrols shows that survey effort has also increased for the last four consecutive years. As a result, the increase in documented sea turtle nesting at this National Seashore may be at least in part a reflection of an increase in the effort to find sea turtle nests. Annual levels of survey effort should be considered during analysis of trends in sea turtle nesting. However, some locations do not maintain thorough documentation of nest survey effort. We recommend that each location maintain a centralized record of survey effort, measured as the total number of survey days each year. For surveys that repeatedly traverse a specific area to detect nesting (such as at PAIS), a measure of the total number of kilometers traveled during nesting patrols and total number of hours spent conducting patrols, should also be recorded. Information should also be maintained on dates efforts started and ended each year, specific areas where monitoring occurred, and other pertinent factors.

- Monitoring programs must be maintained at compatible levels of effort using consistent methods for multiple years. Due to variability in age at sexual maturity among females, sea turtle nesting activities must be monitored consistently for up to 30-50 years to effectively determine the impact of conservation efforts. Positive and negative impacts on sea turtle populations may not become evident in sea turtle nesting activities for decades. Sea turtle nest monitoring programs should be developed and maintained from a long-term perspective.

- Documented impacts to nesting, hatching, and emergence success should be minimized. Management actions should be conducted to alleviate documented problems (beach driving, lighting, predation, etc.). In areas where deemed necessary, impacts to sea turtles from beach driving should be minimized by prohibiting nighttime driving during the sea turtle nesting season, marking nests for avoidance, and/or removing vehicle ruts from in front of nests due to emerge to prevent hatchlings from becoming trapped in them. Nest protection measures should also be undertaken when threats have been documented. Nest protection actions at the six National Seashores must be authorized by state and federal permits, take into consideration National Park Service mandates and policies, meet local needs, and be deemed effective through research or monitoring results. Predator control, including removal of problem animals, may be needed under certain circumstances.

Again, we would like to stress that all the recommendations described above depend on adequate, consistent funding for these labor-intensive projects. Without such funding, accurate monitoring of sea turtle nesting activities and protection of sea turtle nests may not be possible, and efforts to restore sea turtle populations will be hindered.

By maximizing the compatibility of data on sea turtle nesting levels, influences, and reproductive success among National Seashores and between National Seashores and the surrounding states, the National Park Service can determine what conservation efforts benefit sea turtle populations most. Within each monitoring program, scarce resources can be targeted toward those activities that most benefit sea turtle recovery. Specific strategies could be developed for genetically distinct loggerhead nesting subpopulations, or for daytime-nesting Kemp's ridley turtles. In addition, the National Park Service will be able to devise more effective conservation strategies that address problems at the local, regional, national, or international levels.

Budget Requirements

This final report completes work by the authors for this project. No additional funding is required to complete this study.

Project Schedule

Data analyzed for this study were collected by various entities between 1989 and 1998. Data were provided to and analyzed by the authors during 1998. This final report was completed during December 1998.

Expected Products

Expected products from this study include this final report. No other products are expected to result from this study.

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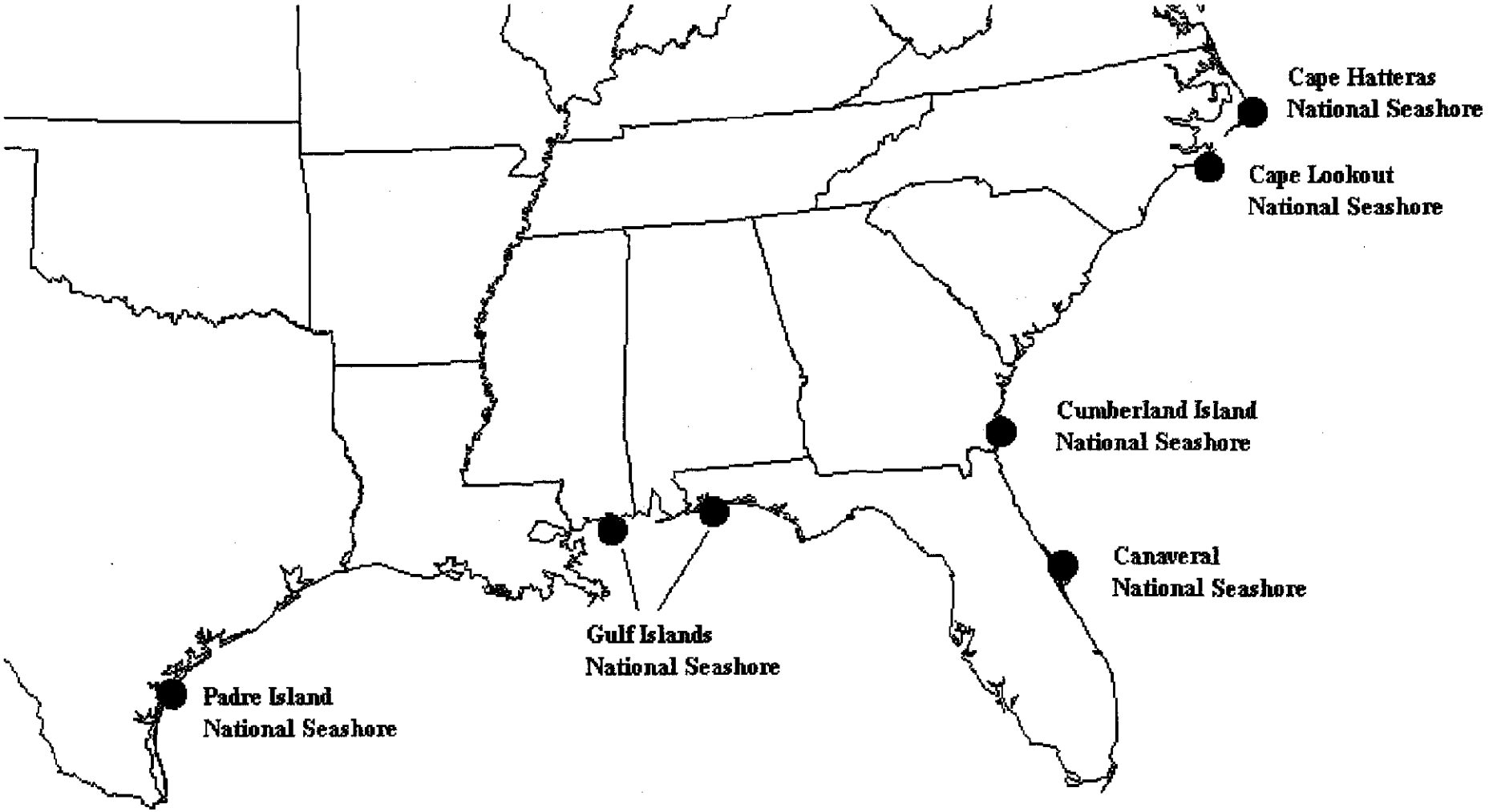
Information on shrimping regulations in federal waters was provided by the South Atlantic Fishery Management Council and the Gulf of Mexico Fishery Management Council. Information on shrimping regulations in state waters was provided by North Carolina Division of Fisheries, South Carolina Department of Natural Resources, Georgia Department of Natural Resources, Florida Marine Fisheries Commission, Alabama Department of Conservation and Natural Resources, Mississippi Department of Marine Resources, Louisiana Department of Wildlife and Fisheries, and Texas Parks and Wildlife Department.



Appendix A. National Seashores of the southeastern U.S.

Appendix B. Southeast Nesting NRPP Project questionnaire.

1) What species have been found nesting?

2) How long have you been monitoring sea turtle nests?

3) How many nests of each species have been found each year?

4) How do you assess nesting? (daily patrols, weekly patrols, on ATV's, in truck,.....)

5) Do you tag nesting adults or only look for nests? What type(s) of tags do you use (PIT tags, metal tags, transmitters)?

6) What is the overall hatching success rate for each year?

7) How do you assess hatching success? (count leftover eggs, count emergent hatchlings...?)
   a) How do you protect and monitor nests (incubation, enclosures, nests on beach = in situ)?
   b) Do you monitor temperatures, environmental factors, anything else?
   c) Please specify your definition of successfully hatched. Do you count everything that comes out of the egg (including dead hatchlings down in the nest) or just what emerges from the nest, or what?

8) Do you conduct any predator controls? If so, then what is done, when is it done, and how often is it done? (consistent effort?)

9) What are your reporting procedures on monitoring and control efforts? (annual reports, ongoing database,....)

10) Who maintains your records?

11) Can you elaborate on any factors that might influence nesting in your area?
   a) Night lighting (directly on the beach or indirectly from nearby sources)
   b) Habitat changes (erosion, armoring, dredging, channelization)
   c) Vehicle use on the beach
   d) Night use of the beach (night tours, camping,....)
   e) Predators
   f) Other factors

12) Can you elaborate on any trends related to nesting in your area, in the corresponding state, in a particular population of turtles, or in the U.S. (overall)?

13) Could you please provide any information you may have on state and/or university contacts related to turtle nesting (both past and present)?

Appendix C. Sea turtle nesting at National Seashores in the southeastern U.S., 1989-1998, as reported by the National Park Service and the U.S. Fish and Wildlife Service.

Loggerhead sea turtle nests										
	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998
Cape Hatteras	26	32	70	38	45	94	69	39	39	101
Cape Lookout	80	99	89	90	99	118	119	94	124	193
Cumberland Island	-	-	-	164	92	248	203	196	188	233
Canaveral	3091	3922	4074	3279	3140	3886	4121	3260	2702	3971
Gulf Islands, Florida District	30	27	10	14	32	37	34	42	22	NA[a]
Gulf Islands, Miss. District	-	9	0	8	0	4	1	2	5	2
Padre Island	0	1	0	2	0	0	1	2	4	2

Green sea turtle nests										
	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998
Cape Hatteras	0	0	0	0	1	1	0	2	0	5
Cape Lookout	0	0	0	0	0	1	0	1	0	5
Canaveral	41	185	25	298	28	364	47	222	21	426
Gulf Islands, Florida District	0	0	0	0	0	3	1	3	0	NA[a]
Padre Island	0	0	0	0	0	0	0	0	0	5

Leatherback sea turtle nests										
	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998
Cape Hatteras	0	0	0	0	0	0	0	0	0	1
Canaveral	1	1	1	0	0	2	1	3	4	5

Kemp's ridley nests										
	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998
Padre Island	0	0	1	0	0	1	2	5	5	9

Hawksbill nests										
	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998
Padre Island	0	0	0	0	0	0	0	0	0	1

- indicates year when sea turtle nest monitoring was not conducted.

[a]Data not yet available.

Appendix D. Sea turtle nesting outside of National Seashores in the southeastern U.S., 1989-1998, as reported by state and federal sources[a].

Loggerhead sea turtle nests

	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998
North Carolina	351	660	769	596	340	772	465	642	405	564
South Carolina	2444	4491	3657	3943	2757	4136	2959	3892	2957	NA[b]
Georgia	533	854	964	828	383	1120	824	918	628	834
Florida	46376	62736	64565	61681	52654	66219	76492	73366	62581	NA[b]
Alabama	-	-	-	-	-	31	30	40	12	NA[b]
Louisiana	8	1	-	-	-	-	-	-	-	-
Texas	-	-	-	-	-	-	-	3	-	-

Green sea turtle nests

	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998
North Carolina	1	9	0	2	1	5	0	2	1	7
South Carolina	0	0	0	0	0	0	0	2	0	3
Florida	538	2081	508	2211	407	3305	520	2837	708	NA[b]
Alabama	-	-	-	-	-	19	2	0	0	NA[b]

Leatherback sea turtle nests

	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998
South Carolina	0	0	0	0	0	0	0	1	0	0
Georgia	0	0	0	0	0	0	0	3	0	0
Florida	98	120	187	177	142	258	229	202	397	NA[b]

Kemp's ridley nests

	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998
North Carolina	0	0	0	1	0	0	0	0	0	0
South Carolina	0	0	0	1	0	0	0	0	0	NA[b]
Florida	1	0	0	0	0	1	0	3	0	NA[b]
Texas	-	-	-	-	-	-	2	1	4	4

Hawksbill nests

	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998
Florida	1	2	0	2	0	1	3	0	3	NA[b]

[a]Data are from North Carolina Wildlife Resources Commission (unpubl. data), South Carolina Department of Natural Resources (unpubl. data), Hopkins-Murphy et al. (in press), Georgia Department of Natural Resources (unpubl. data), Florida Department of Environmental Protection (unpubl. data), Meylan et al. (1995), U.S. Fish and Wildlife Service (unpubl. data), Fuller (unpubl. report), Fuller and Lohoefener (1990), National Park Service (unpubl. data), and Shaver and Caillouet (1998).

- Indicates year when sea turtle nest monitoring was not conducted.

[b]Data not yet available.

Appendix E. Commercial food shrimp trawling seasons in state and federal waters of the southeastern U.S., as reported by state and federal sources.[a]

State	State Waters	State Water Closures	Federal Waters (to 200 naut mi)	Exceptions	Areas permanently closed to shrimp trawling
North Carolina	0-3 mi	Open year-round	Open year-round	none	All inshore waters closed
South Carolina	0-3 mi	~Jan - ~Jun	Open year-round	2 small bays open ~Jul to ~Nov	None in offshore state waters; some in inshore waters
Georgia	0-3 mi	Mar to mid-May, but can be extended to Jan to mid-May	Open year-round	4 beaches have a 1000-ft safety zone that does not open to shrimp trawling until Oct 1	None in offshore state waters; all inshore waters are closed
Florida	0-3 mi on east coast; 0-9 naut mi on Gulf coast	East coast closed Apr-May; Big Bend (NW FL) closed Jul-Aug; intermittent closures off upper portion of Big Bend and SW of Sanibel Island	Open year-round	Night shrimping in all state waters on the South Atlantic side is prohibited except during Jun-Aug	Dry Tortugas in state waters; some in inshore waters
Alabama	0-3 mi	~May - ~Jun	Open year-round	None (only in special situations)	None in offshore state waters ; a few in inshore bays
Mississippi	0-3 mi	All state waters are closed ~May-~Jun; inshore waters are also closed ~Jan-~May	Open year-round	None	None
Louisiana	0-3 mi	~Jul to ~Aug and ~Dec to ~May for inshore waters; offshore state waters open year-round	Open year-round	Have the option to set a closed winter season for Jan-Apr for offshore state waters; Grand Isle Beach is closed in summer out to 500 ft.	None for offshore state waters; a few for inshore lakes
Texas	0-9 naut mi	mid-May to mid-Jul; and mid-Dec to early Feb	~mid-May to ~mid-July	No shrimping at night out to 7 fathoms depth (year-round)	None

[a] Information obtained from North Carolina Division of Fisheries, South Carolina Department of Natural Resources, Georgia Department of Natural Resources, Florida Marine Fisheries Commission, Alabama Department of Conservationa and Natural Resources, Mississippi Department of Marine Resources, Louisiana Department of Wildlife and Fisheries, Texas Parks and Wildlife Department, the South Atlantic Fishery Management Council, and the Gulf of Mexico Fishery Management Council.