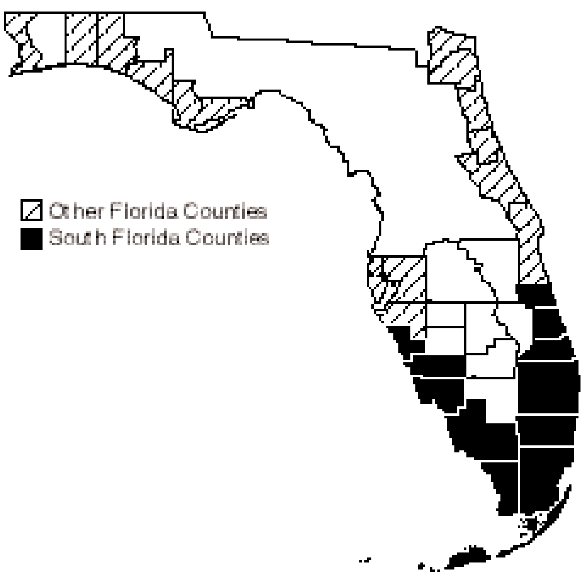
Loggerhead Sea Turtle

Caretta caretta

Federal Status:	**Threatened (July 28, 1978)**
Critical Habitat:	**None Designated**
Florida Status:	**Threatened**
Recovery Plan Status:	**Contribution (May 1999)**
Geographic Coverage:	**South Florida**

Figure 1. Florida nesting distribution of the loggerhead sea turtle.



The loggerhead sea turtle is the most common sea turtle species in South Florida. The nesting and hatching season for loggerhead sea turtles in South Florida extends from mid-March through November. The total number of loggerhead sea turtle nests surveyed in South Florida accounts for approximately 60 percent of all nests reported statewide (Meylan *et al*. 1995). Sea turtles, in general, are susceptible to human-related changes to the marine environment, and to their nesting beaches. This account provides an overview of the biology of the loggerhead turtle throughout its range. The discussion of environmental threats and management activities, however, pertains only to nesting beaches in South Florida. Serious threats to the loggerhead turtle on South Florida's nesting beaches include: destruction or modification of nesting habitat from coastal development, armoring, artificial lighting, beach nourishment, increased human presence, and exotic beach and dune vegetation.

This account is modified from the 1991 Recovery Plan for U.S. Population of Loggerhead Turtle and represents South Florida's contribution to the range-wide recovery plan for the loggerhead sea turtle (NMFS and FWS 1991).

Description

Adult and subadult loggerhead sea turtles have a reddish-brown carapace. The dorsal and lateral head scales and the dorsal scales of the extremities are also reddish-brown, but with light yellow margins that vary enough in extent to provide considerable disparity in appearance among individuals. The unscaled area of the integument (neck, shoulders, limb bases) are dull brown above and medium yellow laterally and ventrally. The plastron is also medium yellow. The thick, bony carapace is covered by non-imbricated horny scutes. There are five pairs of costals (pleurals), 11 or 12 pairs of marginals, five vertebrals and a nuchal (precentral) that is in contact with the first costal. Ventrally there are usually three pairs of poreless inframarginals, paired gulars, humerals, pectorals, abdominals, femorals and anals. An interanal is variable and inconstant. Mean straight carapace length (sCL) of adult Southeastern U.S. loggerheads is about 92 cm; corresponding mean body mass is about 113 kg. Elsewhere adult loggerheads are somewhat smaller; the most notable being those in Colombia (Kaufmann 1975), Greece (Margaritoulis 1982) and Tongaland (Hughes 1975). Loggerheads rarely exceed 122 cm sCL and 227 kg mass.

Hatchling loggerhead turtles lack the reddish tinge of adults and vary from light to dark brown dorsally. Both pairs of appendages are dark brown above and have distinct white margins. The plastron and other ventral surfaces may be described as dull yellowish tan and there is usually some brown pigmentation in the phalangeal portion of the web ventrally. At hatching mean body mass is about 20 g and mean sCL is about 45 mm. Hatchlings have three dorsal keels and two plastral ones.

The loggerhead turtle can be distinguished from other sea turtles by noting, collectively, the presence of five pairs of costal scutes and three pairs of inframarginals. Loggerheads are noted for their disproportionately large head (adults; 20 to 25 cm), and their heart-shaped carapace (DEP undated).

The crawls of nesting female sea turtles are distinctive interspecifically. Female loggerhead sea turtles leave a moderately deep cut track with alternating (asymmetrical) diagonal marks made by the front flippers (Pritchard *et al*. 1983). The nest itself is a smaller mound of sand than those formed by Atlantic green (*Chelonia mydas*) and leatherback (*Dermochelys coriacea*) sea turtles. The body pit depression is also considered insignificant relative to that of Atlantic green and leatherback sea turtles (LeBuff 1990).

Taxonomy

The loggerhead sea turtle was described by Linnaeus (1758) and named *Testudo caretta.* Over the next two centuries more than 35 names were applied to the species (Dodd 1988), but there is now general agreement on *Caretta caretta* as the valid name. While Deraniyagala described an Indo-Pacific form as *C. gigas* in 1933, he revised that view in 1939 to hold that *gigas* was only a subspecies of *C. caretta* and the genus has generally been regarded as monotypic since that time. The subspecific designation of *gigas* has likewise been challenged persuasively (Brongersma 1961, Pritchard 1979). Dodd (1988) declared flatly that “the diagnostic characters used to distinguish *C. c. gigas* from *C. c. caretta* are not valid.” Thorough synonymies and taxonomic reviews of this form are given most recently by Pritchard and Trebbau (1984) and Dodd (1988).

Distribution

The geographic distribution of loggerhead sea turtles includes the temperate and tropical waters worldwide. The species inhabits the continental shelves and estuarine environments along the margins of the Atlantic, Pacific and Indian Oceans. In the Western Hemisphere it ranges as far north as Newfoundland (Squires 1954) and as far south as Argentina (Frazier 1984) and Chile (Frazier

Loggerhead sea turtle.
Original photograph courtesy of U.S. Fish and Wildlife Service.

and Salas 1982). The nesting range is confined to lower latitudes, but loggerhead nesting is clearly concentrated in the north and south temperate zones and subtropics. Pritchard (1979) used the term “antitropical” to describe the aversion exhibited by loggerheads to beaches in Central America, northern South America and throughout the Old World Tropics. Notable exceptions to this rule would include one of the largest known nesting aggregation, on Masirah and the Kuria Muria Islands of Oman in the Arabian Sea (Ross and Barwani 1982) and perhaps, the recently reported nesting assemblage on the Caribbean coast of Quintana Roo (NMFS and FWS 1991). Worldwide, about 88 percent of the loggerhead sea turtle nesting occurs in the southeastern U.S., Oman, and Australia (NMFS and FWS 1991).

Loggerhead sea turtles nest along the coast within the continental U.S. from Louisiana to Virginia. Major nesting concentrations are found on the coastal islands of North Carolina, South Carolina, and Georgia, and on the Atlantic and Gulf coasts of Florida (Hopkins and Richardson 1984). Although they nest in all coastal counties in South Florida (Figure 1), approximately 80 percent of nesting occurs along the east coast of Florida, particularly in Brevard, Indian River, St. Lucie, Martin, Palm Beach and Broward counties (NMFS and FWS 1991).

Habitat

Habitat selection for loggerhead sea turtles is not well understood, but it seems clear that adults can utilize a variety of habitats. Remote recoveries of female loggerhead sea turtles tagged in Florida indicate that many migrate to the Gulf of Mexico, often to the turbid, detritus-laden, muddy-bottom bays and bayous of the northern Gulf Coast. Still others apparently occupy the clear waters of the Bahamas and Antilles, with sandy bottoms, reefs and shoals that constitute a totally different type of habitat. Nothing is known of the relative period of time that loggerhead sea turtles may spend in these disparate habitats or of their propensity to move from one to another.

In most nearshore waters in the Southeast, adult and subadult loggerhead sea turtles appear to use the same habitats. In some of the inshore waters such as the Indian River Lagoon of east Florida the subadults are virtually isolated from the adults, whose foraging areas outside of the nesting season are apparently elsewhere.

As a generality, adult female loggerheads select high-to moderate-energy beaches on barrier strands adjacent to continental land masses for nesting. There is some evidence that loggerhead sea turtles favor steeply-sloped beaches with gradually-sloped offshore approaches (Provancha and Ehrhart 1987). After leaving the beach, hatchlings apparently swim directly offshore and eventually become associated with *Sargassum* and/or debris in pelagic drift lines that result from current convergences (Carr 1986a, 1986b, 1987). The evidence suggests that when post-hatchlings become a part of the *Sargassum* raft community they remain there as juveniles, riding circulating currents for several years and growing to about 45 cm sCL. At that point they abandon the pelagic habitat, migrate to the nearshore and estuarine waters along continental margins and utilize those areas as the developmental habitat for the subadult stage (NMFS and FWS 1991).

Behavior

The recent literature dealing with the biology of loggerhead sea turtles is extensive and only a brief treatment is warranted here. However, a number of thorough synopses of loggerhead biology are currently available. The most recent and extensive is the work of Dodd (1988) but those of Pritchard and Trebbau (1984) and Groombridge (1982) are also very comprehensive and useful.

Reproduction and Demography

It has been assumed that male loggerheads migrate with females from distant foraging areas to the waters off nesting beaches and that courtship and mating take place there. The few reports concerning the seasonality of mating clearly place it in the late-March to early-June period (Caldwell 1959, Caldwell *et al.* 1959a, Fritts *et al.* 1983). While a few adult males may remain off the Florida coast throughout the year (Henwood 1987), most of them apparently depart by about mid-June, leaving the females to ascend the nesting beaches and deposit clutches throughout the summer. Nevertheless, courtship and mating are not well studied in loggerheads and there is no doubt that this and virtually every other aspect of the biology of male loggerheads needs further research and clarification.

In the southeastern U.S., adult female loggerheads begin to nest as early as mid-March and they continue to do so until late September. Nesting activity is greatest in June and July. In Georgia, South Carolina, and North Carolina, the season generally begins in mid-May and ends by mid-August. Loggerheads are known to nest from one to seven times within a nesting season (Talbert *et al.* 1980, Richardson and Richardson 1982, Lenarz *et al.* 1981); the mean is approximately four times (Murphy and Hopkins 1984). The inter-nesting interval varies around a mean of about 14 days. There is general agreement with Caldwell *et al.* (1959b) that female loggerhead sea turtles mate prior to the nesting season (and possibly only once during the nesting season) and then lay multiple clutches of fertile eggs throughout some portion of the nesting season. Along the southeastern U.S. coast, mean clutch size varies from about 100 to 126 eggs (NMFS and FWS 1991).

Loggerheads are nocturnal nesters, but they will infrequently nest during the day (Fritts and Hoffman 1982, Witherington 1986). Although a definitive study of loggerhead nesting behavior has yet to be published, good descriptive accounts have been given by Carr (1952), Litwin (1978) and Caldwell *et al.* (1959a). Multi-annual remigration intervals of two and three years are most common in loggerheads, but the number can vary from 1 to 6 years (Richardson *et al.* 1978, Bjorndal *et al.* 1983). Natural incubation periods for U.S. loggerheads average from 53-55 days in Florida (Davis and Whiting 1977, Witherington 1986) to 63 and 68 days in Georgia (Kraemer 1979) and North Carolina (Crouse 1985), respectively. The length of the incubation period is inversely related to nest temperature (McGehee 1979). Sex determination in loggerhead hatchings is temperature dependent (Yntema 1982, Yntema and Mrosovsky 1980) and the species apparently lacks sex chromosomes (Standora and Spotila 1985). Natural hatching success rates of 73.4 percent and 55.7 percent have been reported in South Carolina (Caldwell 1959) and Florida (Witherington 1986), respectively.

While a number of workers have reported growth rates of post-hatchling and juvenile loggerheads in captivity *(e.g.*, Witham and Futch 1977), such information is totally lacking for these stages in the wild. In captivity young loggerheads can grow to about 63 cm sCL and 37 kg in mass in 4.5 years (Parker 1926). In wild subadults, Limpus (1979) has reported linear growth rates of 1.5 cm/yr in Australia and Mendonca (1981) has reported average linear growth rates of 5.9 cm/yr in Florida. It seems clear now that growth rates of subadults decrease with increasing carapace length (i.e., growth is not linear). Although they lacked data for loggerheads smaller than 53 cm sCL, Frazer and Ehrhart (1985) fitted growth data for Florida subadults to both logistic and van Bertalanffy curves and estimated age at maturity as 12 to 30 years.

Migration

Adults loggerheads become migratory for the purpose of breeding. Recoveries of females tagged while nesting on the Florida east coast suggest widely dispersed foraging in the Gulf of Mexico, Cuba and elsewhere in the Greater Antilles, and the Bahamas (Meylan *et al.* 1983). While conclusive evidence is lacking as yet, it is assumed that these females remigrate hundreds or thousands of km at multi-annual intervals to nest on the good, high energy nesting beaches of east Florida. Bell and Richardson (1978) reported tag recoveries suggesting a migratory path from Georgia to Cape Hatteras, North Carolina and a single recovery of a Georgia tagged female on the Florida Gulf Coast (Tampa Bay). Little else is known of the travels of loggerhead sea turtles that nest in Georgia, South Carolina, and North Carolina outside of the nesting season.

Loggerhead hatchlings engage in a swimming frenzy for about 20 hours after they enter the sea and that frenzy takes them about 22 to 28 km offshore

(Salmon and Wyneken 1987). Upon reaching about 45 cm sCL, they abandon the pelagic existence and migrate to nearshore and estuarine waters, including the eastern U.S., the Gulf of Mexico and the Bahamas, and begin the subadult stage (NMFS and FWS 1991). Little is known of their seasonal movements there, but Henwood (1987) has reported a tendency for subadults of the Port Canaveral (Florida) aggregation to disperse more widely in the spring and early summer. Also, Chesapeake Bay subadults are known to exhibit a variety of movements between waters of differing temperatures and salinities (Killingly and Lutcavage 1983).

Foraging

While the list of food items eaten by loggerheads is lengthy and includes invertebrates from eight phyla (Dodd 1988), it is clear that subadult and adult loggerheads are, first and foremost, predators of benthic invertebrates such as gastropod and pelecypod molluscs and decapod crustaceans. Coelenterates and cephalopod molluscs are also taken by larger turtles but these invertebrates are especially favored by loggerheads in the pelagic stage. Most of the evidence for the latter statement comes from the island groups of the eastern Atlantic (van Nierop and den Hartog 1984). Post-hatchling loggerheads evidently ingest macroplankton associated with weed lines. In one of the few studies of post-hatchling food habits in the southeastern U.S., Carr and Meylan (1980) found two species of small gastropods characteristic of the *Sargassum* raft community as well as fragments of crustaceans and the *Sargassum* plant itself. Although Brongersma (1972) listed Syngnathid fishes among the items found in the stomach contents of loggerhead sea turtles, this species is not a significant fish eater. Loggerheads may scavenge fish or fish parts or ingest fish incidentally in some circumstances.

Relationship to Other Species

In South Florida, loggerhead sea turtles share nesting beaches with the endangered Atlantic green sea turtle, in every county where it nests, and with the endangered leatherback sea turtle, which most commonly nests in Martin and Palm Beach counties. Other federally listed species that occur in coastal dune and coastal strand habitat, and that need to be considered when managing nesting beaches, are the southeastern beach mouse (*Peromyscus polionotus niveiventris*) and the beach jacquemontia (*Jacquemontia reclinata*). Beach nourishment projects, in particular, could affect these species as well as the turtles. The range of the beach mouse in South Florida is estimated to include Indian River County south to Broward County. The beach jacquemontia is found in Palm Beach County south to Miami, Miami-Dade County.

A variety of natural and introduced predators such as raccoons (*Procyon lotor*), feral hogs, opossums (*Didelphis virginiana*), foxes, ghost crabs and ants prey on incubating eggs and hatchling sea turtles. The principal predator of loggerhead sea turtle eggs is the raccoon, which is particularly destructive and may take up to 96 percent of all eggs laid in nests deposited on a beach (Davis and Whiting 1977, Hopkins and Murphy 1980, Stancyk *et al.* 1980, Talbert *et al.* 1980, Schroeder 1981, Labisky *et al.* 1986). In 1996, Hobe Sound NWR experienced depredation in 23 percent of the nests enumerated (FWS 1996). In addition to the destruction of eggs, some of these predators may take considerable numbers of hatchlings just prior to or upon emergence from the sand.

Predation of hatchlings and very young turtles is assumed to be significant and predation of subadult through adult stage turtles is assumed less common, but valid estimates of mortality due to predation at various life history stages are extremely difficult, if not impossible, to obtain, and have not been determined. Hatchlings entering the surf zone and pelagic stage hatchlings may be preyed upon by a wide variety of fish species and to a lesser extent, marine birds. Stancyk (1982), in an extensive literature review, reported predators of juvenile and adult turtles to include at least six species of sharks, *orca* whales, bass and grouper. Tiger sharks appear to be the principal marine predator of subadult and adult turtles.

Status and Trends

The loggerhead was listed on July 28, 1978 as a threatened species under the Endangered Species Act of 1973 (43 FR 32800). Internationally, it is considered endangered by the International Union for Conservation of Nature and Natural Resources (IUCN) and is listed in Appendix I of the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES).

It is not possible, at present, to estimate the size of the loggerhead sea turtle population in U.S. territorial waters if one includes subadults. There is, however, general agreement with Meylan (1982) that enumeration of nesting females provides a useful index to population size and stability. The estimate of 14,150 females nesting per year in the southeastern U.S. given by Murphy and Hopkins (1984) and based on aerial survey data from 1983, was accepted by Mager (1985) and more recently by Ehrhart (1989) as the current best approximation. Given Murphy and Hopkins' (1984) stochastically derived mean number of nests per female (4.1), this figure provides an estimate of approximately 58,000 nests deposited per year in the Southeast. Based on more extensive ground and aerial surveys since 1990, an estimated 60,000 nests are deposited annually in the Southeast (Meylan *et al*. 1995). However, according to Dodd (1995), the numbers of turtles nesting fluctuates substantially from one year to the next, making interpretation of beach counts difficult. These numbers are believed to constitute about 35 to 40 percent of the loggerhead nesting known worldwide (NMFS and FWS 1991).

From a global perspective, the southeastern U.S. nesting aggregation is of paramount importance to the survival of the species and may be second in size only to the nesting aggregation of the islands in the Arabian Sea off of Oman (Ross 1982, Ehrhart 1989, NMFS and FWS 1991). The status of the Oman nesting aggregation has not been evaluated recently, but its location in a part of the world that is vulnerable to disruptive events (e.g., political upheavals, wars, catastrophic oil spills) is cause for considerable concern (Meylan *et al*. 1995). The loggerhead nesting aggregations in Oman, the southeastern U.S., and Australia account for about 88 percent of nesting worldwide (NMFS and FWS 1991). About 80 percent of loggerhead nesting in the southeastern U.S. occurs in six Florida counties: Brevard, Indian River, St. Lucie, Martin, Palm Beach, and Broward (NMFS and FWS 1991).

Table 1. Average annual number of loggerhead nests by county from 1985 to 1995.

County	Average
Indian River	2242.5
St. Lucie	4258.2
Martin	8405.4
Palm Beach	9159.6
Broward	1912.2
Dade	347.45
Monroe	115.73
Collier	480.55
Lee	384.27
Charlotte	420
Sarasota	1643.09

Recent genetic analyses using restriction fragment analysis and direct sequencing of mitochondrial DNA have been employed to resolve management units among loggerhead nesting cohorts of the southeastern U.S. (Bowen *et al.* 1993, B.W. Bowen, University of Florida, personal communication 1994, 1995). Assays of nest samples from North Carolina to the Florida Panhandle have identified three genetically distinct nesting subpopulations: (1) northern nesting subpopulation--Hatteras, North Carolina, to Cape Canaveral, Florida; (2) South Florida nesting subpopulation -Cape Canaveral to Naples, Florida; and (3) Florida Panhandle nesting subpopulation -Eglin Air Force Base and the beaches around Panama City, Florida. These data indicate that gene flow between the three regions is very low. If nesting females are extirpated from one of these regions, regional dispersal will not be sufficient to replenish the depleted nesting subpopulation (Bowen *et al.* 1993, B. Bowen, University of Florida, personal communication 1995).

Throughout Florida, loggerhead sea turtle nests account for the vast majority of reported nesting; they comprised 97.9 percent of the total nesting activity during 1979 to 1992 (Meylan *et al.* 1995). From 1988 to 1992, while survey efforts remained relatively constant, the total number of reported loggerhead nests statewide fluctuated between 37,242 and 68,614. However, to better assess trends in nesting, the State of Florida, in cooperation with the FWS, initiated an Index Nesting Beach Survey (INBS) program in 1989 to collect nesting data that can be used to statistically and scientifically analyze population trends. Between 1989 and 1995, INBS nesting numbers have fluctuated between 39,172 and 59,379. While the results of the INBS program in Florida have shown small fluctuations in the numbers of nests laid annually, it is too soon to decipher with any confidence the trend in nesting population size.

Although the majority of loggerhead nesting during 1988 to 1992 occurred in Brevard County (39.4 percent), just outside of the South Florida Ecosystem, Palm Beach County supported the second highest percentage of nests during that time period with 17.8 percent of loggerhead nests. The average number of nests annually within the South Florida Ecosystem are shown in Table 1. These data show that Palm Beach County is clearly the most important nesting location within South Florida for the threatened loggerhead sea turtle. We chose to only represent the past 10 years of survey data in Table 1, because there was less beach surveyed and the data were not as complete prior to 1985.

Environmental Threats

A number of threats exist to sea turtles in the marine environment, including: oil and gas exploration, development, and transportation; pollution; trawl, purse seine, hook and line, gill net, pound net, longline, and trap fisheries; underwater explosions; dredging; offshore artificial lighting; power plant entrapment; entanglement in debris; ingestion of marine debris; marina and dock development; boat collisions; and poaching. These threats and protective measures are discussed in detail in the Recovery Plan for U.S. Population of Loggerhead Turtle (NMFS and FWS 1991). In South Florida, and for this Recovery Plan, the focus is on the threats to nesting beaches, including: beach erosion, armoring and nourishment; artificial lighting; beach cleaning;

increased human presence; recreational beach equipment; exotic dune and beach vegetation; nest loss to abiotic factors; and poaching.

Beach Erosion: Erosion of nesting beaches can result in partial or total loss of suitable nesting habitat. Erosion rates are influenced by dynamic coastal processes, including sea level rise. Man's interference with these natural processes through coastal development and associated activities has resulted in accelerated erosion rates and interruption of natural shoreline migration (National Research Council 1990).

Beach Armoring: Where beachfront development occurs, the site is often fortified to protect the property from erosion. Virtually all shoreline engineering is carried out to save structures, not dry sandy beaches, and ultimately results in environmental damage. One type of shoreline engineering, collectively referred to as beach armoring, includes sea walls, rock revetments, riprap, sandbag installations, groins and jetties. Beach armoring can result in permanent loss of a dry nesting beach through accelerated erosion and prevention of natural beach/dune accretion and can prevent or hamper nesting females from accessing suitable nesting sites. Clutches deposited seaward of these structures may be inundated at high tide or washed out entirely by increased wave action near the base of these structures.

As these structures fail and break apart they spread debris on the beach, which may further impede access to suitable nesting sites (resulting in higher incidences of false crawls) and trap hatchlings and nesting turtles. Sandbags are particularly susceptible to rapid failure and result in extensive debris on nesting beaches. Rock revetments, riprap, and sandbags can cause nesting turtles to abandon nesting attempts or to construct improperly sized and shaped egg cavities when inadequate amounts of sand cover these structures. Information obtained during preparation of the sea turtle recovery plans indicated that approximately 21 percent (234 km) of Florida's beaches were armored at that time (NMFS and FWS 1991).

Groins and jetties are designed to trap sand during transport in longshore currents or to keep sand from flowing into channels in the case of the latter. These structures prevent normal sand transport and accrete beaches on one side of the structure while starving neighboring beaches on the other side thereby resulting in severe beach erosion (Pilkey *et al.* 1984) and corresponding degradation of suitable nesting habitat.

Drift fences, also commonly called sand fences, are erected to build and stabilize dunes by trapping sand moving along the beach and preventing excessive sand loss. Additionally, these fences can serve to protect dune systems by deterring public access. Constructed of narrowly spaced wooden or plastic slats or plastic fabric, drift fences when improperly placed can impede nesting attempts and/or trap emergent hatchlings and nesting females.

Beach Nourishment: Beach nourishment consists of pumping, trucking, or scraping sand onto the beach to rebuild what has been lost to erosion. Although beach nourishment may increase the potential nesting area, significant adverse effects to sea turtles may result if protective measures are not taken. Placement of sand on an eroded section of beach or an existing beach in and of itself may not provide suitable nesting habitat for sea turtles. Beach nourishment can harm turtles through direct burial of nests and by disturbance to nesting turtles if conducted during the nesting season. Beach nourishment may result in changes in sand density (compaction), beach shear resistance (hardness), beach moisture content, beach slope and profile, sand color, sand grain size, sand grain shape, and sand grain mineral content, if the placed sand is dissimilar from the original beach sand (Nelson and Dickerson 1988a). These changes can affect nest site selection, digging behavior, incubation temperature (and hence sex ratios), gas exchange parameters within incubating nests, hydric environment of the nest, hatching success and hatchling emerging success (Mann 1977, Ackerman 1980, Mortimer 1982, Raymond 1984a).

Beach compaction and unnatural beach profiles that may result from beach nourishment activities could adversely affect sea turtles regardless of the timing of the projects. Very fine sand and/or the use of heavy machinery can cause sand compaction on nourished beaches (Nelson *et al*. 1987, Nelson and Dickerson 1988a). Significant reductions in nesting success have been documented on severely compacted nourished beaches (Raymond 1984a). Increased false crawls result in increased physiological stress to nesting females. Sand compaction may increase the length of time required for female sea turtles to excavate nests, also causing increased physiological stress to the animals (Nelson and Dickerson 1988c).

Nelson and Dickerson (1988b) evaluated compaction levels at 10 renourished east coast Florida beaches and concluded that 50 percent were hard enough to inhibit nest digging, 30 percent were questionable as to whether their hardness affected nest digging, and 20 percent were probably not hard enough to affect nest digging. They further concluded that, in general, beaches nourished from offshore borrow sites are harder than natural beaches, and, while some may soften over time through erosion and accretion of sand, others may remain hard for 10 years or more.

On nourished beaches, steep escarpments may develop along their water line interface as they adjust from an unnatural construction profile to a more natural beach profile (Coastal Engineering Research Center 1984, Nelson *et al*. 1987). These escarpments can hamper or prevent access to nesting sites. Female turtles coming ashore to nest can be discouraged by the formation of an escarpment, leading to situations where they choose marginal or unsuitable nesting areas to deposit eggs (*e.g*., in front of the escarpments, which often results in failure of nests due to repeated tidal inundation). This effect can be minimized by leveling the beach prior to the nesting season.

Beach nourishment may cause changes to the beach profile (wider and higher) which may cause additional light to be visible from the beach and lower the apparent elevation of the landward horizon making sea finding by the hatchlings more difficult (DERM, personal communication 1998).

A change in sediment color due to beach nourishment could change the natural incubation temperatures of nests. This, in turn, could alter natural sex ratios. To provide the most suitable sediment for nesting sea turtles, the color of the nourished sediments must resemble the natural beach sand in the area. Natural reworking of sediments and bleaching from exposure to the sun would help to lighten dark nourishment sediments; however, the time frame for sediment mixing and bleaching to occur could be critical to a successful sea turtle nesting season.

Nourishment projects result in heavy machinery, pipelines, increased human activity and artificial lighting on the project beach. These activities are normally conducted on a 24-hour basis and can adversely affect nesting and hatching activities if conducted during the nesting and hatching season. Pipelines and heavy machinery can create barriers to nesting females emerging from the surf and crawling up the beach, causing a higher incidence of false crawls (non-nesting emergences) and an unnecessary energy expenditure. Heavy equipment on the beach during nesting season and hatching season can also create ruts which can trap hatchlings (DERM, personal communication 1998). Increased human activity on the project beach at night may cause further disturbance to nesting females. Artificial lights along the project beach and in the nearshore area of the borrow site may deter nesting females and disorient or misorient emergent hatchlings from adjacent non-project beaches.

Beach nourishment projects require continual maintenance (subsequent nourishment) as beaches erode; therefore their negative impacts to turtles are repeated on a regular basis. Nourishment of highly eroded beaches (especially those with a complete absence of dry beach) can be beneficial to nesting turtles if conducted properly. Careful consideration and advance planning and coordination must be carried out to ensure timing, methodology and sand sources are compatible with nesting and hatching requirements.

Artificial Lighting: Extensive research has demonstrated that the principal component of the sea finding behavior of emergent hatchlings is a visual response to light (Daniel and Smith 1947, Hendrickson 1958, Carr and Ogren 1960, Ehrenfeld and Carr 1967, Dickerson and Nelson 1989, Witherington and Bjorndal 1991). Artificial beachfront lighting from buildings, streetlights, dune crossovers, vehicles and other types of beachfront lights have been documented in the disorientation (loss of bearings) and misorientation (incorrect orientation) of hatchling turtles (McFarlane 1963, Philibosian 1976, Mann 1977, Ehrhart 1983).

The results of disorientation or misorientation are often fatal. Many lighting ordinance requirements do not become effective until 11 p.m., whereas over 30 percent of hatchling emergence occurs prior to this time (Witherington *et al.* 1990). As hatchlings head toward lights or meander along the beach, their exposure to predators and likelihood of desiccation is greatly increased. Misoriented hatchlings can become entrapped in vegetation or debris, and many hatchlings are found dead on nearby roadways and in parking lots after being struck by vehicles. Hatchlings that successfully find the water may be misoriented after entering the surf zone or while in nearshore waters. Intense artificial lighting can even draw hatchlings back out of the surf (Daniel and Smith 1947, Carr and Ogren 1960). During the period 1989 to 1990, a total of 37,159 misoriented hatchlings were reported to the Florida Department of Natural Resources (now DEP). Undoubtedly a large but unquantifiable number of additional misorientation events occurred but were not documented due to obliteration of observable sign, depredation, entrapment in thick vegetation, loss in storm drains, or obliteration of carcasses by vehicle tires.

The problem of artificial beachfront lighting is not restricted to hatchlings. In June 1992, a nesting loggerhead was killed by an automobile as it wandered onto Highway AlA at Patrick Air Force Base in Cocoa Beach, Florida, misoriented by lights from the west side of the highway. Raymond (1984a) indicated that adult loggerhead emergence patterns were correlated with variations in beachfront lighting in south Brevard County, Florida, and that nesting females avoided areas where beachfront lights were the most intense. Witherington (1986) noted that loggerheads aborted nesting attempts at a greater frequency in lighted areas. Problem lights may not be restricted to those placed directly on or in close proximity to nesting beaches. The background glow associated with intensive inland lighting, such as that emanating from nearby large metropolitan areas, may deter nesting females and disorient or misorient hatchlings crawling on nearby beaches. Cumulatively, along the heavily developed beaches of the southeastern U.S., the negative effects of artificial lights are profound. Another significant effect of heavy coastal development is the increased cutting of coastal vegetation, which blocks beachfront lighting and lowers the darker, landward horizon, thus discouraging adults from nesting and reducing hatchlings ability to find the ocean (DERM, personal communication 1998).

Beach Cleaning: Beach cleaning refers to the redistribution and periodic removal of both abiotic and biotic debris from developed beaches. There are several methods employed, including mechanical raking, hand raking, and picking up debris by hand. Mechanical raking can result in heavy machinery repeatedly traversing nests and potentially compacting sand above nests and also results in tire ruts along the beach, which may hinder or trap emergent hatchlings. Mann (1977) suggested that nest mortality may increase when beach cleaning machinery is used on soft, large-grained sand beaches. Mechanically pulled rakes and hand rakes can penetrate the surface and disturb the sealed nest or may actually uncover pre-emergent hatchlings near the surface of the nest. In some areas, collected debris is buried directly on the beach, and this can lead to excavation and destruction of incubating egg clutches. Disposal of debris near the dune line or on the high beach can cover incubating egg clutches and subsequently hinder and entrap emergent hatchlings and may alter natural nest temperatures.

Increased Human Presence: Residential and tourist use of developed (and developing) nesting beaches can result in negative impacts to nesting turtles, incubating egg clutches, and hatchlings. The most serious threat caused by increased human presence on the beach is the disturbance to nesting females. Nighttime human activity can cause nesting females to abort nesting attempts at all stages of the behavioral process. Murphy (1985) reported that disturbance can cause turtles to shift their nesting beaches, delay egg laying, and select poor nesting sites. Heavy utilization of nesting beaches by humans (pedestrian traffic) may result in lowered hatchling emerging success rates due to compaction of sand above nests (Mann 1977), and pedestrian tracks can interfere with the ability of hatchlings to reach the ocean (Hosier *et al.* 1981). Campfires and the use of flashlights on nesting beaches misorient hatchlings and can deter nesting females (Mortimer 1979).

Recreational Beach Equipment: The placement of physical obstacles (e.g., lounge chairs, cabanas, umbrellas, Hobie cats, canoes, small boats and beach cycles) on nesting beaches can hamper or deter nesting attempts and interfere with incubating egg clutches and the sea approach of hatchlings. The documentation of false crawls at these obstacles is becoming increasingly common as more recreational beach equipment is left in place nightly on nesting beaches. Additionally, there are documented reports of nesting females becoming entrapped under heavy wooden lounge chairs and cabanas on South Florida nesting beaches (NMFS and FWS 1991). The placement of recreational beach equipment directly above incubating egg clutches may hamper hatchlings during emergence and can destroy eggs through direct invasion of the nest (NMFS and FWS 1991).

Exotic Dune and Beach Vegetation: Non-native vegetation has invaded many coastal areas and often outcompetes native species such as sea oats, railroad vine, sea grape, dune panic grass and pennywort. The invasion of less stabilizing vegetation can lead to increased erosion and degradation of suitable nesting habitat. Exotic vegetation may also form impenetrable root mats which can prevent proper nest cavity excavation, invade and desiccate eggs, or trap hatchlings. The Australian pine *(Casuarina equisetifolia)* is particularly detrimental. Dense stands of this species have taken over many coastal strand areas throughout central and South Florida. Australian pines cause excessive shading of the beach that would not otherwise occur. Studies in Florida suggest that nests laid in shaded areas are subjected to lower incubation temperatures, which may alter the natural hatchling sex ratio (Marcus and Maley 1987, Schmelz and Mezich 1988). Fallen Australian pines limit access to suitable nest sites and can entrap nesting females. Davis and Whiting (1977) reported that nesting activity declined in Everglades NP where dense stands of Australian pine took over native beach berm vegetation on a remote nesting beach. Conversely, along highly developed beaches, nesting may be concentrated in areas where dense stands of Australian pines create a barrier to intense beachfront and beach vicinity lighting (NMFS and FWS 1991).

Nest Loss to Abiotic Factors: Erosion or inundation and accretion of sand above incubating nests appear to be the principal abiotic factors that may negatively affect incubating egg clutches. While these factors are often widely perceived as contributing significantly to nest mortality or lowered hatching success, few quantitative studies have been conducted (Mortimer 1989). Studies on a relatively undisturbed nesting beach by Witherington (1986) indicated that, with the exception of a late season severe storm event, erosion and inundation played a relatively minor role in destruction of incubating nests. Inundation of nests and accretion of sand above incubating nests as a result of the late season storm played a major role in destroying nests from which hatchlings had not yet emerged. Severe storm events (e.g., tropical storms and hurricanes) may result in significant nest loss, but these events are typically aperiodic rather than annual occurrences. In the southeastern U.S., severe storm events are generally experienced after the peak of the hatching season and hence would not be expected to affect the majority of incubating nests. Erosion and inundation of nests are exacerbated through coastal development and shoreline engineering. These threats are discussed above under beach armoring.

Predation: Predators, particularly exotics such as fire ants (*Solenopsis invicta*) and human-associated ones including raccoons and opossums are becoming increasingly detrimental to nesting beaches.

Poaching: In the U.S., killing of female loggerheads is infrequent. However, in a number of areas, egg poaching and clandestine markets for eggs

Table 2. Major loggerhead nest survey/protection projects in the South Florida Ecosystem, 1985 to 1990. Includes consistently monitored survey areas reporting greater than 100 nests annually. Not all beaches were surveyed during the entire 6-year period.

Project	Beach length (km)	Number of nests	Conservation measure(s)*
Sebastian Inlet SRA, FL	4.8	513-921	S/PR
Wabasso Beach, FL	8.0	1155-1256	S/PR
Vero Beach, FL	7.0	199-349	S/NR
Hutchinson Island, FL	36.5	4637-6711	S
St. Lucie Inlet SP, FL	4.3	289-432	S/PR
Hobe Sound NWR, FL	5.3	1202-1732	S/PR
Town of Jupiter Island, FL	12.1	2640-6431	S
Juno Beach, FL	8.1	2790-4664**	S
J.D. MacArthur SP, FL	2.9	496-1062	S/PR
Delray Beach, FL	3.5	138-288	S/NR
City of Boca Raton, FL	8.0	874-1100	S/NR/NS
Broward County Beaches, FL	38.6	1244-2283	S/NR/NS
Miami Area Beaches, FL	16.9	64-182	S/NR
Manasota Key, FL	18.9	312-884	S/NR
Casey Key, FL	8.2	107-459	S/NR
Sanibel Island, FL	18.5	110-137	S
Wiggins Pass Area Beaches, FL	6.4	106-215	S/NS
Keewaydin Island, FL	7.2	96-137	S/NR/NS

*S=Survey NR=Nest Relocation
**1989-1990 data only NS=Nest Screening PR=Predator Removal

are not uncommon. From 1983 to 1989, the Florida Marine Patrol, DEP, made 29 arrests for illegal possession of turtle eggs.

Disease

There is little information available to assess the comprehensive effects of disease and/or parasites on wild populations of marine turtles. The vast majority of diseases and conditions which have been identified or diagnosed in sea turtles are described from captive stock, either turtles in experimental headstart programs or mariculture facilities (Wolke 1989). One notable exception is the identification of the disease spirorchidiasis, resulting from infection with intravascular trematodes (Wolke *et al.* 1982). The observable external characteristics of this disease, however, are not exhibited in the majority of loggerhead carcasses that strand along the Atlantic and Gulf of Mexico coasts. In addition, fibropapilloma disease most comonly seen in green turtles is now emerging as a significant threat to the loggerhead.

Management

There are a number of management activities ongoing in South Florida to benefit the loggerhead sea turtle. Table 2 lists some of the major Federal, State and private nest survey and protection projects in the South Florida Ecosystem. In addition to management of coastal habitats, NMFS and FWS (1991) discuss additional conservation measures for the loggerhead turtle in the marine environment. Additional reviews of sea turtle conservation efforts in the southeastern U.S. appear in Possardt (1991).

Conservation of sea turtle nesting habitat is continuing on several NWRs in South Florida, including Archie Carr, Hobe Sound, Ten Thousand Islands, and the complex of satellite refuges in the Florida Keys. Acquisition of high-density nesting beaches between Melbourne Beach and Wabasso Beach, Florida, is continuing to complete the Archie Carr NWR. Approximately 25 percent of the loggerhead nesting in the U.S. occurs along this 33 km stretch of beach. The State of Florida purchased the first parcel specifically for the refuge in July 1990. Federal acquisition began in 1991. When completed, the refuge will protect up to 16 km of nesting beach. Since the initial acquisition, Brevard County and the Richard King Mellon Foundation have joined in as acquisition partners. Hobe

Sound NWR, located north of West Palm Beach in Martin County, contains 5.25 km of Atlantic coast shoreline for nesting habitat. In addition to providing some of the most productive sea turtle nesting habitat in the U.S., the refuge is also home to Florida scrub-jays (*Aphelocoma coerulescens*) and gopher tortoises *(Gopherus polyphemus*). The most longstanding beach management program has been to reduce destruction of nests by natural predators, such as raccoons. Control of numerous exotic plants such as Australian pine and Brazilian pepper (*Schinus terebinthifolius*) are also major issues in managing the refuge.

One of the most difficult habitat protection efforts throughout South Florida is trying to minimize or eliminate the construction of seawalls, riprap, groins, sandbags, and improperly placed drift or sand fences. State and Federal laws designed to protect the beach and dune habitat in South Florida include the Coastal Barrier Resources Act of 1982 and the Coastal Zone Protection Act of 1985. These have had varying degrees of success at maintaining suitable nesting sites for loggerheads. Prior to 1995, DEP permits were required for all coastal armoring projects prior to construction. When issuing these permits, DEP incorporated sea turtle protection measures, and sea turtle concerns were generally well addressed.

However, in 1995, the Florida Legislature passed a law giving coastal counties and municipalities the authority to approve construction of coastal armoring during certain emergency situations. (All non-emergency armoring situations must still receive a DEP permit prior to construction.). Although the new law weakened prior regulations on armoring, it does require that emergency armoring structures approved by a coastal county or municipality be temporary and that the structure be removed or a permit application submitted to DEP for a permanent rigid coastal structure within 60 days after the emergency installation of the structure.

In addition, to implement this new law, DEP finalized a formal agency rule on coastal armoring on September 12, 1996. The new rule recommends that local governments obtain the necessary approval from the FWS prior to authorizing armoring projects. The new rule also requires that several measures be undertaken to address sea turtle concerns for non-emergency armoring and for placement of permanent rigid coastal structures subsequent to an emergency (temporary) armoring event. For example, the new regulations require that (1) special conditions be placed on permitted activities to limit the nature, timing, and sequence of construction, as well as address lighting concerns; (2) structures not be used where the construction would result in a significant adverse impact, and (3) armoring be removed if it is determined to not be effective or to be causing a significant adverse impact to the beach and dune system.

Beach nourishment is a better alternative for sea turtles than seawalls and jetties. When beach nourishment was done mostly in the summer, all nests had to be moved from the beach prior to nourishment. Now FWS and State natural resource agencies review beach nourishment projects with timing in mind, such as abstaining from construction activities on the beach during the nesting and hatching season. In southeast Florida, (Indian River County through Miami-Dade County), the loggerhead nesting and hatching season is from March 15 through November 30. In southwest Florida, Gulf of Mexico (Sarasota County through Monroe County), the nesting and hatching season is from April 1 through November 30. Any management decisions regarding beach nourishment, waterway dredging involving beach disposal, beach armoring and other coastal construction, marina and dock development, and artificial lighting should consider these dates. Beaches where compaction after nourishment is a problem are plowed to a depth of 92 cm to soften the sand so that it is useable for nesting turtles (Nelson and Dickerson 1987). Progress is being made toward better timing of projects and sand quality.

Progress is being made by counties and cities to prevent disorientation and misorientation of hatchlings due to artificial lighting (Ernest *et al.* 1987, Shoup and Wolf 1987). In South Florida, lighting ordinances have been passed by Indian River, St. Lucie, Martin, Palm Beach, Broward, Monroe, Collier, Charlotte, Sarasota and Lee counties, as well as numerous municipalities. Most recently, Witherington and Martin (1996) provide a thorough discussion of the effects of light pollution on sea turtle nesting beaches and on juvenile and adult turtles. They also offer a variety of effective management solutions for ameliorating this problem.

Information on the status and distribution of the loggerhead turtle is critical to its conservation. Monitoring the various life stages of the turtles on nesting beaches is being conducted to evaluate current and past management practices. Data are collected on the number of nests laid, the number of nests that successfully hatch, and the production of hatchlings reaching the ocean. In addition, long-term tagging studies have determined many population attributes for nesting loggerheads (Richardson 1982). Research on hatchling orientation and nesting behavior and how various wavelengths of light affect them is providing needed information to managers (Witherington and Bjorndal 1991, Witherington 1992).

The number of nesting females is determined by knowing the rangewide nesting effort and dividing by the average number of nests a female lays each season (Hopkins and Richardson 1984). Nests can be counted by both aerial and ground surveys. Estimates of nesting females were made from rangewide aerial surveys made in 1980 (Powers 1981), 1982 (Thompson 1983) and 1983 (Murphy and Hopkins 1984). Standardized ground surveys on index beaches are underway throughout the Southeast by the FWS, DEP, county and local agencies, and by private groups and universities. Index beaches include 80 percent of the nesting activity in Florida. Because of turtles' slow growth rates and subsequent delayed sexual maturity, all monitoring will need to be conducted over a long period of time to establish population trends for loggerheads.

Mortality of loggerhead turtles has been monitored since 1980 through the implementation of a regional data collection effort. This voluntary stranding network from Maine to Texas is coordinated by the NMFS and serves to document the geographic and seasonal distribution of sea turtle mortality (Schroeder 1987). DEP is primarily responsible for coordination of the stranding and salvage network in South Florida. Since 1987, four index zones have been systematically surveyed. It is clear that strandings represent an absolute minimum mortality. However, they can be used as an annual index to mortality and are an indication of the size and distribution of turtles being killed. They can also provide valuable biological information on food habits, reproductive condition, and sex ratios.

Public support for sea turtle conservation efforts is essential for the long-term success of conservation programs. This is particularly true when conservation measures are controversial or expensive. To heighten public awareness and understanding of sea turtle conservation issues, a number of educational activities and efforts are underway. For example, personnel conducting turtle projects often advise tourists on what they can do to minimize disturbance to nesting turtles, protect nests and prevent hatchlings from being disoriented. Likewise, State and Federal parks which conduct public awareness sea turtle interpretive walks provide information to visitors. The DEP has developed guidelines for organized sea turtle interpretive walks in order to minimize any disturbance to nesting turtles while still allowing them to be viewed by the public. Many beaches have been posted with signs informing people of the laws protecting sea turtles and providing either a local or a hotline number to report violations.

Private conservation organizations, such as the Center for Marine Conservation, Greenpeace, National Audubon Society, and Federal and State agencies have produced and distributed a variety of audio-visual aids and printed materials about sea turtles. These include: the brochure “Attention Beach Users,” a booklet (Raymond 1984b) on the various types of light fixtures and ways of screening lights to lessen their effects on hatchings, “Lights Out” bumper stickers and decals, a coloring book, video tapes, slide/tape programs, full color identification posters of the different species of sea turtles, and a hawksbill poster. Florida Power and Light Company also has produced a booklet (Van Meter 1990) and two leaflets with information on sea turtles, as well as a coastal roadway lighting manual.

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Recovery for the Loggerhead Sea Turtle

Caretta caretta

Recovery Objective: **DELIST** the species once recovery criteria have been met.

South Florida Contribution: **SUPPORT** delisting actions.

Recovery Criteria

The South Florida recovery contribution parallels the existing recovery plans for sea turtles. South Florida's objective for the loggerhead, green, leatherback and hawksbill sea turtles will be achieved when: the level of nesting for each species is continuously monitored and increases to the species-specific recovery goal; beaches supporting greater than 50 percent of the nesting activity are in public ownership; all important nesting beaches are protected and appropriately managed to prevent further degradation; non-native nuisance species have been controlled or eliminated on public lands; at least 60 percent hatch success is documented on major nesting beaches; effective lighting ordinances or lighting plans are implemented; and beaches are restored or rehabilitated to be suitable for nesting where appropriate.

Species-level Recovery Actions

S1. **Continue standardized surveys of nesting beaches.** Nesting surveys are undertaken on the majority of nesting beaches. In the past, beach coverage varied from year to year, as did the frequency of surveys, experience and training of surveyors, and data reporting. Consequently, no determination of nesting population trends had been possible with any degree of certainty. However, in 1989, to better assess trends in nesting, DEP, in cooperation with FWS, initiated an Index Nesting Beach Survey (INBS) program to collect nesting data that could be used to statistically and scientifically analyze population trends. The INBS program should continue to gather a long-term data base on nesting activities in Florida that can be used as an index of nesting population trends.

S2. **Protect and manage populations on nesting beaches.** Predators, poaching, tidal inundation, artificial lighting, and human activities on nesting beaches diminish reproductive success. Monitoring of nesting activity is necessary to implement and evaluate appropriate nest protection measures and determine trends in the nesting population.

S2.1. **Evaluate nest success and implement appropriate nest protection measures.** Nesting and hatching success and hatchling emerging success on beaches occurring on State or Federal lands and all other important local or regional nesting beaches should be evaluated. Appropriate nest protection measures should be implemented by FWS and DEP, and appropriate local governments or organizations, to ensure greater than 60 percent hatch rate. Until recovery is ensured, however, projects on all Federal and State lands and key nesting beaches, such as those in Brevard, Indian River, St. Lucie, Martin, and Palm Beach Counties, should strive for a higher rate of hatching success. In all cases, the least manipulative method should be employed to avoid interfering with known or unknown natural biological processes. Artificial incubation should be avoided. Where beach hatcheries are necessary, they should be located and constructed to allow self release, and hatch rates approaching 90 percent should be attained. Nest protection measures should always enable hatchling release the same night of hatching.

S2.2. **Determine influence of factors such as tidal inundation and foot traffic on hatching success.** Tidal inundation can diminish hatching success, depending on frequency, duration and developmental stage of embryos. Some nests are relocated due to the perceived threat from tides. The extent to which eggs can tolerate tidal inundation needs to be quantified to enable development of guidelines for nest relocation relative to tidal threats. The effect of foot traffic on hatching success is unknown, although many beaches with significant nesting also have high public use. FWS should support research and, in conjunction with DEP, develop recommendations for nest protection from tidal threat and foot traffic.

S2.3. **Reduce effects of artificial lighting on hatchlings and nesting females.** Studies have shown that light pollution can deter female sea turtles from coming onto the beach to nest; in fact, brightly lit beaches have been determined to be used less frequently for nesting. Also, females attempting to return to sea after nesting can be disoriented by beach lighting and have difficulties making it back to the ocean. In some cases, nesting females have ended up on coastal highways and been struck by vehicles. Artificial beach lighting is even more detrimental to hatchling sea turtles, which emerge from nests at night. Under natural conditions, hatchlings move toward the brightest, most open horizon, which is over the ocean. However, when bright light sources are present on the beach, they become the brightest spot on the horizon and attract hatchlings in the wrong direction, making them more vulnerable to predators, desiccation, exhaustion, and vehicles.

S2.3.1. **Implement and enforce lighting ordinances and resolve lighting problems in areas where lighting ordinances have not been adopted.** FWS and DEP should identify and resolve artificial lighting impacts to sea turtles in South Florida. Since 1987, hatchling disorientation incidents observed by DEP marine turtle permit holders and park personnel have been reported through standardized reporting forms. Report forms serve as documentation for lighting problems on nesting beaches and allow the identification of specific problem light sources. FWS and DEP should use these report forms to locate and resolve lighting problems, with the help of local governments, through public education efforts, and by directly contacting the owners of the problem lights and making recommendations for their modification. FWS and DEP should also proactively conduct pre-season lighting inspections to identify and make recommendations for correcting problem light sources before they result in disorientation events.

Where lighting ordinances have been adopted and enforced, hatchling disorientation and misorientation have been drastically reduced. All coastal counties and communities with nesting beaches should adopt ordinances (March through October on the Atlantic Coast and May through October on the Gulf Coast). Many incorporated communities within Broward and Palm Beach counties, Florida, are particularly problematic because of the high-density nesting beaches and the lack of effective lighting regulations. DEP should ensure appropriate lighting on new construction projects.

S2.3.2. Evaluate extent of hatchling disorientation and misorientation on all important nesting beaches. FWS, DEP, and counties should continue to evaluate hatchling disorientation and misorientation problems on all important nesting beaches. Many lighting ordinance requirements do not become effective until 11 p.m., whereas over 30 percent of hatchling emergence occurs prior to this time (Witherington *et al*. 1990). FWS, DEP, and county governments should also support research to gather additional quantitative data on hatchling emergence times and nesting times on representative beaches throughout South Florida to support the most effective time requirements for lighting ordinances.

S2.3.3. Prosecute individuals or entities responsible for hatchling disorientation and misorientation under the Endangered Species Act or appropriate State laws. Hatchling disorientation and misorientation from artificial lights can cause high mortality and be the major source of hatchling mortality on some nesting beaches if not controlled. Law enforcement efforts should be focused where lighting ordinances are not being implemented or enforced on major nesting beaches and where repeated violations are not corrected.

S2.4. Ensure beach nourishment and coastal construction activities are planned to avoid disruption of nesting and hatching activities. These activities can cause significant disruption of nesting activities during the nesting season when viewed cumulatively over the nesting range. Nest relocation can involve manipulation of large numbers of nests, which can result in lowered hatch success and altered hatchling sex ratios, and therefore is not an acceptable alternative to altering the timing of projects during the peak nesting period. COE, FWS, and DEP should ensure beach nourishment and other beach construction activities are not permitted during the nesting season on important nesting beaches.

S2.5. Ensure law enforcement activities eliminate poaching and harassment. Poaching, while not a significant cause of nest loss regionally, is occasionally a local problem. Poaching has been repeatedly reported around the Ten Thousand Islands NWR and adjacent islands in southwest Florida. In addition, intentional and unintentional disturbance and harassment of nesting turtles is an increasing problem on many beaches. FWS should work closely with DEP to identify problem areas and focus intensive law enforcement efforts to eliminate poaching and deter harassment of nesting turtles.

S3. Continue to gather information on species and population biology.

S3.1. Determine etiology of fibropapillomatosis. Research on the sea turtle fibropapilloma disease should be continued and expanded. Fibropapillomatosis (FP) is a disease of sea turtles characterized by the development of multiple tumors on the skin and also internal organs, most frequently the lungs and kidneys. The tumors interfere with swimming, eating, breathing, seeing, and reproduction, and turtles with heavy tumor burdens become severely debilitated and die. FP has seriously impacted green turtle populations in Florida (about 50 percent of juvenile green turtles in Indian River Lagoon and Florida Bay have fibropapillomas) and is now emerging as a significant threat to the loggerhead as well. FP is a transmissible disease caused by a virus, and, while both a unique herpesvirus and retroviruses have been identified in FP tumors, neither has yet been proven to be the cause of the disease. Researchers are concerned that there may be environmental (contaminant) cofactors for this disease in nearshore areas. Continuation and expansion of research on the disease is essential to developing an approach to remedying the problem.

S3.2. Maintain the Sea Turtle Stranding and Salvage Network. Most accessible U.S. beaches in the Atlantic and Gulf of Mexico are surveyed for stranded sea turtles by volunteer or contract personnel. Through the Sea Turtle Stranding and Salvage Network, stranding data are archived and summarized by the NMFS Miami Laboratory. These data provide an index of sea turtle mortality and are thought to be a cost-effective means of evaluating the effectiveness of the Turtle Exclusion Device (TED) regulations. These data also provide basic biological information on sea turtles and are useful in determining other sources of mortality. The systematic stranding surveys of index areas need to be continued in South Florida. Periodic review of the efficacy of surveys should also be conducted.

S3.3. Centralize administration and coordination of tagging programs. Sea turtle researchers commonly tag turtles encountered during their research projects, and usually maintain independent tagging data bases. The lack of centralization for administering these tagging data bases often results in confusion when tagged turtles are recaptured, and delays in reporting of recaptures to the person originally tagging the turtle. NMFS and FWS should investigate the possibilities of establishing a centralized tagging data base, including Passive Integrated Transponder (PIT) tags.

S3.3.1. Centralize tag series records. A centralized tag series data base is needed to ensure that recaptured tagged turtles can be promptly reported to persons who initially tagged the animal. The tag series data base would include listings of all tag series that have been placed on sea turtles in the wild, including the name and address of the researcher. This would eliminate problems in determining which researcher is using which tag series or types of tags, and would preclude unnecessary delays in reporting of tag returns. NMFS and/or FWS should establish and maintain this data base.

S3.3.2. Centralize turtle tagging records. In addition to the need for a centralization of tag series records, there are advantages in developing a centralized turtle tagging data base. Such a data base would allow all turtle researchers to trace unfamiliar tag series or types to their source, and also to have immediate access to important biological information collected at the time of original capture. The major disadvantage is that this data base would require frequent editing and updating, and would be costly and somewhat time consuming to maintain. It would also make it possible for unethical researchers to exploit the work of others, while providing no guarantees that such contributions would be acknowledged. NMFS and FWS should determine whether such a data base can be established and is feasible to maintain.

S3.4. **Develop requirements for care and maintenance of turtles in captivity, including diet, water quality, tank size, and treatment of injury and disease.** Sea turtles are maintained in captivity for rehabilitation, research, or educational display. Proper care will ensure the maximum number of rehabilitated turtles can be returned to the wild and a minimum number removed from the wild for research or education purposes. None of these requirements has been scientifically evaluated to determine the best possible captive conditions for sea turtles. FWS and NMFS should support the necessary research to develop these criteria, particularly relating to diet and the treatment of injury and disease. These criteria should be published and required for any permit to hold sea turtles in captivity. FWS, NMFS and/or DEP should inspect permitted facilities at least annually for compliance with permit requirements.

S4. **Monitor trends in nesting activity.** DEP and FWS should continue to refine standardized nest survey criteria, identify additional index survey beaches to be monitored, and continue to conduct training workshops for surveyors. Consequently, DEP and FWS should ensure that routine monitoring of nesting beaches is done on at least a weekly basis during the nesting period of the loggerhead turtle, and any nesting period outside of their regular survey period.

S5. **Continue information and education activities.** Sea turtle conservation requires long-term public support over a large geographic area. The public must be factually informed of the issues, particularly when conservation measures conflict with human activities, such as commercial fisheries, beach development, and public use of nesting beaches. Public education is the foundation upon which a long-term conservation program will succeed or fail.

S5.1. **Update existing slide programs and information leaflets on sea turtle conservation for the general public.** FWS has developed a bilingual slide tape program on sea turtle conservation and should keep the program current and available for all public institutions and conservation organizations. FWS and DEP should continually update and supply the public with informational brochures on sea turtle ecology and conservation needs.

S5.2. **Disseminate information from brochures and reports on recommended lighting modifications or measures to reduce hatchling disorientation and misorientation.** Recently published literature contains information on the types of light, screening or shading that is best for turtles (*e.g.*, Witherington and Martin 1996).

S5.3. **Develop public service announcements (PSA) regarding the sea turtle artificial lighting conflict and disturbance of nesting activities by public nighttime beach activities.** A professionally produced public service announcement for radio and TV would provide tremendous support and reinforcement of the many coastal lighting ordinances. It would generate greater support through understanding. FWS should develop a high-quality PSA that could be used throughout the Southeast during the nesting season.

S5.4. **Ensure facilities permitted to hold and display captive sea turtles have appropriate informational displays.** Over 50 facilities are permitted to hold sea turtles for rehabilitation, research, and public education. Many are on public display and afford opportunities for public education. Display of accurate information on the basic biology and conservation problems should be a requirement of all permittees. All facilities should be visited by FWS, NMFS and/or DEP to ensure captive sea turtles are being displayed in a way to meet these criteria.

S5.5. **Ensure standard criteria and recommendations for loggerhead sea turtle nesting interpretive walks are being implemented.** Sea turtle walks are popular with the public and afford tremendous opportunities for public education or, if poorly conducted, misinformation. DEP has developed standard criteria for permittees conducting walks. These objective criteria should continue to be used, and DEP should continue to evaluate sea turtle walks to ensure they are professional, provide accurate biological information, convey an accurate conservation message, and are a positive experience. Just as importantly they should not cause unnecessary or significant disturbance to nesting turtles.

S5.6. **Post informational signs at public access points on nesting beaches.** Public access points to nesting beaches provide excellent opportunities to inform the public of necessary precautions for compatible public use on the nesting beach and to develop public support through informational and educational signs. FWS, NPS, DEP and other appropriate organizations should post such educational and informational signs on nesting beaches as appropriate.

Habitat-level Recovery Actions

H1. **Protect and manage nesting habitat.** Coastal development has already destroyed or degraded many miles of nesting habitat in South Florida. Although sea turtle nesting occurs on over 2,240 km of beaches within the southeast United States, development pressures are so great that cumulative impacts could result in increased degradation or destruction of nesting habitat and eventually lead to a significant population decline if not properly managed.

H1.1. **Ensure beach nourishment projects are compatible with maintaining good quality nesting habitat.** Beach nourishment can improve nesting habitat in areas of severe erosion and is a preferred alternative to beach armoring. However, placement of sand on an eroded section of beach or an existing beach in and of itself may not provide suitable nesting habitat for sea turtles. Although beach nourishment may increase the potential nesting area, significant negative impacts to sea turtles may result if protective measures are not incorporated during construction.

H1.1.1. **Evaluate sand transfer systems as an alternative to beach nourishment.** Sand transfer systems can diminish the necessity for frequent beach renourishment, thereby reducing disruption of nesting activities. This system also minimizes sand compaction while adding sand to downdrift beachs. The construction and operation of these systems must be carefully evaluated to ensure important nearshore habitats are not degraded or sea turtles injured or destroyed.

H1.1.2. **Refine a sand budget formulation methodology for Sebastian Inlet.** Inlets interrupt the natural flow of longshore sediment transport along the shoreline. The interrupted flow of sand is diverted either offshore in ebb tide shoals, into bays or lagoons in flood tide shoals, or in navigation channels (National Research Council 1990). As a result, erosion occurs downdrift of the interrupted shoreline. There are six man-made inlets on the Atlantic coast from Indian River County to Broward County. In Indian River County, for example, erosion has been nearly 2 m per year at Sebastian Inlet SRA (just south of Sebastian Inlet), when the average erosion rate for the county is just under .3 m per year. DEP, Sebastian

Inlet Tax District, and Indian River County should conduct engineering studies to refine a sand budget formulation methodology for the Sebastian Inlet. Other needs include: annually bypassing sand to downdrift beaches, conducting further studies of the long-term effects of the flood shoal on the inlet-related sediment budget, identifying the long-term impacts of sand impoundment and sediment volume deficit to downdrift areas, and determining the area of inlet influence.

H1.2. **Prevent degradation of nesting habitat from seawalls, revetments, sand bags, sand fences or other erosion-control measures.** One of the most difficult habitat protection efforts throughout South Florida is trying to minimize or eliminate the construction of seawalls, riprap, groins, sandbags, and improperly placed drift or sand fences. In 1995, the Florida Legislature passed a law giving coastal counties and municipalities the authority to approve construction of coastal armoring during certain emergency situations. (All non-emergency armoring situations must still receive an DEP permit prior to construction.) Although the new law weakened prior regulations on armoring, it does require that emergency armoring structures approved by a coastal county or municipality be temporary and that the structure be removed, or a permit application submitted to DEP for a permanent rigid coastal structure, within 60 days after the emergency installation of the structure. In addition, to implement this new law, DEP finalized a formal agency rule on coastal armoring on September 12, 1996.

H1.2.1. **Ensure laws regulating coastal construction and beach armoring are enforced.** The 1996 DEP rule recommends that local governments obtain an incidental take permit from FWS under section 10 of the Endangered Species Act and develop a sea turtle habitat conservation plan prior to authorizing armoring projects. The new rule also requires that several measures be undertaken to address sea turtle concerns for non-emergency armoring and for placement of permanent rigid coastal structures subsequent to an emergency (temporary) armoring event. For example, the new regulations require that (1) special conditions be placed on permitted activities to limit the nature, timing, and sequence of construction, as well as address lighting concerns; (2) structures not be used where the construction would result in a significant adverse impact; and (3) armoring be removed if it is determined to not be effective or to be causing a significant adverse impact to the beach and dune system.

H1.2.2. **Ensure failed erosion control structures are removed.** Failed erosion control structures such as uncovered plastic bags or tubes and fragmented concrete or wooden structures degrade nesting habitat and deter nesting activities. DEP should ensure failed structures are removed from nesting beaches.

H1.2.3. **Develop standard requirements for sand fence construction.** Sand fences can effectively build dune systems and improve nesting habitat; however, improperly designed sand fences can trap nesting females or hatchlings and prevent access to suitable nesting habitat. DEP and FWS should develop and evaluate sand fencing designs and establish standard requirements for sand fence construction.

H1.3. Identify important nesting beaches experiencing greater than 40 percent nest loss from erosion and implement appropriate habitat restoration measures. Some important nesting beaches now suffer severe erosion as a result of inlet maintenance or jetty construction. In some situations, limited safe locations for relocating nests place constraints on nest relocation programs. Nest relocation programs should be considered as a short-term measure at best to protect nests in these situations, with primary efforts directed toward habitat restoration. DEP and FWS should review all important nesting beaches and identify those with 40 percent or more nest loss due to erosion or tidal inundation. Habitat restoration plans should be developed and implemented for identified nesting beaches.

H1.4. Acquire or otherwise ensure the long-term protection of important nesting beaches. Acquisition of important sea turtle nesting beaches would ensure long-term protection of U.S. nesting habitat. Acquisition and protection of undisturbed nesting habitat would enhance sea turtle nesting and hatching success.

H1.4.1. Continue to acquire in fee title all undeveloped beaches between Melbourne Beach and Wabasso Beach, Florida, for the Archie Carr National Wildlife Refuge. The Archie Carr NWR was designated by Congress in 1989 in recognition of the need for long stretches of quiet, undisturbed sandy beaches, with little or no artificial lighting, to ensure the reproductive success and survival of sea turtles. The refuge is located within a 33-km stretch of beach on the barrier islands of Brevard and Indian River Counties on the Atlantic coast of Florida. Approximately 25 percent of all loggerhead nesting in the U.S. occurs along this stretch of beach. The proposed acquisition plan for the refuge set a goal for purchase of 15 km within four sections of this 33-km stretch. Three of the sections are located in Brevard County and one in Indian River County.

Partners in the land acquisition effort for the refuge and adjacent buffer areas on the barrier island include FWS, DEP, Brevard County, Indian River County, Richard King Mellon Foundation, The Conservation Fund, and The Nature Conservancy. To date, contributions from the State of Florida and local county partnerships account for over 70 percent of land acquisition expenditures, while contributions from the Richard King Mellon Foundation account for over 21 percent of acquisition costs for lands on the barrier island. Federal acquisition efforts account for about 8 percent of purchases to date.

About 61 percent of the available beachfront acquisitions for the refuge have been completed. Of the original 15 km of beachfront identified for acquisition, approximately 8 km have been acquired and 5 km are awaiting purchase. The remaining lands have been purchased for private development and are no longer available. Escalating coastal development in Brevard and Indian River counties threatens the remaining parcels identified for acquisition. Ongoing development continues to fragment the remaining habitat and could result in increased lighting and beach armoring, which negatively impact sea turtles. A narrow window of opportunity is left to acquire the last remaining lands required for the refuge.

H1.4.2. Evaluate the status of the high density nesting beaches on Hutchinson Island, Florida, and develop a plan to ensure its long-term protection. Approximately 10 percent of loggerhead turtle nesting in the United States occurs along this 32-km beach. Development is degrading nesting habitat, and public use is causing significant disturbance to nesting activities. DEP and FWS should evaluate the threats and take appropriate measures, including acquisition, to ensure long-term protection.

H1.4.3. Evaluate status of other undeveloped beaches that provide important habitat for maintaining the historic nesting distribution and develop a plan for long-term protection. DEP and FWS should evaluate other nesting beaches in the Southeast that contribute significantly to the historic nesting distribution to ensure long-term protection.

H2. Restore areas to suitable habitat.

H2.1. Reestablish dunes and native vegetation. Dune restoration and revegetation with native plants should be a required component of all renourishment projects. This will enhance beach stability and nesting habitat and may result in the need for less frequent renourishment activities.

H2.2. Remove exotic vegetation and prevent spread to nesting beaches. Australian pine trees shade nests and can alter natural hatchling sex ratios. Australian pines also aggressively replace native dune and beach vegetation through shading and chemical inhibition and consequently exacerbate erosion and loss of nesting habitat. Erosion can topple trees and leave exposed roots that can entrap nesting females. Removal of exotics, such as is ongoing at St. Lucie Inlet SP, Hobe Sound NWR, and Dry Tortugas NP, Florida, should continue. DEP, FWS, and NPS should identify other important nesting beaches where exotic vegetation is degrading nesting habitat and work with responsible parties to restore natural vegetation.

H3. Conduct research to evaluate the relationship of sand characteristics (including aragonite) and female nesting behavior, nesting success, hatching success, hatchling emerging success, hatchling fitness, and sex ratios. Beach nourishment may result in changes in sand density (compaction), beach shear resistance (hardness), beach moisture content, beach slope, sand color, sand grain size, sand grain shape, and sand grain mineral content if the placed sand is dissimilar from the original beach sand. These changes could result in adverse impacts on nest site selection, digging behavior, clutch viability, and emergence by hatchlings. Gas diffusion of nests could be affected by sand grain shape, size, and compaction and variations could alter hatching success. Sand color and moisture influence nest incubation temperature and can affect hatchling sex determination. The effect of importing non-native materials, such as aragonite, to U.S. beaches for beach nourishment adds additional unknowns that could conceivably affect female nesting behavior, nesting success, hatching success, hatchling emerging success, hatchling fitness and sex ratios, and should be fully evaluated before large-scale use.

Studies of alternative sand sources for beach renourishment and their suitability for sea turtles are needed. After years of beach renourishment, Miami-Dade County is running out of suitable sand material for future renourishment projects. Broward and Palm Beach counties will also be running out of sand sources in the near future. COE is exploring the potential use of sand from upland sand sources and the importation of sand from the Bahamas and the Turks and Caicos Islands. Concerns have been raised about the long-term consequences to nesting and incubating sea turtles using these alternative beach renourishing materials. In order to adequately address these concerns in section 7 consultations, studies must be conducted on the suitability of these materials prior to receiving a proposal for large-scale nourishment of Florida beaches with these alternative sand sources.