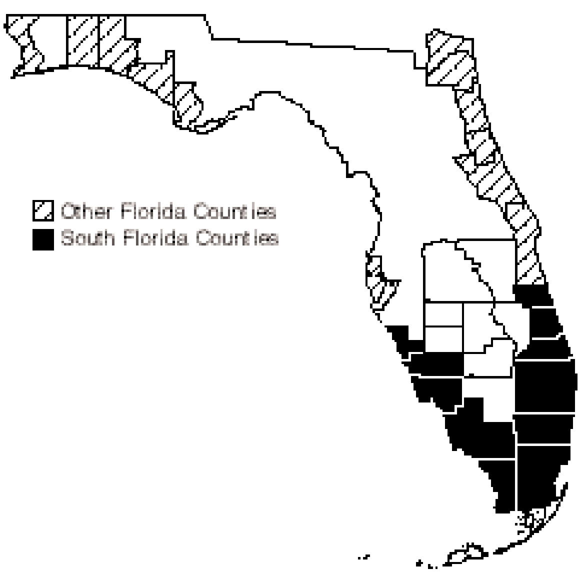
Green Sea Turtle

Chelonia mydas

Federal Status:	**Endangered (Florida, Pacific coast of Mexico; July 28, 1978) Threatened (except as above; July 28, 1978)**
Critical Habitat:	**Designated (September 1998): Waters of Culebra Island, Puerto Rico, and its outlying keys.**
Florida Status:	**Endangered**
Recovery Plan Status:	**Contribution: May 1999**
Geographic Coverage:	**South Florida**

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



The green sea turtle nests regularly in South Florida, predominantly on the east coast between Volusia and Broward counties. The green sea turtle accounts for about 1.9 percent of total nesting reported statewide. The green turtle nesting and hatching season in South Florida extends from May through November. Sea turtles, in general, are susceptible to anthropogenic impacts in the marine environment, as well as on their nesting beaches. This account provides an overview of the biology of the green sea turtle throughout its range. The discussion of environmental threats and management activities, however, pertains only to South Florida. Serious threats to the green sea turtle on South Florida's nesting beaches include: artificial lighting, beach nourishment, beach armoring, increased human presence, and exotic beach and dune vegetation.

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

Description

The green turtle is among the largest of the sea turtles; adults commonly reach 1 m in carapace length and 150 kg in mass. The mean size of female green turtles nesting in Florida is 1.5 m standard straight carapace length and 136.1 kg body mass (Witherington and Ehrhart 1989). Hatchling green turtles weigh approximately 25 g, and the carapace is about 50 mm long. The dorsal surface is black, and the ventral surface is white. The plastron of Atlantic green turtles remains a yellowish white throughout life, but the carapace changes in color from solid black to a variety of shades of grey, green, brown and black in starburst or irregular patterns.

Characters that distinguish the green turtle from other sea turtle species are a smooth carapace with four pairs of lateral (or costal) scutes and a single pair of elongated

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prefrontal scales between the eyes. The nuchal scute does not touch the first costal scute and the inframarginal scutes do not have pores. Each flipper has a single claw and the carapace is oval-shaped and depressed. The crawls of nesting green turtles are deeply cut, with symmetrical diagonal marks made by the front flippers (Pritchard *et al.* 1983).

Taxonomy

The green sea turtle was described by Linnaeus in 1758 as *Testudo mydas* with Ascension Island as the type locality. Schweigger first applied the binomial we use today, *Chelonia mydas,* in 1812. The taxonomic status of the green turtle is not clear. There is believed to be little genetic exchange among isolated breeding colonies, and, thus, these colonies may deserve sub-specific recognition. Although trinomials have been applied to various populations in the past, they are generally not in use today. Advances in DNA research are helping to solve these taxonomic questions by identifying genetically isolated populations. For a complete discussion of the systematics of green turtles, see Pritchard and Trebbau (1984) and Hirth (1980a).

Distribution

The green sea turtle is a circum-global species in tropical and sub-tropical waters. The worldwide distribution of green turtles has been described by Groombridge (1982). In the U.S., green turtles are found around the U.S. Virgin Islands and Puerto Rico, and in the continental U.S. from Texas to Massachusetts. Areas that are known as important feeding areas for green turtles in Florida include: Indian River Lagoon, the Florida Keys, Florida Bay, Homosassa River, Crystal River and Cedar Key.

Major green turtle nesting colonies in the Atlantic occur on Ascension Island, Aves Island, Costa Rica and Surinam. In U.S. Atlantic waters, green turtles nest in small numbers in the U.S. Virgin Islands and in Puerto Rico. Although they nest in all coastal counties in South Florida (Figure 1), the largest nesting occurs along the east coast of Florida, particularly in Brevard, Indian River, St. Lucie, Martin, Palm Beach and Broward counties. Nesting along the southwest coast of Florida was documented for the first time in 1994 (Foley 1997).

Habitat

Green turtles occupy three habitat types: high-energy oceanic beaches, convergence zones in the pelagic habitat, and benthic feeding grounds in relatively shallow, protected waters. Females deposit egg clutches on high-energy beaches, usually on islands, where a deep nest cavity can be dug above the high water line. Hatchlings leave the beach and apparently move into convergence zones in the open ocean where they spend an undetermined length of time (Carr 1986). When turtles reach a carapace length of approximately 20 to 25 cm, they leave the pelagic habitat and enter benthic feeding grounds. These foraging habitats are commonly pastures of seagrasses and/or algae, but

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

small green turtles can also be found over coral reefs, worm reefs, and rocky bottoms. Some feeding grounds only support certain size classes of green turtles; the turtles apparently move among these foraging areas--called developmental feeding grounds--as they grow. Other feeding areas, such as Miskito Cays, Nicaragua, support a complete size range of green turtles from 20 cm to breeding adults. Coral reefs or rocky outcrops near feeding pastures are often used as resting areas, both at night and during the day.

Critical Habitat

Critical habitat was designated for the green sea turtle in September 1998. Although this designation does not include Florida, is does include the waters of Culebra Island, Puerto Rico, and its outlying keys. Critical habitat for green sea turtles identifies specific areas which have those physical or biological features essential to the conservation of the green sea turtle and/or may require special management considerations.

Behavior

The discussion of behavior in this account is brief. Several excellent reviews of the biological characteristics of green turtles that have been published in recent years include Hirth 1980a, Groombridge 1982, Ogren 1984, Pritchard and Trebbau 1984, and Ehrhart and Witherington 1992.

Reproduction and Demography

Female green turtles emerge on nesting beaches at night to deposit eggs; the process takes an average of two hours. Descriptions of the behavioral sequences have been reviewed by Ehrhart (1982). From one to seven clutches are deposited within a breeding season at 12 to 14 day intervals. The average number is usually given as two to three clutches (Carr *et al.* 1978), but accurate data on the number of clutches deposited per season are difficult to obtain. Mean clutch size is usually 110 to 115 eggs, but this average varies among populations. Average clutch size reported for Florida was 136 eggs in 130 clutches (Witherington and Ehrhart 1989). Only occasionally do females produce clutches in successive years. Usually 2 to 4, or more years intervene between breeding seasons. Mating occurs in the water off the nesting beaches. Very little is known about the reproductive biology of males, but it is thought that males may migrate to the nesting beach every year (Balazs 1983). Hatching success of undisturbed nests is usually high, but on some beaches, predators destroy a high percentage of nests (Stancyk 1982). Large numbers of nests are also destroyed by inundation and erosion. Temperature-dependent sex determination has been demonstrated for green turtles (see review in Standora and Spotila 1985). Eggs incubated below a pivotal temperature—which may vary among populations—produce primarily males, and eggs incubated above the pivotal temperature produce primarily females. Reviews of the reproductive biology of green turtles can be found in Hirth (1980b), Ehrhart (1982) and Bjorndal and Carr (1989).

Growth rates of pelagic-stage green turtles have not been measured under natural conditions. However, growth rates of green turtles have been measured on the benthic feeding grounds. Green turtles grow slowly. In the southern Bahamas, green turtles grew from 30 to 75 cm in 17 years, and growth rate decreased with increasing carapace length (Bjorndal and Bolten 1988). Growth rates measured in green turtles from Florida (Frazer and Ehrhart 1985), U.S. Virgin Islands (Boulon and Frazer 1990) and Puerto Rico (Collazo *et al.* 1992) fall within the range of growth rates measured in the southern Bahamas (Bjorndal and Bolten 1988). Based on growth rate studies of wild green turtles, estimates of age at sexual maturity range from 20 to 50 years (Balazs 1982, Frazer and Ehrhart 1985).

Migration

The navigation feats of the green turtle are well known, but poorly understood. We know that hatchlings and adult females on the nesting beach orient toward the ocean using photic cues (Ehrenfeld 1968, Mrosovsky and Kingsmill 1985). We do not know what cues are employed in pelagic movements, in movements among foraging grounds, or in migrations between foraging grounds and nesting beaches. Because green turtles nest on high energy beaches and feed in quiet, low-energy marine pastures, these areas tend to be located some distance apart. Green turtles that nest on Ascension Island forage along the coast of Brazil, some 1,000 km away (Carr 1975). Genetic analysis using restriction fragment analysis and direct sequencing of mitochondrial DNA have shown that green turtles return to nest on their natal beaches (Allard *et al.* 1994, Bowen *et al.* 1989, Bowen *et al.* 1992, Meylan *et al*. 1990).

Foraging

It is assumed that post-hatchling, pelagic-stage green turtles are omnivorous, but there are no data on diet of this age class. It is known that once green turtles shift to benthic feeding grounds they are herbivores. They feed on both seagrasses and algae. Information on diet and nutrition of green turtles has been reviewed (Mortimer 1982a, Bjorndal 1985). The location of the foraging grounds of green turtles that nest in Florida is not known.

A population of juvenile green turtles (2-60 kg) forage as herbivores in the central Indian River Lagoon near Sebastian (Ehrhart *et al*. 1986), from Mosquito Lagoon in Brevard County south to Palm Beach County, and along coastal areas of Sabelleriid worm reefs and anastasia rock (A. Meylan, DEP, personal communication 1998). Post-nesting females have recently been tracked by satellite telemetry from the beaches of the Archie Carr NWR to the shallow, benthic habitats of the Florida Keys (P. Tritaik, FWS, personal communication 1998).

Relationship to Other Species

In South Florida, the green sea turtle shares nesting beaches with the threatened loggerhead sea turtle (*Caretta caretta*) in every county where it nests, and with the endangered leatherback sea turtle (*Dermochelys coriacea*), most commonly 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, foxes, ants, and ghost crabs prey on incubating eggs and hatchling sea turtles. The principal predator of sea turtle eggs, the raccoon, may take up to 96 percent of all eggs 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, certain predators may take considerable numbers of hatchlings just prior to or upon emergence from the sand.

Predation of hatchling 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, killer whales, bass, and grouper. Tiger sharks appear to be the principal predator of subadult and adult turtles. While stranded turtles may exhibit shark-inflicted injuries, caution must be exercised in attributing a cause of death, as these wounds can be inflicted postmortem.

Table 1. Average number of green sea turtle nests by county from 1985 to 1995.

County	Average
Indian River	55
St. Lucie	48
Martin	163
Palm Beach	301
Broward	58
Miami-Dade	4.5
Monroe	6.5
Collier*	9
Lee**	3.5
Charlotte*	9
Sarasota*	5

*Nesting activity reported from 1994 only
**Nesting activity reported from 1994-1995 only

Status and Trends

The green turtle is listed as endangered by the International Union for Conservation of Nature and Natural Resources (IUCN) and is listed on Appendix I of the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES). On July 28, 1978 (43 FR 32800), under the U.S. Endangered Species Act of 1973, the green sea turtle was listed as threatened except for the breeding populations in Florida and on the Pacific coast of Mexico, where they were listed as endangered. Green turtles continue to be heavily exploited by man, and degradation of nesting and feeding habitats is a serious problem. Overexploitation by man has already caused the extinction of large green turtle populations, including those that once nested on Bermuda and the Cayman Islands. The status of green turtle populations is difficult to determine because of the long generation time and inaccessibility of early life stages. The number of nests deposited in Florida appears to be increasing, but whether this upward trend is due to an increase in the number of nests or is a result of more thorough monitoring of the nesting beaches is uncertain.

The following discussion of sea turtle nesting within the South Florida Ecosystem, as well as comparisons to statewide nesting trends, was derived from data provided by Meylan *et al.* (1995) and DEP (1996).

Statewide, green sea turtle nests amounted to 1.9 percent of total sea turtle nesting during 1979 to 1992. From 1988 to 1992, while survey efforts remained relatively constant, the total number of reported green sea turtle nests statewide fluctuated between 455 and 2,509. In addition, it appears that green sea turtle nesting exhibits a 2-year cycle in activity. Although Meylan *et al.* (1995) report that an increase in green sea turtle nesting has been observed statewide, the reason for this increase is unknown and is regarded with cautious optimism.

Although the majority of green turtle nesting occurred in Brevard County (39.5 percent), just outside of the South Florida Ecosystem, Palm Beach County supported the second highest percentage of green turtle nests during that period with 23.1 percent of nests. The average number of nests that annually occur within the South Florida Ecosystem are shown in Table 1. Although the green sea turtle nests in all coastal counties in South Florida, these data show that Palm Beach County is clearly the most important nesting location. 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 complete prior to 1985. In addition, nesting along the southwest coast of Florida was documented for the first time in 1994 (Foley 1997).

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 the Atlantic Green Turtle (NMFS and FWS 1991). In South Florida, and for this recovery plan, we are focusing 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 trapping both adults and hatchlings, impede access to suitable nesting areas and cause higher incidences of false crawls (non-nesting emergences). 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 impact 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, 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 1982b, 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). Escarpments may also form during turtle nesting season postnourishment, which creates a seemingly safe place for nesting turtles, only to be washed out (DEP personal communication 1998). This effect can be minimized by leveling the beach prior to the nesting season.

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. 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 and an unnecessary energy expenditure. 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 (1992) found that both green and loggerhead sea turtles showed a significant tendency to avoid stretches of beach lighted with white mercury-vapor luminaires. 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 navigating the nearshore waters. Cumulatively, along the heavily developed beaches of the southeastern U.S., the negative effects of artificial lights are profound.

Beach Cleaning: Beach cleaning refers to the 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. Resulting tire ruts along the beach may hinder or trap emergent hatchlings. Mann (1977) suggested that mortality within nests may increase when externally applied pressure from beach cleaning machinery is common on soft beaches with large grain sand. 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* spp.*)* 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 National Park 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 excluding 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 *(Procyon lotor)* and opossums (*Didelphis virginiana*) are becoming increasingly detrimental to nesting beaches.

Poaching: In the U.S., killing of female turtles is infrequent. However, in a number of areas, egg poaching and clandestine markets for eggs are not

Table 2. Major green turtle nest survey/protection projects in South Florida (1985-1990).

Project	Beach length (km)	Number of nests/year	Conservation Measures
Sebastian Inlet SRA	4.8	7-56	S/PR
Hutchinson Island	36.5	45-132	S
St. Lucie Inlet SP	3.8	7-17	S/SP
Hobe Sound NWR	5.7	3-30	S/SP
Town of Jupiter Island	12.1	45-228	S
J.D. MacArthur SP	2.9	9-65	S/SP
City of Boca Raton	5.6	2-43	S/NS/NR
Broward County Beaches	39.0	4-106	S/NR
Miami-Dade Co. Beaches	22.5	3-11	S/NR
Wabasso Beach	8.0	14-55	S/PR

NS=Nest Screening NR=Nest Relocation
PR=Predator Removal S=Survey

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 green sea 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 occurrence of fibropapillomatosis in the green sea turtle, first described by Smith and Coates (1938). Fibropapillomatosis is a disease characterized by one or more non-cancerous fibrous tumors, commonly located on areas of soft skin. The tumors can be debilitating and, in severe cases, fatal. They can result in reduced vision, disorientation, blindness, physical obstruction to normal swimming and feeding, an apparent increased susceptibility to parasitism by marine leeches, and an increased susceptibility to entanglement in monofilament fishing line (Balazs 1986). Blood counts and serum profiles of green turtles inflicted with fibropapillomas indicate marked debilitation (Jacobson 1987). Fibropapillomas are now common on immature green sea turtles in the central Indian River system, Florida Bay, and in the Florida Keys (Ehrhart *et al.* 1986, Witherington and Ehrhart 1987, Schroeder 1987a). In the central Indian River lagoon, approximately half of all green sea turtles captured have been found to bear papillomas of varying severity (Ehrhart *et al.* 1986). Fibropapillomas are also commonly found on Hawaiian green turtles. Since 1989, incidence of this disease at Kancohe Bay, Oahu, has ranged from 49 to 92 percent (Barrett 1996). Though green sea turtles collected in Puerto Rico and the U.S. Virgin Islands have shown a very low occurrence of fibropapillomas (NMFS and FWS 1991), recent reports from those areas indicate the incidence of disease is greater.

Management

There are a number of management activities ongoing in South Florida to benefit the green 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 green sea 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 35 percent of the green sea turtle 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 sea turtles. 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 to ensure appropriate timing of nourishment during the nesting and hatching season. In southwest Florida's Gulf coast (Sarasota County through Monroe County), the green sea turtle nesting and hatching season is from May 15 through October 31. In southeast Florida's, Atlantic coast (Indian River County through Miami-Dade County), the nesting and hatching season is from May 1 through November 30. Any management decisions regarding beach nourishment, 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 hatchling and adult turtles. They also offer a variety of effective management solutions for ameliorating this problem.

Information on the status and distribution of the green 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 number of hatchlings that reach the ocean. Standardized ground surveys on index beaches are underway throughout Florida by the FWS, DEP, and by private groups and universities. Index beaches include 80 percent of the nesting activity in Florida. Because of 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.

Mortality of green sea 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 1987a,b). During 1987-89, four index zones were 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.

Research is underway at NMFS in Honolulu and at the University of Florida to determine the cause of the fibropapillomatosis disease affecting the green sea turtle. Evidence of a herpes-like virus was found, but it is unclear whether this is a primary or secondary infection. Management recommendations to reduce the incidence and impact of this disease include improving habitat quality in areas where occurrence is high, using strict hygiene techniques when handling affected turtles, and minimizing translocations of affected turtles (Barrett 1996).

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. 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, and the National Audubon Society, as well as 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 Green Sea Turtle

Chelonia mydas

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

South Florida Contribution: SUPPORT delisting actions.

Recovery Criteria

The South Florida recovery contribution parallels the existing recovery plans for the sea turtles. South Florida's objective for the loggerhead turtle, green turtle, leatherback turtle and hawksbill turtle 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 can 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 and ensure follow-up surveys to assess continued compliance with lighting plans.

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 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 sea 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 United States 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 time that green turtles are nesting, including the timeframes of any nesting that occurs outside of the 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 bi-lingual 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 and DEP 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 of sea turtles 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. **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 and thereby reduce disruption of nesting activities and eliminate sand compaction. 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 (J. Tabar, Indian River County, personal communication 1996). 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 impoundments 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 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.

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 (without relocation).** 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 30 to 35 percent of all green sea turtle 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 green sea 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 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 may 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.