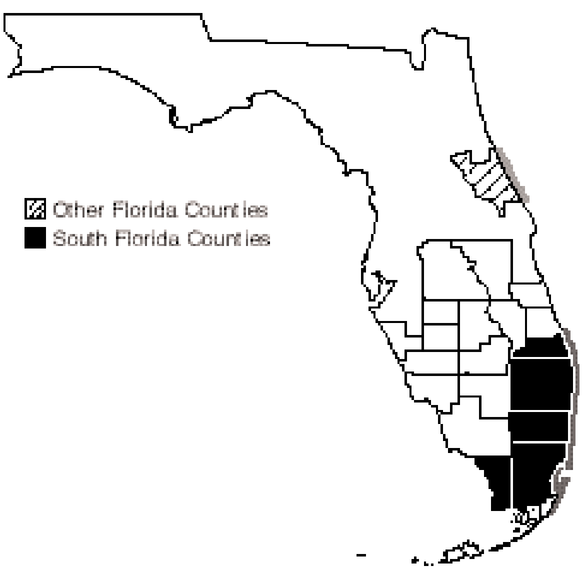
Hawksbill Sea Turtle

Eretmochelys imbricata

Federal Status:	**Endangered (June 2, 1970)**
Critical Habitat:	**Designated (June 1982 and September 1998): Selected beaches and/or waters of Mona, Monito, Culebrita, and Culebra Islands, Puerto Rico**
Florida Status:	**Endangered**
Recovery Plan Status:	**Contribution (May 1999)**
Geographic Coverage:	**South Florida**

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



Nesting by the hawksbill sea turtle is rare in Florida. During 1979 to 1992 only 11 nests were reported statewide, and of these, 10 were in South Florida (Meylan *et al*. 1995). Surveys for this species are difficult because of the similarities with loggerhead crawls and hatchlings, and because the nesting season for the hawksbill extends beyond the normal timeframe for the statewide survey. This account provides an overview of the biology of the hawksbill turtle throughout its range. The discussion of environmental threats and management activities, however, pertains only to the species in Florida and the U.S. Caribbean. Serious threats to the hawksbill turtle on its nesting beaches include artificial lighting, beach nourishment, increased human presence and exotic beach and dune vegetation.

This account is modified from the 1993 Recovery Plan for the Hawksbill Turtle in the U.S. Caribbean, Atlantic and Gulf of Mexico and represents South Florida's contribution to the range-wide recovery plan for this species (NMFS and FWS 1993).

Description

The following combination of characters distinguishes the hawksbill from other sea turtles: two pairs of prefrontal scales; thick, posteriorly overlapping scutes on the carapace; four pairs of costal scutes (the anteriormost not in contact with the nuchal scute); two claws on each flipper; and a beak-like mouth. In addition, when on land the hawksbill has an alternating gait, unlike the leatherback (*Dermochelys coriacea*) and green (*Chelonia mydas*) sea turtles.

The carapace is heart-shaped in very young turtles and becomes more elongate or subovate with maturity. The lateral and posterior carapace margins are sharply serrated in all but very old individuals. The epidermal scutes that overlay the bones of the shell are unusually thick and overlap posteriorly on the carapace in all but hatchlings and very old individuals. Carapacial scutes are often richly patterned with irregularly radiating streaks of brown and black on an amber background. The scutes of the plastron of Atlantic hawksbills are usually clear yellow, with little or no dark pigmentation. The soft skin on the hawksbill's venter is cream or yellow and may be pinkish-orange in mature individuals. There are typically four pairs of inframarginal scales. The head is elongate and tapers sharply to a point. The lower jaw is V-shaped. The scales of the head and forelimbs are dark brown or black and have yellow borders.

The hawksbill is a small to medium-sized marine turtle. Nesting females average about 87 cm in curved carapace length (Eckert 1992) and weight may be to 80 kg in the Caribbean (Pritchard *et al.* 1983), with a record weight of 127 kg (Carr 1952). Hatchlings in the U.S. Caribbean average about 42 mm in straight carapace length and range in weight from 13.5 to 19.5 g (Hillis and Mackay 1989, Van Dam and Sarti 1989, Eckert 1992).

Hawksbill crawls are difficult to distinguish from those of the loggerhead turtle (*Caretta caretta*), and hatchlings of the two species are also very similar, making identification of nests and estimates of productivity very difficult.

Taxonomy

The hawksbill turtle was originally named *Testudo imbricata* by Linnaeus (1766). A specimen at the University of Uppsala in Sweden, bearing Linnaeus' No. 130, is probably the type (Smith and Smith 1979). Taxonomic reviews appear in Smith and Smith (1979), Witzell (1983), and Pritchard and Trebbau (1984). Two subspecies *(Eretmochelys imbricata imbricata* in the Atlantic Ocean and *E. i. bissa* in the Indian and Pacific oceans) are recognized by Smith and Smith (1979). However, criteria for distinguishing the two forms are unreliable (Pritchard and Trebbau 1984) and subspecific designations are rarely used. A complex pattern of phenotypic variation exists. Some widely separated populations appear highly similar in color and pattern, whereas other populations that occupy the same ocean basin show marked differences (Pritchard and Trebbau 1984). Common names for the hawksbill turtle include tortoise-shell turtle, carey, caret, and tortue imbriquee.

Distribution

The hawksbill occurs in tropical and subtropical seas of the Atlantic, Pacific, and Indian oceans. Detailed descriptions of its worldwide distribution are given by Groombridge (1982), Witzell (1983), and Groombridge and Luxmoore (1989). The species is widely distributed in the Caribbean Sea and western Atlantic Ocean. Representatives of at least some life history stages regularly occur in southern Florida, northern Gulf of Mexico, Texas, in the Greater and Lesser Antilles, and along the Central American mainland south to Brazil. In U.S. Caribbean Sea waters, hawksbills are most common in Puerto Rico and its associated islands (particularly Mona, Culebra, and Vieques) and in the U.S. Virgin Islands. In the continental U.S., the hawksbill occurs along all of the Gulf states and along the eastern seaboard as far north as Massachusetts, but sightings north of Florida are rare.

Hawksbills are observed in Florida with some regularity in the waters near the Florida Keys and on the reefs off Palm Beach County (Lund 1985), where

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

the warm Gulf Stream current passes close to shore. According to DeSola (1932), before their numbers were reduced by overfishing, the Florida Keys were once considered the world's finest fishing grounds for hawksbill turtles.

Texas is the only other state where hawksbills are sighted with any regularity. A total of 77 observations, most involving posthatchlings and juveniles, have been recorded there between 1972 and 1984 (Amos 1989). These small turtles are believed to originate from nesting beaches in Mexico (Hildebrand 1987, Amos 1989).

Within U.S. jurisdiction in the Caribbean Sea, nesting occurs on beaches in Puerto Rico and the U.S. Virgin Islands. The most important sites are Mona Island (Puerto Rico) and Buck Island (St. Croix, U.S. Virgin Islands). Nesting also occurs on other beaches of St. Croix, Culebra Island, Vieques Island, mainland Puerto Rico, St. John, and St. Thomas.

Within the continental U.S., nesting is restricted to the southeastern coast of Florida, and has been reported from Broward, Miami-Dade, Martin, Monroe, Palm Beach, and Volusia counties (Figure 1) (Meylan 1992, Meylan *et al*. 1995). Nesting by hawksbills has been recorded several times on Soldier Key, a small, mangrove-fringed islet in Biscayne Bay (DeSola 1932, Dalrymple *et al.* 1985). The only reported nesting in Manatee County on the west coast of Florida (Conley and Hoffman 1987) was not adequately documented. Low levels of nesting are suspected to occur in the Marquesas and Dry Tortugas.

Throughout their range, hawksbills typically nest at low densities; aggregations consist of a few dozen, at most a few hundred individuals. This is in contrast to green turtles and loggerhead turtles, which nest by the thousands or tens of thousands at concentrated sites. The largest known nesting concentrations in the Caribbean are in the Yucatan Peninsula of Mexico (Meylan 1989), where approximately 800 to 1,000 nests are made each year between Isla Holbox (Quintana Roo) and Isla Carmen (Campeche) (NMFS and FWS 1993, cited in Eckert 1992). This corresponds to approximately 178 to 222 turtles, given an estimated average of 4.5 nests per female per season (Corliss *et al.* 1989). Other important (but relatively small) nesting beaches in the Caribbean region are located in Belize, Nicaragua, Panama, Venezuela, Antigua, and the Grenadines. Hawksbills are also known to nest in Cuba, possibly in significant numbers, but population estimates are not available. With few exceptions, all of the countries in the Caribbean report fewer than 100 females nesting annually (Meylan 1989).

Habitat

Hawksbill sea turtles use different habitats at different stages of their life cycle. Sightings (Hornell 1927, Gunter 1981), strandings (Vargo *et al.* 1986, Carr 1987, Amos 1989) and gut-content analyses (Meylan 1984b) suggest that posthatchling hawksbills occupy the pelagic environment, taking shelter in weed lines that accumulate at convergence zones. *Sargassum* and floating debris such as styrofoam, tar droplets, and plastic bits—common components of weed lines—are consistently found in the stomachs of posthatchling hawksbills that strand in Texas (Plotkin and Amos 1988). Thus, it seems likely that weed lines in the Gulf of Mexico serve as habitat for hawksbills that enter U.S. waters from nesting beaches in Mexico and Central America. Posthatchlings from beaches in the U.S. are presumed to occupy weed lines in the Atlantic Ocean.

Hawksbills reenter coastal waters when they reach approximately 20 to 25 cm carapace length. Coral reefs are widely recognized as the resident foraging habitat of juveniles, subadults, and adults. This habitat association is undoubtedly related to their diet of sponges, organisms that need solid substrate for attachment. The ledges and caves of the reef provide shelter for resting both during the day and night. Hawksbills are found around rocky outcrops and high-energy shoals, which are optimum sites for sponge growth. Hawksbills are known to inhabit mangrove-fringed bays and estuaries, particularly along the eastern shore of continents where coral reefs are absent (Carr 1952). In Texas, juvenile hawksbills are associated with stone jetties (Hildebrand 1987, Amos 1989).

Hawksbills nest on low- and high-energy beaches in tropical oceans of the world, frequently sharing the high-energy beaches with green turtles. Both insular and mainland nesting sites are known. Hawksbills will nest on small pocket beaches and, because of their small body size and great agility, can traverse fringing reefs that limit access by other species. They exhibit a wide tolerance for nesting substrate type.

Critical Habitat

Critical habitat was designated for the hawksbill sea turtle in June 1982 and September 1998. Although the designation did not include Florida, is does include selected beaches and/or waters of Mona, Monito, Culebrita, and Culebra Island, Puerto Rico. Critical habitat for hawksbill sea turtles identifies specific areas which have those physical or biological features essential to the conservation of the hawksbill sea turtle and/or may require special management considerations.

Behavior

The biology of the hawksbill has been extensively reviewed (Carr *et al.* 1966, Witzell 1983, Meylan 1984a, Pritchard and Trebbau 1984, and Eckert 1992). Only a brief overview is presented here.

Reproduction and Demography

The 6-month nesting season of the hawksbill is longer than that of other sea turtles. Most nests on Buck Island Reef NM are made from July to October (Hillis 1990). The peak season on Mona Island is from August to October (Richardson 1990). Courtship and mating apparently begin somewhat earlier, and may occur either along the migratory route or off the nesting beach. Nesting in the Caribbean is principally nocturnal, although rare daytime nesting is known. Nesting behavior, described by Carr *et al.* (1966), follows the general sequence of that of other species of sea turtles: emergence from the sea, site selection, site clearing and body pit construction, egg chamber construction, egg laying, filling in the egg chamber, disguising the nest site, and returning to sea. The entire process takes approximately 1 to 3 hours.

Hawksbills nest an average of 4.5 times per season (Corliss *et al.* 1989, Van Dam and Sarti 1990) at intervals of approximately 14 days. Earlier estimates of two to three nests per season reported at various projects around the world probably resulted from incomplete beach coverage. As many as 12 clutches may be produced by a single female in one season (Melucci *et al.* 1992). Not all emergences or nesting attempts result in eggs being laid. On Mona Island, an average of two emergences per successful nest was calculated; one female was observed making as many as 11 digging attempts on a single emergence (Kontos 1988). The ratio of crawls to nests varies geographically depending on local conditions, making site-specific information necessary for accurate interpretation of aerial survey data. On the basis of limited information, 2- and 3-year re-migration intervals appear to predominate; annual nesting by the hawksbill has not been recorded in the Caribbean.

Hawksbills have strong philopatry for their nesting beaches (Bjorndal *et al.* 1985, NMFS and FWS 1993), and are capable of returning to specific beach areas (Carr and Stancyk 1975, Diamond 1976, Lund 1985, Melucci *et al.* 1992). The extent to which site fixity is expressed among and within populations, or even by individuals over time, remains to be quantified.

Clutch size is directly correlated with carapace length (Hirth 1980) and varies markedly throughout the range of the species. In Florida and the U.S. Caribbean, clutch size is approximately 140 eggs, and several records exist of over 200 eggs per nest. Eggs are approximately 40 mm in diameter and take about 60 days to hatch. Hatching success at nesting beaches in the U.S. is approximately 80 percent (Van Dam and Sarti 1990, Hillis 1990).

Few data are available on the growth rates of wild hawksbill turtles. Most information has come from a study involving recaptures of 32 turtles (size range: 39.5 to 87.5 cm curved carapace length) on the Great Barrier Reef

(Limpus 1992). Mean growth rates ranged from 0.06 cm/yr for two adults, to 2.17 cm/yr for immature turtles ranging in size from 50 to 60 cm initial curved carapace length. The study concluded that hawksbills recruiting onto the reef at 35 cm in length would begin breeding 31 years later. Because the time required for these turtles to reach 35 cm is unknown, the actual age at sexual maturity is not known.

Boulon (1983) reported an average growth rate of 0.28 cm straight carapace length per month (3.36 cm/yr) for hawksbills ranging in size from 27.4 to 60.7 cm in St. Thomas (U.S. Virgin Islands). In the southern Bahamas, growth rates of four wild juvenile hawksbills ranged from 2.4 to 5.9 cm/yr (Bjorndal and Bolten 1988). Growth rates of adult females on the nesting beach in Costa Rica averaged 0.3 cm/yr (Bjorndal *et al.* 1985).

The few data available suggest slow growth and an advanced age at sexual maturity, as has been demonstrated for several other species of sea turtles. Rates of growth vary among different size classes (Limpus 1992) and seem to decrease considerably after sexual maturity is reached.

Migration

Very little is known of the movement patterns of posthatchling hawksbills, although their occupation of the pelagic environment is relatively well documented. Posthatchlings in Texas waters are presumed to have been passively transported there by currents that pass along Mexico. The movement patterns of hatchlings entering the sea from U.S. beaches are unknown.

Immature hawksbills show evidence of residency on specific feeding grounds (Nietschmann 1981, Limpus 1992), but developmental migrations may occur with changes in habitat occupation (Limpus 1992). Immature hawksbills tagged in the U.S. Virgin Islands have been recovered in eastern Puerto Rico, the British West Indies, St. Martin, and St. Lucia, representing travel distances of 95 km, 46 km, 185 km, and 650 km, respectively (Boulon 1989). Other recaptures of immature hawksbills have documented the long-distance travel of an 11 kg hawksbill from Great Inagua, Bahamas, to the Turks and Caicos Islands (Bjorndal *et al.* 1985) and the migration of a subadult hawksbill from Brazil to Dakar, Senegal, a distance of 3,680 km (Marcovaldi and Filippini 1991). The purpose and regularity of migrations by immature hawksbills deserve further study.

Recoveries of tagged adult hawksbills suggest that some populations or groups within a population undertake reproductive migrations (Meylan 1982, 1984a, Bjorndal *et al.* 1985). Migrations have been documented of adult females from beaches in Costa Rica to feeding grounds in Nicaragua, and from Nicaragua feeding grounds to a beach in Jamaica. An adult male tagged on the foraging grounds in Nicaragua was recovered in Panama (Meylan 1982). NMFS and FWS (1993) reported the travel of a hawksbill from Isla Mujeres, Mexico, to Bani, Dominican Republic, a distance of 2,925 km. Indirect evidence of migration by hawksbills was provided by Limpus (1992), who described a population of immature hawksbills in the Great Barrier Reef that reside at least 1,400 km from any regular hawksbill nesting site.

Foraging

Very little is known about the diet of posthatchling hawksbills in the pelagic environment. Eggs of pelagic fish, pelagic species of *Sargassum,* and various floating debris such as tar droplets, styrofoam, and plastic have been identified (Meylan 1984b).

Although a wide variety of benthic organisms have been recorded from digestive tracts, sponges are the principal diet of hawksbills once they enter shallow coastal waters and begin feeding on the bottom (Meylan 1988). Quantitative studies have focused on the Caribbean, but there is evidence that spongivory is a worldwide feeding habit. It is unquestionably a highly unusual one, being shared by only about a dozen other vertebrates. A high degree of feeding selectivity is indicated by the consumption of a limited number of sponge species. Sponge predation by hawksbills may influence reef succession and diversity by freeing up space on the reef for settlement by benthic organisms. The hawksbill's highly specific diet, and its dependence on filter-feeding, hard-bottom communities make it vulnerable to deteriorating conditions on coral reefs.

Relationship to Other Species

Although the hawksbill turtle is rare in South Florida, it shares nesting beaches with the threatened loggerhead turtle, and the endangered green and leatherback turtles. 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.

Some hawksbill nests have been discovered that are believed to be the result of hybrid crosses. Preliminary genetic testing in some of these cases has revealed the female parent was a loggerhead; tests are pending to reveal the identities of the male parent as a hawksbill or a hybrid (Meylan *et al*. 1995).

A variety of natural and introduced predators prey on hawksbill eggs and hatchlings. Until eradicated in 1987, mongooses were destroying up to 55 percent of all nests on Buck Island Reef NM (Small 1982). Prior to extensive live trapping, mongooses were destroying an estimated 24 percent of all turtle eggs in 1980 and 1981 on St. John, U.S. Virgin Islands. Feral hogs destroyed 44 to 100 percent of all hawksbill nests deposited outside of fenced areas on Mona Island, Puerto Rico, during 1985 to 1987 (Kontos 1985, 1987, 1988).

Status and Trends

The hawksbill is listed as endangered by the International Union for the 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) (Groombridge 1982). It was also listed as endangered throughout its range on June 2, 1970 (35 FR 8495) under the Endangered Species Act of 1973, as amended (FWS 1989). Groombridge and

Luxmoore (1989) carried out an exhaustive review of the worldwide conservation status of the hawksbill turtle and concluded that the species is suspected or known to be declining in 38 of the 65 geopolitical units for which nesting density estimates are available. They noted severe declines in the western Atlantic Ocean and Caribbean region, as did Meylan (1989), who reported that current nesting levels may be far lower than previously estimated. Despite protective legislation, international trade in tortoiseshell and subsistence use of meat and eggs continue unabated in many countries and pose a significant threat to the survival of the species in this region.

In the U.S. Caribbean, there is evidence that hawksbill nesting populations have been severely reduced during the 20th century (Eckert 1992). At present, they are not believed to be declining, but neither are there signs of recovery, despite over a decade of protection. The most recent status review of the species in the U.S. recognized that numerous threats still exist for U.S. populations and recommended that the hawksbill remain listed as endangered throughout its range (Eckert 1992).

Estimates of the size of nesting populations are available for only a few localities. Richardson (1990) reported that an average of 160 nests were made annually on Mona Island, Puerto Rico, during seven years of monitoring (1974, 1984 to 1989). This corresponds to approximately 36 nesting females per year. A total of 196 nests were recorded on the island in 1990 (Van Dam *et al.* 1991). Approximately 65 to 125 nests are made annually on Buck Island Reef NM, St. Croix, U.S. Virgin Islands (Eckert 1992). Since research began in 1988, between 15 to 30 female hawksbills have been recorded nesting on Buck Island Reef NM each year.

The hawksbill sea turtle does not nest frequently or commonly in Florida. Since 1989, nesting has been reported from Broward, Miami-Dade, Martin, Monroe, Palm Beach and Volusia counties, and the number of known nests each year through 1996 varied from zero to two. Results of surveys, however, undoubtedly underestimate the actual number of nests in Florida, and it appears that hawksbills are using the more remote islands and cays of the Florida Keys, where surveys are not conducted regularly (Meylan *et al.* 1995).

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, long line, 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 the Hawksbill Turtle in the U.S. Caribbean, Atlantic and Gulf of Mexico (NMFS and FWS 1993). 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; and recreational beach equipment.

Beach Erosion: Hawksbill nesting beaches are usually small and the sand builds up over long periods of time. Storms periodically remove the sand, but it is usually replaced by wind and wave action. Storms may cause trees to fall that hinder the hawksbills from reaching nesting habitat. Buck Island Reef NM's nesting beaches were severely degraded in this manner by Hurricane Hugo in 1989. Buck Island Reef NM staff selectively removed fallen trees and debris and constructed sand ramps in the steep berms to provide access to high-density nesting areas. Normal, periodic erosion cycles may remove and replace large areas of a nesting beach, such as occurs at Sandy Point NWR, St. Croix. The overall effect is to clean and renourish the nesting beach. Occasionally, vulnerable nests may need to be relocated in such areas. Hawksbill nests are regularly relocated at Humacao, Pinones, Mona Island, and Caja de Muertos, Puerto Rico. Natural processes of beach erosion are not generally a significant threat to hawksbills.

Beach Armoring: Problems are caused by humans placing immovable structures on ephemeral shorelines. Beaches naturally recede and replenish but real estate boundaries are fixed. Where beachfront development occurs, the site is often fortified to protect the property from erosion. The purpose of virtually all shoreline engineering is to save structures, not dry sandy beaches, and it ultimately causes environmental damage. Beach armoring includes sea walls, rock revetments, riprap, sandbag installations, groins, and jetties. Approximately 21 percent (234 km) of Florida's beaches are armored (NMFS and FWS 1991). Although not quantified, beach armoring is extensive in some regions of Puerto Rico but rare in the U.S. Virgin Islands.

Beach armoring, may result in the permanent loss of a dry nesting beach by accelerating erosion and preventing natural beach or dune accretion. It may prevent or hamper nesting females from reaching suitable nesting sites. Clutches deposited seaward of these structures may be inundated at high tide or may be 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, thus impeding access to suitable nesting areas and causing 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. When inadequate amounts of sand cover these structures, turtles attempting to nest may construct improperly sized and shaped egg cavities.

Groins and jetties are designed to trap sand during transport in longshore currents. Jetties keep sand from flowing into channels. These structures prevent normal sand transport and accrete beaches on one side of the structure while starving beaches on the other side. Severe beach erosion (Pilkey *et al.* 1984) and corrresponding degradation of suitable nesting habitat may result (S. MacPherson, FWS, personal communication 1998).

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 entails pumping, trucking, or scraping sand onto the beach to rebuild what has been lost to erosion. It is a common practice in Florida but is much less common in Puerto Rico and the U.S. Virgin Islands. 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 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.

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 (non-nesting emergences) 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 that 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, Mrosovsky 1978, Dickerson and Nelson 1989, Witherington and Bjorndal 1991). Artificial beachfront lighting from buildings, streetlights, dune crossovers, vehicles, and other sources has been documented as causing the disorientation (loss of bearings) and misorientation (incorrect orientation) of hatchling turtles, including hawksbills (McFarlane 1963, Philibosian 1976, Mann 1977, Ehrhart 1983). In Florida, 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). On Sandy Point NWR, hawksbill and leatherback hatchlings are strongly attracted, especially on moonless nights, to the lights of Frederiksted (several km to the northeast). Another example is the Hotel Palmas del Mar parking lot lights at Humacao, Puerto Rico. These lights regularly disorient or misorient hawksbill hatchlings.

The results of disorientation or misorientation are often fatal. As hatchlings head toward lights or meander along the beach, their exposure to predators and the likelihood of desiccation are greatly increased. Misoriented hatchlings can become entrapped in vegetation or debris, and in Florida loggerhead hatchlings are frequently 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).

The problem of artificial beachfront lighting is not restricted to hatchlings. Nesting turtles can also be misoriented by lights. Witherington (1992) determined that broad-spectrum artificial lights significantly reduced loggerhead and green turtle nesting activity. In addition to the lights on or near the 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 continental U.S., Puerto Rico, and U.S. Virgin Islands, the adverse effects from artificial lights may be 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. Large expanses of open sand may be cleaned with mechanical devices to a depth of several inches. The top of a clutch of hawksbill eggs is often no more than 10.1 to 15.2 cm below the surface of the sand and hawksbill nests on resort beaches are often subject to damage from raking and cleaning. This 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.

Wind erosion is another threat exacerbated by beach cleaning. The complete removal of leaf litter and herbaceous vegetation on a beach allows prevailing winds to move sand to areas outside of the prime nesting area, and the vegetated nearshore berm may be lowered by 0.9 m or more. On a cleaned beach in Antigua, the wind has moved the sand more than 30 m back from the shoreline. Today, limestone bedrock is too close to the surface to permit turtle nesting on several historic nesting areas.

Increased Human Presence: Residential and tourist use of developed (and developing) nesting beaches can negatively affect nesting turtles, incubating egg clutches, and hatchlings. The most serious threat caused by increased human presence on the beach is the disturbance of nesting females. Nighttime human activity can cause nesting females to abort nesting attempts at any stage of the process. Murphy (1985) reported that disturbance has caused turtles to shift to other nesting beaches, delay egg laying, and select poor nesting sites. Female hawksbills ascending a beach to nest are easily deterred by the presence of people, noise, and flashlights. Turtles frightened from a protected public beach may go to an adjacent beach, where they may be more vulnerable to poaching. Pedestrian traffic in the nesting area can also break and destroy vegetation and crush eggs. Pedestrian tracks can hinder hatchlings, efforts 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). Hatchlings have been drawn into campfires. A campfire placed over a hawksbill nest will kill the developing embryos or pre-emergent hatchlings.

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 seaward movement of hatchlings. The placement of recreational beach equipment directly above incubating egg clutches may hamper hatchlings during their emergence and can destroy eggs through direct invasion of the nest. Nesting females gravitate to dark horizons when seeking a nest site, whether the horizon be a beach forest or a cabana. Hawksbills may nest in the shadow of a chair or umbrella on the open beach. If the structure is removed, the nest is no longer protected from direct sunlight and the nest may get too hot.

Predation: Predators, particularly exotics, such as fire ants (*Solenopsis invicta*); and human-associated ones including racoons *(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 uncommon. From 1983 to 1989, the Florida Marine Patrol, DEP, made 29 arrests for illegal possession of turtle eggs.

The greatest threat to hawksbills on nesting beaches in Puerto Rico (Matos 1987), St. Thomas, and St. Croix (NMFS and FWS 1993) is poaching. While on the beaches, adult females are killed for their shell. Better surveillance by law enforcement and volunteer groups is believed to be reducing the levels of take. Hawksbills that use the remote beaches on Mona and Culebra islands are vulnerable to poaching. Hawksbills that use Pinones (a beach close to San Juan, Puerto Rico) are taken, in spite of the fact that Pinones has been given one of the largest Puerto Rico DNR ranger contingents deployed on any Puerto Rican beach. Although the rate of poaching may be limited on any given beach, the overall effect is an enormous drain on hawksbill populations.

Other Threats: In nearshore waters, hawksbills are periodically captured in the cooling water intakes of industrial facilities, such as Florida Power and Light Company's St. Lucie Power Plant on Hutchinson Island. Between March 1976 (when the St. Lucie Plant opened) and November 1988, six hawksbills were captured (Ernest *et al.* 1989). As of June 1, 1992, three more had been captured. All were released unharmed (NMFS and FWS 1993).

Management

Because the hawksbill is rare in South Florida, there is no specific management ongoing for this species. Conservation measures to protect nesting beaches for sea turtles in general, however, will also benefit the hawksbill. The following discussion taken from the Recovery Plan for the Hawksbill Turtle in the U.S. Caribbean, Atlantic and Gulf of Mexico (NMFS and FWS 1993) provides specific management and conservation measures being implemented for the species in the U.S. Caribbean.

The most important hawksbill conservation achievement in recent years was Japan's decision to end import of hawksbill shell by 1993 and to drop its CITES reservations on sea turtles by July 1, 1994. Because Japan is the largest importer of stuffed hawksbills and hawksbill shells in the world, this decision should significantly diminish the future demand for the species.

The two most important hawksbill nesting beaches in the U.S. Caribbean are now fully protected. Buck Island Reef NM, St. Croix, U.S. Virgin Islands, became part of the NPS in 1962. Mona Island, Puerto Rico, was established as a natural reserve under the protection of the Puerto Rico Department of Natural Resources in 1980. In addition, Isla Culebrita was transferred to Culebra NWR in 1982. Sandy Point NWR (a 2.4-km beach at Sandy Point, St. Croix) was established in 1984.

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. 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 (*Casuarina equisetifolia*) 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 southeast Florida, the hawksbill nesting and hatching season is from June 1 through December 31. 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 juvenile and adult turtles, and offer a variety of effective management solutions for ameliorating this problem.

In the U.S. Virgin Islands, the coastal zone management commissions have imposed lighting and monitoring restrictions on projects being built adjacent to nesting beaches (NMFS and FWS 1993). In 1986, it became illegal to drive vehicles or ride horses on beaches in the U.S. Virgin Islands.

In 1988, the NPS initiated a study of the hawksbill nesting population at Buck Island Reef NM to monitor long-term trends. In 1991, the FWS collaborated with the NPS in a study of hawksbill postnesting migrations and movements at Buck Island Reef NM. In 1991, the NPS also used radio and sonic telemetry to study internesting movements, and the NPS initiated nesting surveys of hawksbill beaches on St. John, U.S. Virgin Islands.

Since 1986, a nesting-behavior study has been conducted at Humacao under the auspices of Puerto Rico DNR. A similar study has been initiated on Caja del Muertos. Since 1990, with U.S. Navy support, Puerto Rico Department of Natural Resources has been tagging hawksbills on Vieques.

Mortality of hawksbill 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 and Warner 1988). 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.

A substantial effort is being made by government and non-government agencies and private individuals to increase public awareness of sea turtle conservation issues. Federal and State agencies and private conservation organizations, such as the Center for Marine Conservation, Caribbean Conservation Corporation, Greenpeace, and National Audubon Society, have produced and distributed a variety of audio-visual aids and printed materials about sea turtles. These include a booklet on various types of light fixtures and ways of screening lights to lessen their effects on hatchlings (Raymond 1984b), the brochure “Attention Beach Users,” “Lights Out” bumper stickers and decals, a coloring book, video tapes, slide and tape programs, full-color identification posters of the eight species of sea turtles, and a hawksbill poster. Florida Power and Light Company has also produced a booklet (Van Meter 1992) and two leaflets containing general information on sea turtles, as well as a coastal roadway lighting manual.

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Recovery for the Hawksbill Sea Turtle

Eretmochelys imbricata

Recovery Objective: **DELIST** the species once recovery criteria are 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, green, leatherback, and hawksbill sea 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.

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 hawksbill 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 individual states and 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 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 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. Surveys in Florida do not routinely cover the end of the hawksbill nesting season. Consequently, DEP and FWS should ensure that routine monitoring of nesting beaches is done on at least a weekly basis during the time period that hawksbill turtles nest, including any period of nesting that occurred 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 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 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.

H1.1.2. 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.

H1.1.3. 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 impoundment of sand 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 (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 nesting habitat for sea turtles nesting in the United States. 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. 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 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 sea turtles and incubating nests of renourishing beaches with these altrnative 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.