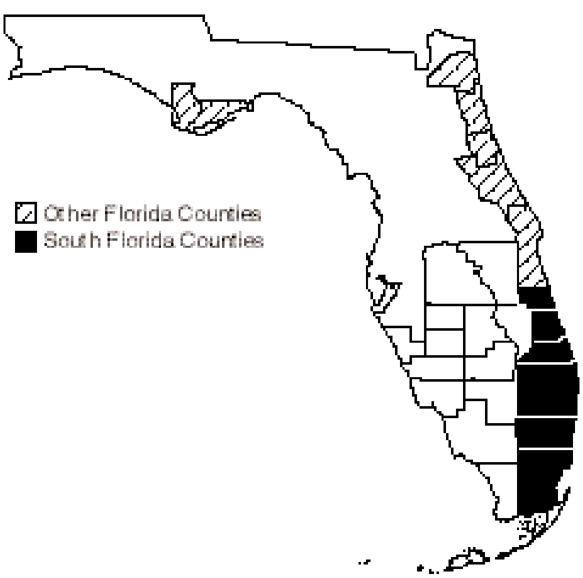
Leatherback Sea Turtle

Dermochelys coriacea

Federal Status:	**Endangered (June 2, 1970)**
Critical Habitat:	**Designated (September 1978 and March 1979): Sandy Point, St. Croix, U.S.Virgin Islands, and surrounding waters.**
Florida Status:	**Endangered**
Recovery Plan Status:	**Contribution (May 1999)**
Geographic Coverage:	**South Florida**

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



The leatherback sea turtle is the largest of all the sea turtles. It is also unique among sea turtles, because instead of a bony carapace, it has leather-like outer skin in which is embedded a mosaic of small bones. The leatherback nests regularly in small numbers on the east coast of Florida. The nesting and hatching season extends from mid-February through mid-November. Sea turtles, in general, are susceptible to human changes to the marine environment, as well as to their nesting beaches. This account provides an overview of the biology of the leatherback sea turtle throughout its range. The discussion of environmental threats and management activities, however, pertains only to Florida and the U.S. Caribbean. Serious threats to the leatherback turtle on its nesting beaches include: artificial lighting, beach nourishment, increased human presence, and exotic beach and dune vegetation.

This account is from the 1992 Recovery Plan for Leatherback Turtles in the U.S. Caribbean, Atlantic, and Gulf of Mexico (NMFS and FWS 1992). Updated information is included only for South Florida.

Description

The leatherback sea turtle is the largest of the sea turtles and is so distinctive that it is placed in a separate family, Dermochelyidae. The leatherback sea turtle possesses a skeletal morphology unique among turtles (Rhodin *et al*. 1981) and recent karyological studies with this species (Medrano *et al*. 1987) support classifications which segregate extant sea turtle species into two distinct families (Gaffney 1975, 1984, Bickham and Carr 1983). All other extant sea turtles are in the family Cheloniidae.

The carapace of the leatherback sea turtle is also different from that of other sea turtles. Other sea turtles have bony plates covered with horny scutes on the carapace, while the slightly flexible carapace of the leatherback is distinguished by a rubber-like texture. The carapace of the leatherback is about 4 cm thick and is made primarily of tough, oil-saturated connective tissue raised into seven prominent longitudinal ridges and tapered to a blunt point posteriorly. A nearly continuous layer of small dermal bones lies just below the leathery outer skin of the carapace. No sharp angle is formed between the carapace and the plastron, resulting in a barrel-shaped appearance. The front flippers are proportionally longer than in other sea turtles and may span 270 cm in an adult. The leatherback's mean curved carapace length for adult females nesting in the U.S. Caribbean is 155 cm (range 137 to 176). On Sandy Point NWR, weights of 262 kg to 506 kg have been recorded (Eckert and Eckert 1985, Basford *et al*. 1986, Brandner *et al*. 1987). Adults and near adults captured in Virginia waters have ranged from 137 to 183 cm curved carapace length (NMFS and FWS 1992). Size and weight relationships calculated from adult females in St. Croix suggest the Virginia leatherbacks range in weight from 204 to 696 kg. The largest leatherback on record (a male stranded on the coast of Wales in 1988) weighed 916 kg (Morgan 1989).

Leatherback hatchlings are dorsally mostly black and covered with tiny polygonal or bead-like scales; the flippers are margined in white and rows of white scales appear as stripes along the length of the back. In the U.S. Virgin Islands hatchlings average 61.3 mm in straightline carapace length and 45.8 g in weight (Eckert *et al*. 1984). Both front and rear flippers lack claws. In the adult the epidermis is black (with varying degrees of pale spotting) and scaleless. This scaleless condition is unique among sea turtles. The undersurface is mottled, pinkish-white and black, the proportion of light to dark pigment being highly variable. In both adults and hatchlings, the upper jaw bears two tooth-like projections, each flanked by deep cusps, at the premaxillary-maxillary sutures (Pritchard 1971).

The crawl of the nesting leatherback is very deep and broad, with symmetrical diagonal marks left by the front flippers usually with a deep incised median groove formed by dragging of the relatively long tail (Pritchard *et al.* 1983).

The internal anatomy and physiology of the leatherback is also distinctive. The core body temperature, at least for adults in cold water, has been shown to be several degrees C above the ambient temperature (Frair *et al*. 1972). This may be due to several features, including the thermal inertia of a large body mass, an insulating layer of subepidermal fat, countercurrent heat exchangers in the flippers, potentially heat-generating brown adipose tissue, and a relatively low freezing point for lipids (Mrosovsky and Pritchard 1971, Friar *et al*. 1972, Greer *et al*. 1973, Neill and Stevens 1974, Goff and Stenson 1988, Davenport *et al*. 1990, Paladino *et al*. 1990). The skeleton of the leatherback remains extensively cartilaginous, even in adult animals, and the species is unique among turtles in showing an extensive cartilage canal vascular system in the epiphyseal regions (Rhodin *et al.* 1981).

Taxonomy

The generic name *Dermochelys* was introduced by Blainville (1816). The binomial refers to the distinctive leathery, scaleless skin of the adult turtle. The specific name *coriacea* was first used by Vandelli (1761) and adopted by Linneaus (1766) (see Rhodin and Smith 1982). Refer to Pritchard and Trebbau (1984) for a more detailed discussion of taxonomy and synonymy.

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

Distribution

The wide-ranging leatherback sea turtle nests on shores of the Atlantic, Pacific and Indian Oceans. Non-breeding animals have been recorded as far north as the British Isles and the maritime Provinces of Canada and as far south as Argentina and the Cape of Good Hope (Pritchard 1992).

Efforts to determine the distribution and numbers of leatherback sea turtles in the marine environment have met with varying degrees of success. A 1987 aerial survey of shallow Gulf of Mexico waters (Perdido Bay, Alabama to Cape San Blas, Florida) described leatherbacks as "uncommon" in all study areas (though relatively more common in autumn than in spring), the highest density being 0.027 leatherbacks/100 km^2 offshore Louisiana in October (Lohoefener *et al*. 1988). Earlier surveys (April 1982 to February 1983) in the Atlantic revealed leatherbacks in the study area (Key West, Florida to Cape Hatteras, North Carolina, out to the western boundary of the Gulf Stream) year-round, but no density estimates were given (Thompson 1984). Thompson (1984) reported a significant negative correlation between leatherbacks and water temperature in the spring, fall and winter, suggesting that the species is not dependent upon warm temperatures and is likely to be associated with cooler, perhaps more productive waters. The same study reported that leatherbacks appeared to prefer water about 20°C (± 5°) and were rarely sighted in the Gulf Stream sampling areas. Summarizing incidental catch and interview data (1897 to 1980), as well as at-sea observations recorded during shore to Gulf Stream summer transects, Lee and Palmer (1981) also concluded that (at least off North Carolina) leatherbacks were rarely seen in the Gulf Stream and were most often seen in waters < 915 m in depth.

A survey conducted during March 1982 to August 1984, but restricted to the Cape Canaveral area, reported that 94.5 percent of all leatherback sightings (n=128 total) occurred east of the 20 m isobath, and 90.6 percent occurred during the summer (Schroeder and Thompson 1987). In contrast, New England Aquarium surveys of Florida and Georgia (1984 to 1988) reported few leatherbacks prior to 1988, but in mid-February of that year 168 leatherbacks were sighted along the northeast coast of Florida, with peak densities reported along 80 km of coastline between Daytona Beach and Cape Canaveral (Knowlton and Weigle 1989). The impetus for this sudden winter abundance in Florida nearshore waters is unknown; by the following survey (16 March) the animals had disappeared (Knowlton and Weigle 1989). The extent to which distribution and abundance are defined by transient phenomena is presently unclear.

A 1979 aerial survey of the mid- and north-Atlantic areas of the U.S. Outer Continental Shelf (shoreline to the surface projection of the 2,000 m isobath) between Cape Hatteras, North Carolina and Cape Sable, Nova Scotia, showed leatherbacks to be present April to November throughout the study area (but most likely to be observed from the Gulf of Maine south to Long Island); peak estimates of relative abundances during the summer were in the hundreds (Shoop *et al*. 1981). The same study concluded that leatherbacks were observed more frequently in colder waters at higher latitudes during the summer than were other sea turtle species.

Nesting grounds for the leatherback are distributed circumglobally (ca. 40°N to 35°S; Sternberg 1981), with the Pacific coast of Mexico supporting the world's largest known concentration of nesting turtles. Pritchard (1982) estimates that 115,000 adult female leatherbacks remain worldwide and that some 50 percent of them may nest in western Mexico. The largest nesting colony in the wider Caribbean region is found at Ya:lima:po-Les Hattes, French Guiana, where the total number of adult females is estimated to be 14,700 to 15,300 (Fretey and Girondot 1989). Lower density Caribbean nesting is also reported from Surinam (Pritchard 1973, Schulz 1975), Guyana (Pritchard 1988a,b), Colombia and Venezuela (Pritchard and Trebbau 1984), Panama (Meylan *et al*. 1985, Garcia 1987), and Costa Rica (e.g., Carr and Ogren 1959, Hirth and Ogren 1987).

On the islands of the eastern Caribbean, Bacon (1970) estimated that 150 to 200 leatherbacks nested annually in Trinidad, primarily at Matura and Paria bays. Shortly thereafter, Bacon and Maliphant (1971) indicated that perhaps 200 to 250 leatherbacks nested annually in Trinidad; recent population estimates are not available. Nesting north of Trinidad in the Lesser and Greater Antilles is predictable, but occurs nowhere in large numbers (Caldwell and Rathjen 1969, Carr *et al*. 1982, Meylan 1983). The largest sub-regional nesting colony is in the Dominican Republic, where an estimated 300 leatherbacks nest annually (Ross and Ottenwalder 1983). The U.S. Caribbean supports relatively minor nesting colonies (probably 150-200 adult females per annum, combined) but represents the most significant nesting activity within the U.S.

Leatherback nesting in the U.S. Caribbean is reported from the Virgin Islands (St. Croix, St. Thomas, St. John) and Puerto Rico, including Islas Culebra, Vieques, and Mona. The total number of nests deposited annually on Sandy Point NWR has ranged from 82 (1986) to 355 (1994) (Eckert and Eckert 1985, Basford *et al*. 1986, 1988, McDonald *et al*. 1991, 1992, 1993, 1994). On

Isla Culebra, the colony is smaller (88 to 271 nests per year 1984 to 1995, Tallevast *et al*. 1990, FWS unpublished reports). Playas Resaca and Brava receive 91 to 100 percent of all leatherback nesting on Culebra (Tucker 1988).

Throughout the southeastern U.S. the geography of beach coverage is more or less complete, but the timing is often inadequate to gain a complete picture of leatherback nesting. Beach patrols generally commence in May and are designed to maximize observations of leatherback sea turtle nests. However, leatherbacks have been known to start nesting as early as late February or March, thus, current data may slightly underestimate the actual nesting activity. Leatherback nests reported from Florida and Georgia are probably deposited by 10 to 25 females annually. Leatherback turtles have been known to nest in Georgia and South Carolina, but only on rare occasions. Hildebrand (1963) was informed by a resident of Padre Island, Texas that a few nesting individuals had been seen on the island in the 1930s, but none in recent years.

Leatherback nesting in Florida was once considered extremely rare (Carr 1952, Caldwell *et al*. 1956, Allen and Neill 1957). However, the leatherback is now known to nest regularly in small numbers on Florida's east coast (Meylan *et al*. 1995). Leatherback nesting has also been reported on the west coast of Florida on St. Vincent NWR (LeBuff 1990), St. Joseph Peninsula State Park and St. George Island (S. MacPherson, FWS, personal communication 1997). In South Florida, leatherbacks have been observed on nesting beaches in Indian River, St. Lucie, Martin, Palm Beach, Broward and Miami-Dade counties on the east coast (Figure 1).

Virtually nothing is known of the pelagic distribution of hatchling or juvenile leatherback turtles. The paths taken by hatchlings leaving their natal beaches are uncharted. Discussions of the "lost year" (the early pelagic stage of sea turtle development) which include tabulated summaries of neonate and juvenile sea turtles associated with *Sargassum* weed or taken from pelagic habitats (e.g., Carr 1987) have not mentioned sightings of young *Dermochelys.* Our knowledge of juvenile distribution rests on a handful of chance observations, and includes sightings in waters within (Caldwell 1959, Johnson 1989) and outside (e.g., Brongersma 1970, Hughes 1974, Pritchard 1977, Horrocks 1987) the U.S.

Strandings

Leatherbacks stranding on U.S. shores are generally of adult or near adult size, demonstrating the importance of pelagic habitat under U.S. jurisdiction to turtles breeding in tropical and subtropical latitudes. Direct evidence of this is available from Caribbean and South American tagged turtles stranding on U.S. shores. Nesters tagged in French Guiana subsequently stranded in Georgia (NMFS and FWS 1992), as well as in New York (NMFS and FWS 1992), New Jersey, South Carolina, and Texas (Pritchard 1976). Nesters tagged in Trinidad and St. Croix subsequently stranded in New York (Lambie 1983) and New Jersey (Boulon *et al*. 1988), respectively. Conversely, an individual tagged in Virginia waters in 1985 was killed a year later in Cuba (Barnard *et al*. 1989). Additional evidence of the importance of U.S. coastal waters for leatherbacks is provided by the Sea Turtle Stranding and Salvage Network. During the period 1980 to 1991, 816 leatherback strandings were recorded along the continental U.S. coastline. During this same period, 161 leatherbacks were recovered dead along Florida's coast. Curved carapace lengths for the Florida strandings ranged from 110 to 195 cm. Eighty-four percent of all leatherback strandings in Florida occurred between January to April and October to December. Strandings were lowest (16 percent) during summer months, May to September.

Habitat

Adult leatherback sea turtles are highly migratory and believed to be the most pelagic of all sea turtles. Habitat requirements for juvenile and post-hatchling leatherbacks, however, are virtually unknown. Nesting females prefer high-energy beaches with deep, unobstructed access (Hirth 1980, Mrosovsky 1983), which occur most frequently along continental shorelines (Hendrickson 1980).

Critical Habitat

Critical habitat was designated for the leatherback sea turtle in September 1978 and March 1979. Although the designation did not include Florida, is does include nesting beach on Sandy Point, St. Croix and the surrounding waters. Critical habitat for leatherback sea turtles identify specific areas which have those physical or biological features essential to the conservation of the leatherback sea turtle and/or may require special management considerations.

Behavior

Reproduction and Demography

Mating behavior of the leatherback is described by Carr and Carr (1986) in waters off Puerto Rico, though there is some indirect evidence that mating typically occurs prior to (or during) migration to the nesting ground (Eckert and Eckert 1988). Nesting behavior (i.e., the basic sequence entailing beaching, ascent, selection of a suitable site, "body pitting", egg chamber excavation, oviposition, nest filling and camouflage, departure) is similar to that of other marine turtle species (detailed descriptions in Deraniyagala 1936, Carr and Ogren 1959). Gravid females emerge from the sea nocturnally; diurnal nesting occurs only occasionally. Because of a proclivity for nesting in high-energy and thus frequently unpredictable environments, it is not uncommon that large numbers of eggs are lost to erosion (Bacon 1970, Pritchard 1971, Hughes 1974, Mrosovsky 1983, Eckert 1987), though this is not always the case (Tucker 1989). While the majority of females return to the same nesting beach repeatedly throughout the nesting season, some females are known to nest on separate beaches > 100 km apart within a season.

In the U.S. Caribbean, nesting commences in March (a very few nests are laid in February) and continues into July. The most systematic data available on reproductive output has been gathered at Sandy Point NWR and Isla Culebra. Data from these projects reveal that females arrive at the nesting beach asynchronously, renest an average of every 9 to 10 days, deposit 5 to 7 nests per annum (observed maximum = 11), and remigrate predominantly at 2 to 3 year intervals. The annual nest : false crawl ratio on Culebra (all beaches) is 4:1 to

6.2:1 (1984 to 1987; Tucker 1988); 1.2:1 to 3:1 on Sandy Point (1982-1988; NMFS and FWS 1992). Clutch size averages 116 eggs, including 80 yolked eggs, on Sandy Point NWR, 103 eggs, including 70 yolked eggs, on Culebra. Clutch size averages 101 eggs, including 76 yolked, on Hutchinson Island, Florida (NMFS and FWS 1992). Similar clutch sizes are reported elsewhere on St. Croix (Adams 1988) and Puerto Rico (Matos 1986, 1987), as well as in Georgia (Ruckdeschel *et al*. 1982) and Florida (Carr 1952, Caldwell 1959, Broward County Erosion Prevention District/Environmental Quality Control Board--now Department of Natural Resource Protection--1987). Eggs incubate for 55 to 75 days, consistently averaging 63 days on both Sandy Point and Culebra and 64 days on Hutchinson Island, Florida. *In situ* hatch success for nests surviving to term is about 55 percent on Manchenil Bay, St. Croix (Adams 1988), about 65 percent on Sandy Point NWR (Eckert and Eckert 1985, Brandner *et al*. 1987, 1990), and about 66 percent on Hutchison Island, Florida (NMFS and FWS 1992). Higher success (about 75 percent) is reported on Culebra (Tucker 1988, 1989).

No data on the growth rate of juvenile leatherback turtles in the wild are available. This situation arises from the unfortunate fact that the distribution of juvenile leatherback turtles is unknown, and thus specimens are unavailable for capture-recapture methodologies designed to measure growth. The problem is exacerbated by poor survivability in captivity, which further limits opportunities for study. Nonetheless, some investigators have been successful in raising leatherbacks and publishing data on captive growth rates (Deraniyagala 1936, Glusing 1967, Frair 1970, Spoczynska 1970, Phillips 1977, Witham 1977, Bels *et al*. 1988). With the exception of Bels *et al*. (1988), turtles did not survive beyond 2 years.

Captive growth data are widely disparate, but the very rapid growth reported by some investigators (coupled with evidence of chondro-osseous development conducive to rapid growth) has led to speculations that leatherbacks may reach sexual maturity in 2 to 3 years (Rhodin 1985). Bels *et al*. (1988) challenge this hypothesis in their report of a healthy captive leatherback 1,200 days of age weighing 28.5 kg, with a carapace 82 cm in length. While leatherbacks may grow to sexual maturity at an earlier age than other sea turtles, it is clear that more data are needed before growth rates can be accurately calculated.

Migration

The leatherback migrates farther (Pritchard 1976) and ventures into colder water than does any other marine reptile (e.g., Threlfall 1978, Goff and Lien 1988). The evidence currently available from tag returns and strandings in the western Atlantic suggests that adults engage in routine migrations between boreal, temperate and tropical waters, presumably to optimize both foraging and nesting opportunities (Bleakney 1965, Pritchard 1976, Lazell 1980, Rhodin and Schoelkopf 1982, Boulon *et al*. 1988). The composition of epibiotic barnacle communities on Caribbean-nesting leatherbacks provides indirect evidence that gravid females embark from and subsequently return to temperate latitudes (Eckert and Eckert 1988).

Direct evidence of long-distance movement is scarce, but is available from leatherbacks tagged while nesting in the Caribbean and subsequently stranding in northern latitudes (Pritchard 1973, 1976, Lambie 1983, Boulon *et al*. 1988); and also from a turtle tagged in Chesapeake Bay in 1985 and killed in Cuba in 1986 (Barnard *et al*. 1989). In addition, a nester tagged at Jupiter Beach, Florida, was recaptured near Cayo Arcas, Gulf of Campeche (Hildebrand 1987), and a nester tagged at Sandy Point NWR, St. Croix, was recaptured near Cayos Triangulos, also in the Gulf of Campeche, 2 years later and some 3,000 km from the tagging site (Boulon 1989). The longest known movement is that of an adult female who traveled 5,900 km to Ghana, West Africa, after nesting in Surinam (Pritchard 1973). An adult female tagged with a satellite transmitter while nesting in French Guiana in 1986 traveled 820 km in three weeks (an average speed of 40 km/day, Duron-DuFrenne 1987). A nester tagged with a satellite transmitter on Sandy Point NWR, St. Croix in 1989 travelled 515 km (and ventured some 200 km south of St. Croix) before the transmitter was removed 18 days later when the turtle emerged to nest on Isla Culebra (NMFS and FWS 1992).

Foraging

Food habits are known primarily from the stomach samples of slaughtered animals (Brongersma 1969, Hartog 1980, Hartog and Van Nierop 1984). Leatherbacks feed on pelagic medusae (jellyfish), siphonophores, and salpae in temperate and boreal latitudes (e.g., Bleakney 1965, Brongersma 1969, Duron 1978, Eisenberg and Frazier 1983, Musick 1988). Aerial surveys document leatherbacks in Virginia waters, especially May to July during peak jellyfish *(Chrysaora* spp., *Aurelia* spp.*)* abundance (Musick 1988, NMFS and FWS 1992). Further south, foraging on the cabbage head jellyfish *(Stomolophus meleagris)* has been observed in waters off North Carolina (NMFS and FWS 1992). In February 1989, an adult female leatherback (originally tagged in French Guiana) stranded on the Georgia coast and stomach contents revealed unidentified medusae and *Libinia* sp., a small crab commensal on *Stomolophus* (NMFS and FWS 1992). Captain Joe Webster has observed leatherbacks feeding on “jellyballs” *(Stomolophus)* in Georgia waters and notes that the turtles are seen in water as shallow as 5.6 m where jellyballs are abundant (NMFS and FWS 1992). In the Gulf of Mexico, aerial survey data often show leatherbacks associated with *Stomolophus* (Leary 1957, Lohoefener *et al*. 1988). Other observers have also reported a “co-incidence” of leatherbacks and maximum jellyfish abundance, especially *Aurelia,* in the Gulf (NMFS and FWS 1992).

Foraging has most often been observed at the surface, but Hartog (1980) after finding nematocysts from deep water siphonophores in leatherback stomach samples, speculated that foraging may occur at depth. Limpus (1984) reported a leatherback feeding on octopus bait on a handline at 50 m depth off western Australia. Based on offshore studies of diving by adult females nesting on St. Croix, Eckert *et al*. (1989) proposed that the observed internesting dive behavior reflected nocturnal feeding within the deep scattering layer (strata comprised primarily of vertically migrating zooplankters, chiefly siphonophore and salp colonies in the Caribbean, (Michel and Foyo 1976). Eckert *et al*. (1989) calculate a maximum dive depth of 1,300 m, but report that 95 percent of all dives are < 20 minutes in length and < 200 m in depth.

Relationship to Other Species

In South Florida, the leatherback sea turtle shares nesting beaches with the threatened loggerhead turtle (*Caretta caretta*) and the endangered green sea turtle (*Chelonia mydas*) in several counties where it nests, 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, opossums (*Didelphis virginiana*), ghost crabs (*Ocypode quadratus*), and ants prey on incubating eggs and hatchlings. The principal predator of leatherback sea turtle eggs is the raccoon. Raccoons are particularly destructive and may take up to 96 percent of all 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. In addition to the destruction of eggs, certain predators may take considerable numbers of hatchlings just prior to or upon emergence from the sand.

Table 1. Average number of leatherback nests by

County	Average
Indian River*	3.3
St. Lucie	14
Martin	43
Palm Beach	66
Broward	10
Dade	3.2
Monroe**	-
Collier**	-
Lee**	-
Charlotte**	-
Sarasota**	-

*Nesting activity reported from 1993-1995 only
**Nesting activity not reported

Status and Trends

The leatherback sea turtle was listed as endangered under the Endangered Species Act on June 2, 1970 (35 FR 8495). Internationally, it is considered "endangered" by the International Union for Conservation of Nature and Natural Resources (IUCN). It is also included on Appendix I of the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES), which the U.S. ratified in 1974. The nesting beach at Sandy Point NWR, St. Croix, became the first nesting beach of any marine turtle to be proposed as critical habitat (Federal Register, 23 March 1978; 43 FR 12050-12051) (Dodd 1978). In September 1978, the FWS designated the nesting beach on Sandy Point, St. Croix, as critical habitat; in March 1979, the NMFS determined the surrounding waters as critical habitat.

Declines in the number of nesting females have been documented in Malaysia (Brahim *et al*. 1987), India (Cameron 1923, Kar and Bhaskar 1982), Thailand (Polunin 1977), and the West Indies (Bacon 1970, Eckert and Lettsome 1988, Eckert 1989). It is not known whether leatherback populations within the U.S. are stable, increasing or declining, but there is no question that some nesting populations (*e.g*., St. John, St. Thomas) have been virtually exterminated. The number of leatherbacks nesting in the past at what is now Sandy Point NWR is unknown, but studies of the population since 1981 show annual fluctuations which do not project a long-term decline.

Today, most beaches in Florida are monitored for sea turtle nesting. Here, leatherback nesting has fluctuated widely during the survey period between 1979 and 1994 (Meylan *et al.* 1995, DEP 1996). Between 1988 and 1992, annual reported leatherback sea turtle nests varied between 98 and 188 statewide. The distribution of these nests differs from the loggerhead and green sea turtle nests. Leatherback nests have a center of distribution at Palm Beach County which supports half of the total nests reported throughout Florida. Martin and St. Lucie county beaches have been the site of 27.7 percent and 13.2 percent of leatherback nests, respectively. South of Palm Beach County, the number of leatherback nests declines more sharply. Broward County supported 3.0 percent of leatherback nesting and Miami-Dade County supported 1.6 percent.

The average number of nests annually for leatherback turtles within South Florida is shown in Table 1. These data show that Palm Beach County is clearly the most important nesting location within the region for the endangered leatherback. Leatherback nests constitute 0.8 percent of the total in Palm Beach County but only 0.4 and 0.5 percent in Broward and Miami-Dade Counties, respectively. We chose to represent only 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.

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 Leatherback Turtles in the U.S. Caribbean, Atlantic and Gulf of Mexico (NMFS and FWS 1992). 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, 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 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 1992).

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 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 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 and Dickerson 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 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. 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. Raymond (1984a) indicated that adult loggerhead emergence patterns were correlated with variations in beachfront lighting in south Brevard County, Florida, and that nesting females avoided areas where beachfront lights were the most intense. Witherington (1986) noted that loggerheads aborted nesting attempts at a greater frequency in lighted areas. Problem lights may not be restricted to those placed directly on or in close proximity to nesting beaches. The background glow associated with intensive inland lighting, such as that emanating from nearby large metropolitan areas, may deter nesting females and disorient or misorient hatchlings 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 and also results in tire ruts along the beach, which may hinder or trap emergent hatchlings. Mann (1977) suggested that mortality within nests may increase when externally applied pressure from beach cleaning machinery is exerted 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 1992). 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 1992).

Exotic Dune and Beach Vegetation: Non-native vegetation has invaded many coastal areas and often outcompetes native species such as sea oats, railroad vine, sea grape, dune panic grass and pennywort. The invasion of less stabilizing vegetation can lead to increased erosion and degradation of suitable nesting habitat. Exotic vegetation may also form impenetrable root mats which can prevent proper nest cavity excavation, invade and desiccate eggs, or trap hatchlings. The Australian pine *(Casuarina equisetifolia)* is particularly detrimental. Dense stands of this species have taken over many coastal strand areas throughout central and South Florida. Australian pines cause excessive shading of the beach that would not otherwise occur. Studies in Florida suggest that nests laid in shaded areas are subjected to lower incubation temperatures, which may alter the natural hatchling sex ratio. 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.

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. Studies on a relatively undisturbed nesting beach by Witherington (1986) indicated that excepting a late season severe storm event, erosion and inundation played a relatively minor role in destruction of incubating nests. Inundation of nests and accretion of sand above incubating nests as a result of the late season storm played a major role in destroying nests from which hatchlings had not yet emerged. Severe storm events (e.g., tropical storms and hurricanes) may result in significant nest loss, but these events are typically aperiodic rather than annual occurrences. In the southeastern U.S., severe storm events are generally experienced after the peak of the hatching season and hence would not be expected to affect the majority of incubating nests. Erosion and inundation of nests are exacerbated through coastal development and shoreline engineering. These threats are discussed above under beach armoring.

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

Poaching: In the U.S., killing of female 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.

Management

Conservation efforts for the leatherback have greatly improved since it was federally listed as endangered on June 2, 1970. During the 1970s, nest survey and protection efforts were generally sporadic and did little to reduce the widespread egg poaching on U.S. Caribbean beaches. Beginning in 1981, however, intensive nest survey and protection efforts were initiated on the single most important leatherback nesting beach in the U.S. Caribbean, Sandy Point, St. Croix. Prior to this, the majority of the 150 to 350 nests deposited annually were lost to poaching or erosion. Now overall hatch success exceeds 50 to 60 percent in most years. The FWS, in cooperation with Earthwatch, initiated similar measures on the other main U.S. Caribbean leatherback nesting beaches on Isla Culebra in 1984. Prior to the intensive nighttime patrolling, a high percentage of the nests on this island were poached. Overall hatch success is now greater than 75 percent in most years. Nest survey and protection efforts occur on several other U.S. Caribbean beaches of lesser but still significant importance such as Manchenil, St. Croix, and Pinones, Humacao, and Luquillo beaches in Puerto Rico.

In Florida, leatherback nesting data are collected in conjunction with loggerhead nesting surveys, which generally begin in early to mid-May. While a portion of the leatherback nesting season is missed by the systematic loggerhead and green sea turtle surveys, most nests are observed by someone and probably reported because of intensive public use of the main leatherback nesting beaches in Florida.

Along with the basic information on nest numbers, clutch size, and hatching success, the Sandy Point and Culebra projects have included additional studies of the nesting females and provided information on intra- and inter-nesting frequency, movements, survivorship, turtle size and weight, diving behavior, pre-reproductive migrations, nest temperature and expected hatchling sex ratio, depredation rates, nest site selection, and embryonic deformities.

In 1982, 310 ha of land on Isla Culebra, including Playas Resaca and Brava, were transferred to Culebra NWR. In 1984 the FWS purchased the 2.4 km long leatherback nesting beach at Sandy Point, St. Croix, establishing

Sandy Point NWR. These actions ensure the long-time protection of the most important leatherback nesting beaches in the U.S. Virgin Islands and Puerto Rico, although neither area is immune from external threats such as light pollution.

Recent reviews of sea turtle conservation efforts in the southeastern U.S. appear in Hopkins-Murphy (1988) and Possardt (1991). In addition to management of coastal habitats, NMFS and FWS (1992) discuss conservation measures for the leatherback turtle in the marine environment. In the South Florida Ecosystem, there are a number of management activities ongoing to benefit the leatherback sea turtle.

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 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 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. 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 leatherback nesting and hatching season is from February 15 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 juvenile and adult turtles, and offer a variety of effective management solutions for ameliorating this problem.

Information on the status and distribution of the leatherback sea turtle is critical to its conservation. Monitoring the various life stages of the turtles on nesting beaches is being conducted to evaluate current and past management practices. Data are collected on the number of nests laid, the number of nests that successfully hatch, and the production of hatchlings reaching the ocean. Standardized ground surveys on index beaches are underway throughout Florida by the FWS, DEP, and private groups and universities. Because of the turtles' slow growth rates and subsequent delayed sexual maturity, all monitoring will need to be conducted over a long period of time to establish population trends.

Mortality of leatherback turtles has been monitored since 1980 through the implementation of a regional data collection effort. This voluntary stranding network from Maine to Texas is coordinated by the NMFS and serves to document the geographic and seasonal distribution of sea turtle mortality (Schroeder 1987). 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, 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 the different 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/tape programs, full color identification posters of the various species of sea turtles, and a leatherback 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. 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.

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Recovery for the Leatherback Sea Turtle

Dermochelys coriacea

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

Species-level Recovery Actions

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

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

S2.1. Evaluate nest success and implement appropriate nest protection measures. Nesting and hatching success and hatchling emerging success on beaches occurring on State or Federal lands and all other important local or regional nesting beaches should be evaluated. Appropriate nest protection measures should be implemented by FWS and DEP, and appropriate local governments or organizations, to ensure greater than 60 percent hatch rate. Until recovery is ensured, however, projects on all Federal and State lands and key nesting beaches, such as those in Brevard, Indian

River, St. Lucie, Martin, and Palm Beach counties, should strive for a higher rate of hatching success. In all cases, the least manipulative method should be employed to avoid interfering with known or unknown natural biological processes. Artificial incubation should be avoided. Where beach hatcheries are necessary, they should be located and constructed to allow self release, and hatch rates approaching 90 percent should be attained. Nest protection measures should always enable hatchling release the same night of hatching.

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

S4. **Monitor trends in nesting activity.** DEP and FWS should continue to refine standardized nest survey criteria, identify additional index survey beaches to be monitored, and continue to conduct training workshops for surveyors. Surveys in Florida do not routinely cover the first two months of the leatherback 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 that leatherback turtles are nesting, including 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 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 that facilities permitted to hold and display captive sea turtles have appropriate informational displays.** Over 50 facilities are permitted to hold sea turtles for rehabilitation, research, and public education. Many are on public display and afford opportunities for public education. Display of accurate information on the basic biology and conservation problems should be a requirement of all permittees. All facilities should be visited by FWS, NMFS and/or DEP to ensure captive sea turtles are being displayed in a way to meet these criteria.

S5.5. 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 0.3 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 associated with the inlet in terms of sand impoundment and sediment volume deficit to downdrift areas, and determining the area of inlet influence.

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

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

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

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

H1.3. Identify important nesting beaches experiencing greater than 40 percent nest loss from erosion and implement appropriate habitat restoration measures (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. 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 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.