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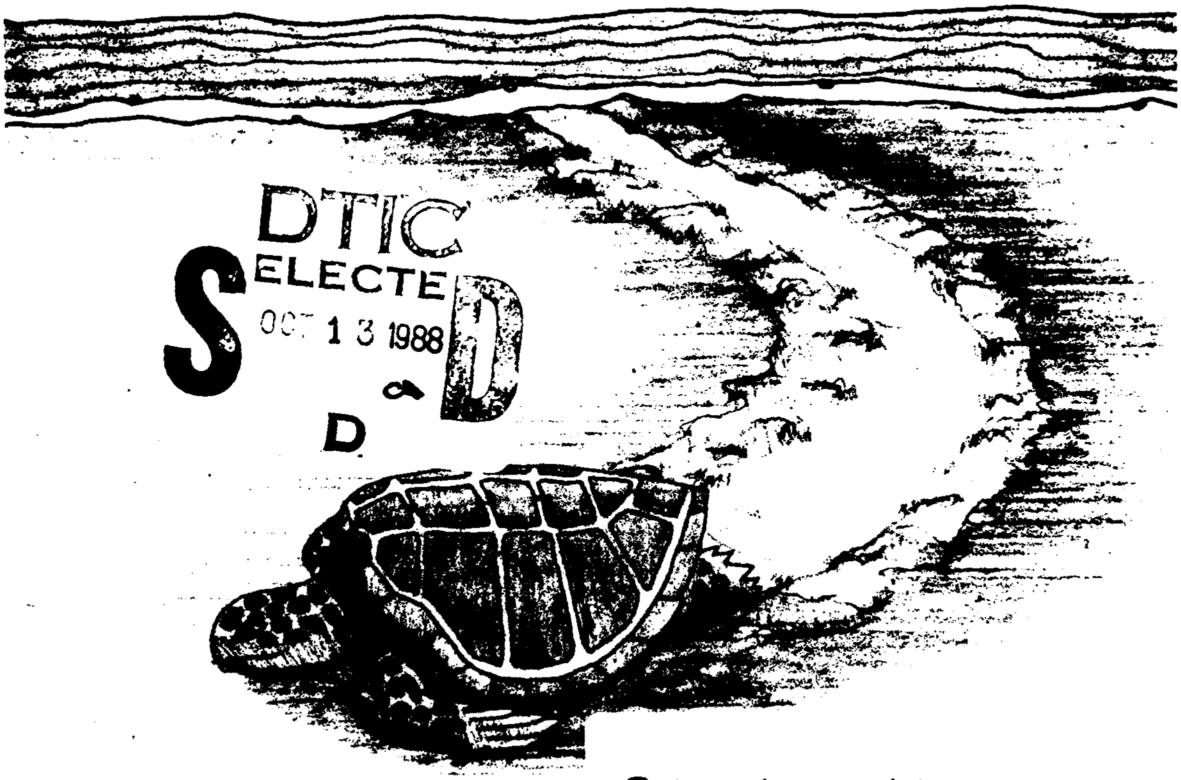
LIFE HISTORY AND ENVIRONMENTAL REQUIREMENTS OF LOGGERHEAD TURTLES



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FWS
Biological Report 88(23)
WES/TR/EL-86-2 (Rev.)
August 1988

LIFE HISTORY AND ENVIRONMENTAL REQUIREMENTS OF LOGGERHEAD TURTLES

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Performed for

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Waterways Experiment Station
U.S. Army Corps of Engineers
Vicksburg, MS 39180

and

U.S. Department of the Interior
Fish and Wildlife Service
Research and Development
National Wetlands Research Center
Washington, DC 20240

Library of Congress Cataloging-in-Publication Data

Nelson, David A.
Life history and environmental requirements of loggerhead turtles.
(Biological report ; 88(23))
Supt. of Docs. no. : I 49.89/2:88(23)
Bibliography: p.
1. Loggerhead turtle. I. U.S. Fish and Wildlife Service. II. Title. III. Series: Biological report (Washington, D.C.) ; 88(23).
QL666.C536N44 1988 587.92 88-600257

This report should be cited as:

Nelson, D.A. 1988. Life history and environmental requirements of loggerhead turtles. U.S. Fish Wildl. Serv. Biol. Rep. 88(23). U.S. Army Corps of Engineers TR EL-86-2(Rev.). 34 pp

PREFACE

This report is designed to provide coastal managers, engineers, and biologists with a brief comprehensive sketch of the biological characteristics and environmental requirements of the loggerhead turtle and to describe how populations of the species may be expected to react to environmental changes caused by coastal development. The report has sections on taxonomy, life history, ecological role, environmental requirements, growth, exploitation, and management. There is a focus on loggerhead populations in the United States.

Suggestions or questions regarding this report should be directed to one of the following addresses.

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or

U.S. Army Engineer Waterways Experiment Station
Attention: WESER-C
Post Office Box 631
Vicksburg, MS 39180

CONVERSION TABLE

Metric to U.S. Customary

Multiply	*By*	*To Obtain*
millimeters (mm)	0.03937	inches
centimeters (cm)	0.3937	inches
meters (m)	3.281	feet
meters (m)	0.5468	fathoms
kilometers (km)	0.6214	statute miles
kilometers (km)	0.5396	nautical miles
square meters (m^2)	10.76	square feet
square kilometers (km^2)	0.3861	square miles
hectares (ha)	2.471	acres
liters (l)	0.2642	gallons
cubic meters (m^3)	35.31	cubic feet
cubic meters (m^3)	0.0008110	acre-feet
milligrams (mg)	0.00003527	ounces
grams (g)	0.03527	ounces
kilograms (kg)	2.205	pounds
metric tons (t)	2205.0	pounds
metric tons (t)	1.102	short tons
kilocalories (kcal)	3.968	British thermal units
Celsius degrees (°C)	1.8(°C) + 32	Fahrenheit degrees

U.S. Customary to Metric

inches	25.40	millimeters
inches	2.54	centimeters
feet (ft)	0.3048	meters
fathoms	1.829	meters
statute miles (mi)	1.609	kilometers
nautical miles (nmi)	1.852	kilometers
square feet (ft^2)	0.0929	square meters
square miles (mi^2)	2.590	square kilometers
acres	0.4047	hectares
gallons (gal)	3.785	liters
cubic feet (ft^3)	0.02831	cubic meters
acre-feet	1233.0	cubic meters
ounces (oz)	28350.0	milligrams
ounces (oz)	28.35	grams
pounds (lb)	0.4536	kilograms
pounds (lb)	0.00045	metric tons
short tons (ton)	0.9072	metric tons
British thermal units (Btu)	0.2520	kilocalories
Fahrenheit degrees (°F)	0.5556 (°F - 32)	Celsius degrees

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FIGURES

ACKNOWLEDGMENTS

We gratefully acknowledge reviews by Llewellyn Ehrhart, University of Central Florida, staff of the National Marine Fisheries Service, Miami, FL, Edward J. Pullen, Tom Fredette, and Doug Clark, USAE Waterways Experiment Station, and David Moran, National Wetlands Research Center. We also thank Carol Mayes for assistance in preparation of figures.

LIFE HISTORY AND ENVIRONMENTAL REQUIREMENTS OF LOGGERHEAD TURTLES

NOMENCLATURE/TAXONOMY/RANGE

Scientific name	*Caretta caretta*
Preferred common name	Loggerhead
Class	Reptilia
Order	Chelonia

In the United States loggerhead turtles may be encountered along coastlines and offshore from Texas through Florida on the Gulf of Mexico coast and from Florida to Nova Scotia on the Atlantic coast (Rebel 1974; Lee and Palmer 1981; Hildebrand 1982; Hopkins and Richardson 1984). Scattered nesting may occur in most of its range; however, nesting concentrations are on coastal islands of North Carolina, South Carolina, and Georgia and on the east and west coasts of Florida (Figure 1) (Hopkins and Richardson 1984).

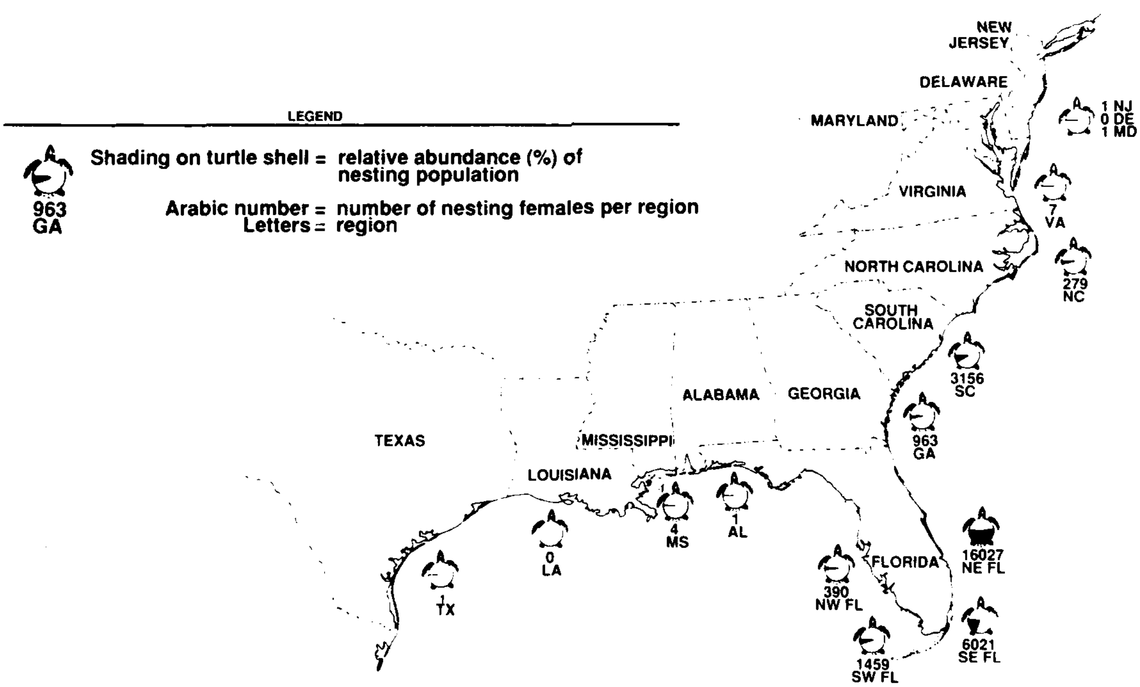


Figure 1. Distribution and relative abundance of nesting female loggerhead turtles along the Gulf of Mexico and Atlantic coasts (adapted from Gordon 1983).

MORPHOLOGY/IDENTIFICATION AIDS

Adult

The adult loggerhead turtle is slightly elongate with a heart-shaped carapace that tapers posteriorly (Figure 2) (Pritchard et al. 1983). It has a very large triangular head that may be as wide as 25 cm. Loggerheads normally weigh up to 200 kg and attain a carapace length (straight line) up to 120 cm (Pritchard et al. 1983). Their general coloration is reddish-brown dorsally and cream-yellow ventrally (Hopkins and Richardson 1984). Loggerheads can usually be distinguished from other sea turtles by the following combination of characteristics: (1) a hard shell, (2) two pairs of scutes on the front of the head (prefrontal scutes), (3) five pairs of lateral scales on the carapace, (4) plastron (ventral) with three pairs of enlarged scutes (inframarginals) connecting to the carapace, (5) two claws on each flipper, and (6) the typical brownish-red coloration (Figure 3 and Table 1) (Marquez 1978).

Hatchlings

Loggerhead hatchlings are brown above with light margins below (Marquez 1978). The shade of brown varies from light to dark (Pritchard et al. 1983). Hawksbill and loggerhead hatchlings look alike but can be differentiated; loggerheads have five pairs of lateral scales (scutes) and hawksbills have four pairs (Pritchard et al. 1983).

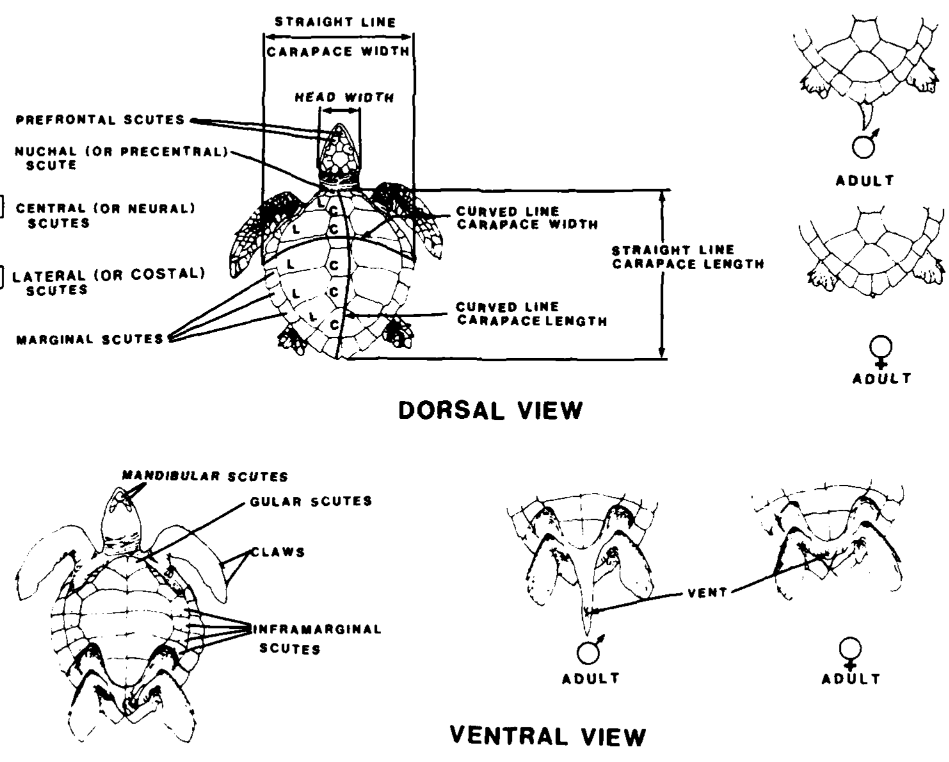


Figure 2. General external morphology of sea turtles (adapted from Pritchard et al. 1983).

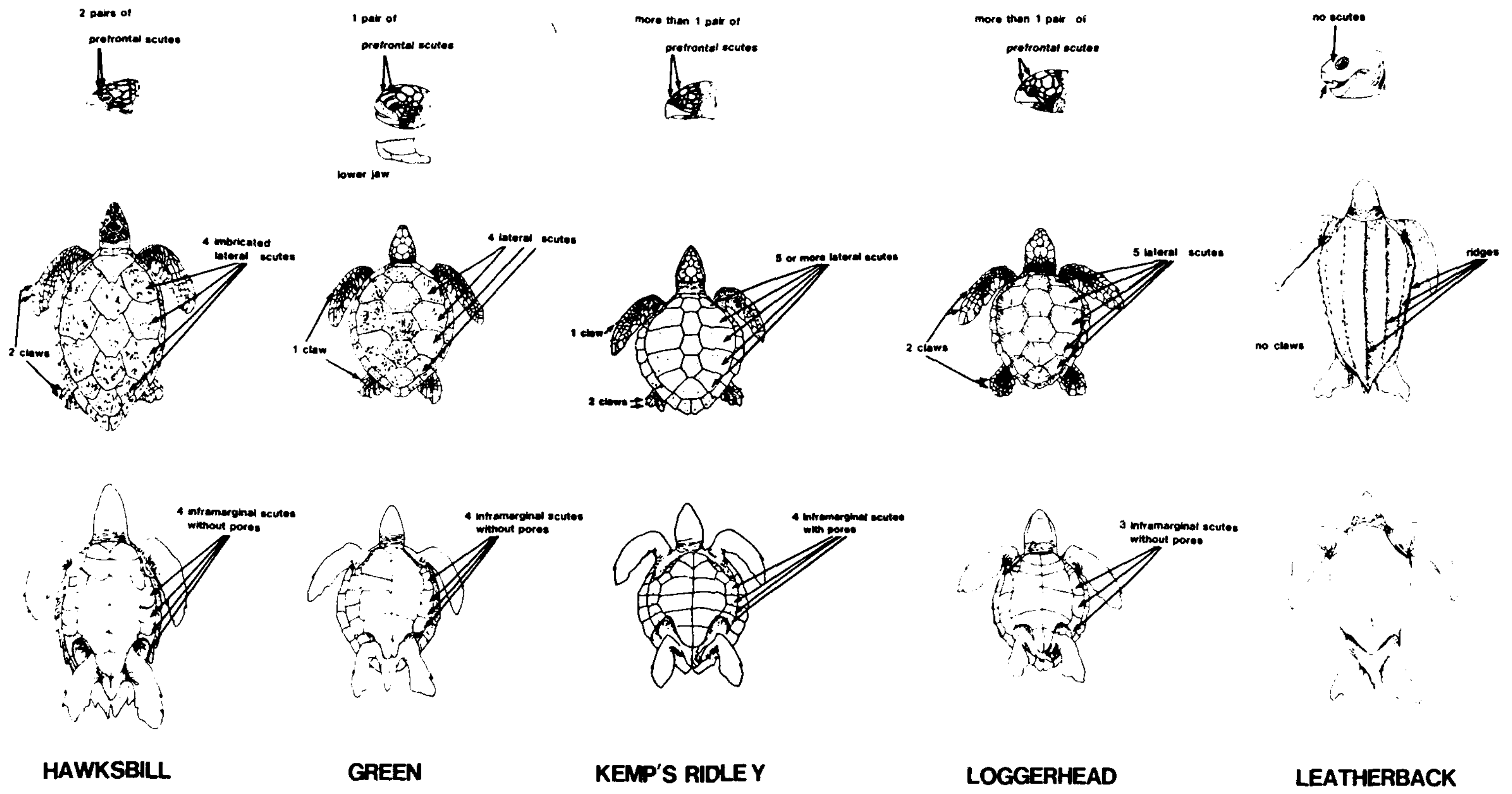


Figure 3. Morphological features used to distinguish between different sea turtle species (adapted from Marquez 1978).

Table 1. Adult sea turtle characteristics for five species. Source: (Conant 1975; Zwinenberg 1977; Marquez 1978; Limpus et al. 1983a; Pritchard et al. 1983; Hopkins and Richardson 1984).

Species	Length (cm)	Weight (kg)	Carapace shape	Carapace color	Plastron color	Head size and shape	Head width (cm)
Leatherback	155-183 (140)[a]	272-725 (300)[a]	Elongate, triangular	Blue-black	White	Medium round	25
Green	51-105 (90)[a]	113-140 (100)[a]	Broad, oval	Olive, dark-brown mottled	White-yellowish	Small round	15
Loggerhead	79-125 (110)[a]	77-140 (105)[a]	Heart-shaped	Reddish-brown	Cream-yellow	Very large triangular	25
Kemp's ridley	59-73 (70)[a]	36-45 (42)[a]	Circular	Olive-green	Yellow	Medium pointed	13
Hawksbill	76-90 (80)[a]	43-120 (60)[a]	Shield-shaped	Greenish-brown mottled	Yellow	Narrow pointed	12

Species	Number of coastal scutes	Scutes on bridge	Number of prefrontal scutes (pair)	First nuchal touching	Number of claws Front	Number of claws Rear	Track width (cm)	Track pattern
Leatherback	N/A	N/A	N/A	N/A	0	0	150-200	Symmetrical
Green	4	4	1	No	1	1	100	Symmetrical
Loggerhead	5	3-4	2	Yes	2	2	90-100	Asymmetrical
Kemp's ridley	5	4 (5 rarely)[b]	2	Yes	1	2	80	Asymmetrical
Hawksbill	4	4	2	No	2	2	75-80	Asymmetrical

[a]Common length or weight given in parentheses [b]With pores in inframarginal scutes; other species without pores.

Tracks and Nests

When loggerheads crawl up on a beach, they leave an asymmetrical pattern of 90- to 100-cm-wide depressions in the sand (Figure 4) (Pritchard et al. 1983). When they crawl ashore to nest, loggerheads, like hawksbills and Kemp's ridleys, dig a shallow pit for their bodies (Figure 5) and then dig a flask-shaped nest cavity (Pritchard et al. 1983). In contrast, leatherbacks and green turtles dig a deep body pit when nesting.

LIFE HISTORY

The greatest portion of a sea turtle's life is spent in ocean and estuarine waters where it breeds, feeds, migrates, and hibernates. The remainder of the female's life is spent on beaches where she digs a nest and lays her eggs. The eggs then hatch and the hatchlings crawl to the water to become part of the marine system again (Figure 6).

Mating

Mating has been observed in offshore waters adjacent to nesting beaches just prior to nesting and egg laying (Hopkins and Richardson 1984). Detailed observations of mating in loggerheads are not available; however, mating in loggerheads probably begins prior to the nesting season and probably occurs only once a season for each female (Caldwell et al. 1959). Matings have been observed during daylight and probably occur at night as well (Caldwell 1959). During mating, the male mounts the female, holding

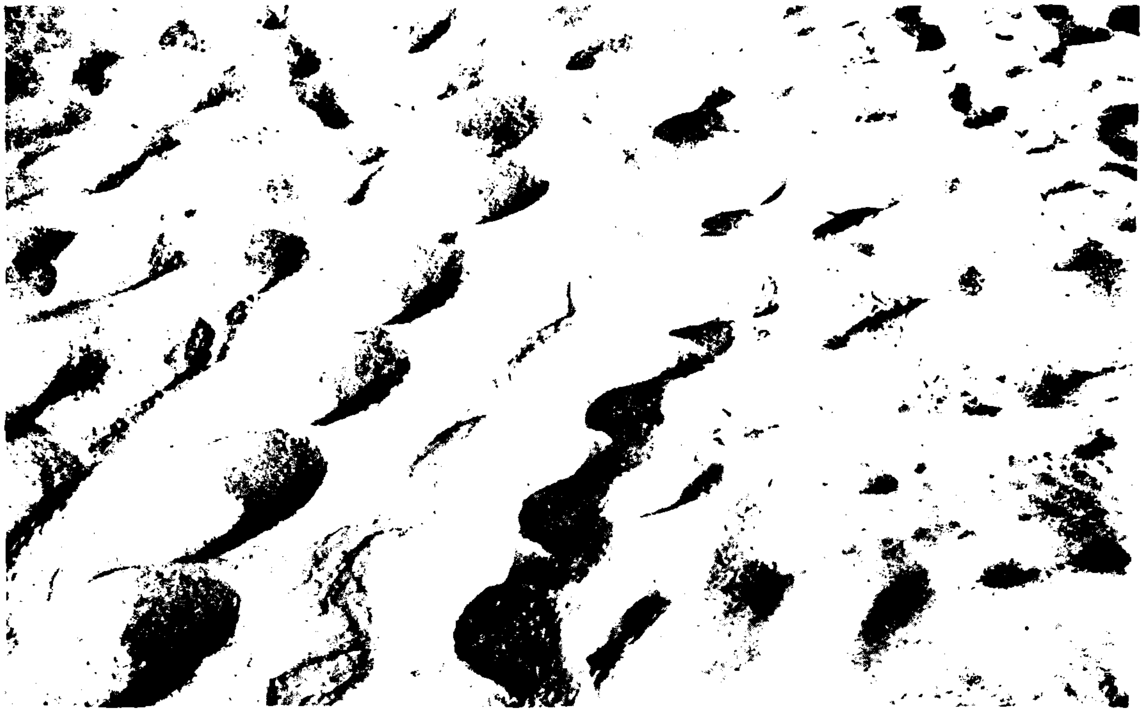
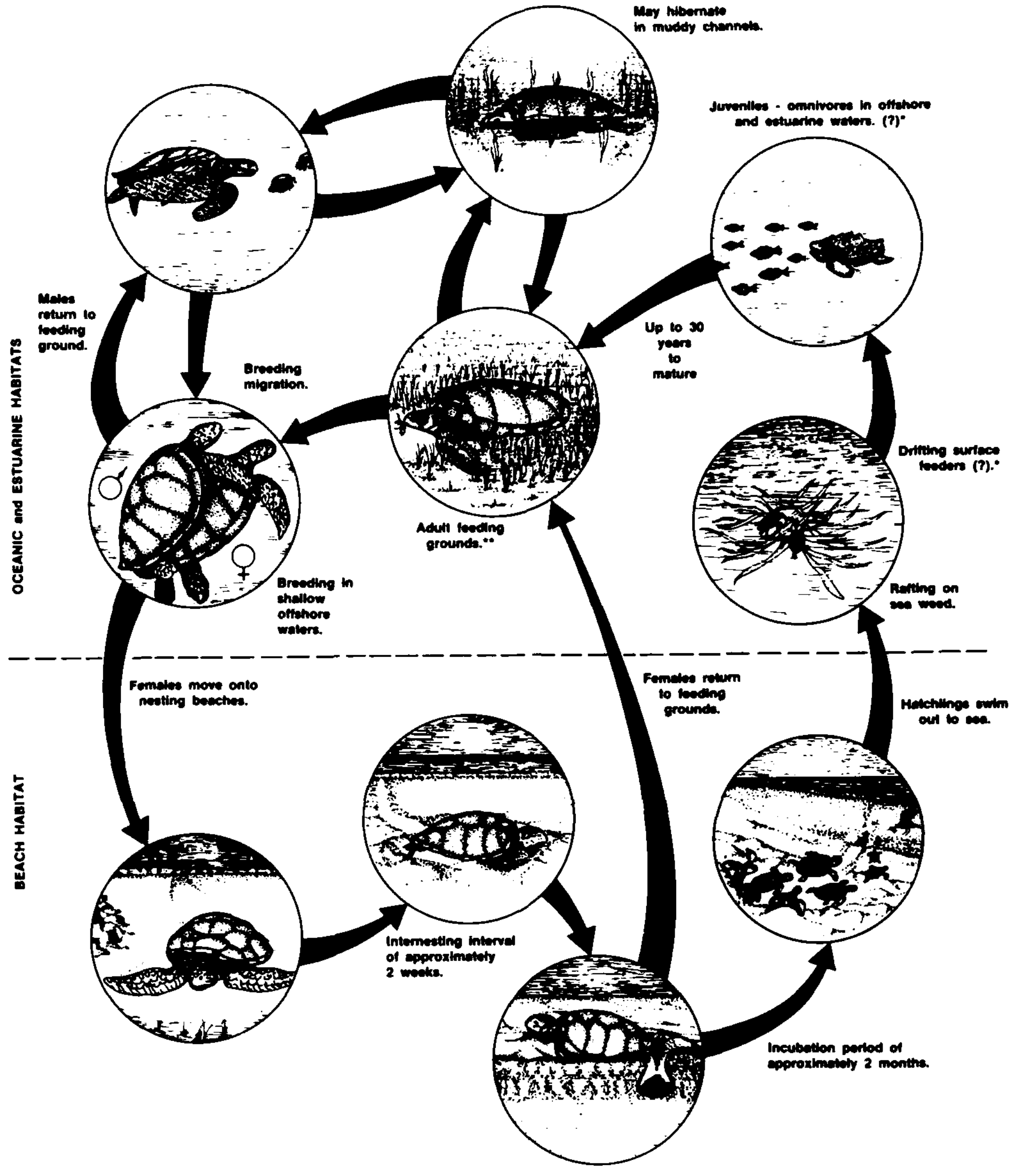


Figure 4. Alternating track of female loggerhead crawl.

Figure 5. Shallow body pit of loggerhead nest.



* Developemental habitats are not well known and probably vary with species.

** Feeding habits depend on species.

Figure 6. Diagram of general life cycle of sea turtles (adapted from Mrosovsky 1983).

onto her carapace with his four limbs. The male's 8-inch (20-cm) or longer tail, which is much longer than the female's, is bent downward, thereby pressing his cloacal opening against the female's cloaca (Caldwell 1959).

Nesting

On Hutchinson Island, FL, nesting begins in the spring (April or usually May) when local water temperatures reach 23 to 24 °C (Williams-Walls

et al. 1983), increasing with increased temperatures and photoperiod to a peak in June and July, and declining until completion in late summer (August-September) (Fletemeyer 1981, 1982, 1983; Stoneburner 1981; Richardson and Richardson 1982).

Loggerhead females generally nest every other year or every third year, although a small percentage nest at intervals of less than 2 or more than 3 years (Richardson and Richardson 1982; Bjorndal et al. 1983; Ehrhart and Raymond 1983; Fletemeyer 1983). When a loggerhead nests, it usually will lay 2 to 3 clutches (range, 1 to 7) of eggs per season (Table 2) (Ehrhart 1979; Talbert et al. 1980; Fletemeyer 1981; Lenarz et al. 1981; Richardson and Richardson 1982). The maximum number of clutches laid in a single season by an individual is probably determined by the duration of the nesting season and by physiological constraints which require 2 weeks for eggs to mature for each successive clutch (Frazer and Richardson 1986). These intraseasonal nestings are generally 12 to 14 days apart (range 11 to 20 days) (Fletemeyer 1983; Williams-Walls et al. 1983; Frazer 1984). Intraseasonal nesting intervals may vary with ambient water temperature. As water temperature increases, the interval between clutches may decrease (Hughes and Brent 1972). A 2-week-long cold water intrusion off Hutchinson Island, FL, lowered the mean surface temperature 3.7 °C, from 29.4 to 25.7 °C. The mean intraseasonal renesting interval was increased from 13.4 to 17.5 days as a result of the decrease in ambient water temperature (Williams-Walls et al. 1983). Loggerheads are not

Table 2. Summary of breeding information on sea turtles. (Conant 1975; Marquez 1978; Marquez et al. 1982; Hopkins and Richardson 1984).

Species	Egg diameter (cm)	Number of eggs	Number of clutches	Nest depth (cm)	Hatchling carapace length (cm)	U.S. season
Leatherback	5.1-6.3	50-170 (92-110)[a]	1-9 (5-6)[a]	75-100	5.5	Mar-Sep
Green	4.5-5.0	100-200 (100)	1-8 (3-7)	75-100	5.0	Jun-Sep
Loggerhead	3.5-4.9	35-180 (120)	1-7 (2-3)	45-90	4.5	Apr-Sep
Kemp's ridley	3.8-4.0	50-185 (110)	2-3	4-35	4.2	Apr-Jul
Hawksbill	3.5-4.0	50-250 (160)	1-4 (2+)	50-60	4.5	May-Aug

Species	Incubation length (days)	Interval between nests (days)	Nesting frequency (years)	Age at maturity (years)	Estimated number of nests/year[b]
Leatherback	50-70	9-17 (9-10)[c]	2-3	----	43
Green	45-60	10-15 (14)	2-4 (2)	20-30 (4-13)[d]	204
Loggerhead	46-65	11-20 (12-14)	2-3 (2.5)	6-30 (30)	29,759
Kemp's ridley	45-70	20-28	2-3 (1)	5-7	<1
Hawksbill	45-75	14-27 (19)	1-4 (3)	3-5	2

[a]Numbers in parentheses equal average or common number or value reported in literature.
[b]U.S. continent. Information from Gordon (1983).
[c]Common number of days between nests.
[d]Common age at maturity (age at maturity is largely based on animals raised in captivity).

considered to be as site specific when returning to a nest between or within seasons as are green sea turtles (Caldwell et al. 1959; Talbert et al. 1980; Bjorndal et al. 1983). Distance between nest sites of a particular turtle during a season (renesting distance) is generally less than 5 km (Hughes 1974; LeBuff 1974; Ehrhart 1979; Williams-Walls et al. 1983; Talbert et al. 1980; Fletemeyer 1983); the longest known internesting distance interval is 700 km (Stoneburner and Ehrhart 1981).

Beach selection for nesting may be based on repeated use of the same nest site (Carr 1967; Richardson and Richardson 1982; Fletemeyer 1983; Hopkins and Richardson 1984), learned behavior (Hendrickson 1958), position of beach rocks (Hughes 1974; Mann 1978), and proximity of offshore reefs (Stoneburner 1982; Williams-Walls et al. 1983). Loggerheads may return to a beach to nest because of (1) nest site fixity, or (2) inheritance of the ability to return to a particular beach, together with imprinting at birth to a beach. Rock outcrop on the shoreline may serve to guide turtles to a certain beach in Africa (Hughes 1974) while, in the United States, rocks which are narrowly spaced may reduce the use of a beach for nesting (Mann 1978). Beaches close to offshore reefs are used more frequently for nesting. Offshore reefs are used for resting and feeding areas between egg-laying sessions (Stoneburner 1982; Williams-walls et al. 1983).

Loggerheads emerge from the surf at night and crawl ashore (Frazer 1983b). Approximately 30%-50% of the time they crawl onto the beach (sometimes excavating a cavity, sometimes not) and return to the water without depositing eggs (false crawl) (Stoneburner 1981; Ehrhart and Raymond 1983; Williams-Walls et al. 1983). The reasons for these "false crawls" are not well understood but may be influenced by a turtle's "readiness" to lay, physical properties of the beach, temperature of the beach sand, and disturbance of the emerging turtle (Mann 1978; Fletemeyer 1981; Stoneburner and Richardson 1981; Ehrhart and Raymond 1983). Sand which is too firm may inhibit or prevent turtles from digging nests; sand may be compacted by vehicular traffic on the beach or beach nourishment (Fletemeyer 1981; Ehrhart and Raymond 1983; Williams-Walls et al. 1983). Emerging turtles that encounter human or animal activity or lights shining directly onto the beach may return to the water without nesting (Mann 1978; Fletemeyer 1979; Ehrhart and Raymond 1983). Moving lights, such as from automobiles, may also deter nesting in some locations (Mann 1978).

Loggerheads usually locate their nests between mean high tide and the top of the primary dune, most often at the seaward base of the dune. Each female turtle may dig in one to five spots before finally laying (Ehrhart and Raymond 1983). Nest-digging and egg-laying usually take about 1 h. Between 35 and 180 eggs ($\bar{x}$ = 120) are deposited into the nest hole (Fletemeyer 1983, Hopkins and Richardson 1984). In Georgia and Florida, loggerhead clutch size does not significantly increase or decrease monotonically for sequential clutches by an individual over the course of a nesting season (Ehrhart 1980, Frazer and Richardson 1985). However, clutch size does increase with individual straight-line (SL) carapace length (Ehrhart 1980, Frazer and Richardson 1986). The nest site usually has a very shallow depression or body pit. The depth of the flask-shaped nest from the beach surface to the bottom of the eggs ranges from 43 to 86 cm ($\bar{x}$ = 58.7 cm, SD = 7.92 cm). The vertical thickness of egg mass ranges from 10 to 40 cm ($\bar{x}$ = 23 cm, SD = 6.5 cm) (Limpus et al. 1979). The nest cavity is 20.3 to 25.4 cm wide (Caldwell 1959). The depth from the beach surface to the top of the eggs ranges from 12.7 to 55.9 cm but most often is 27.9 to 40.6 cm.

Eggs

Loggerhead eggs are slightly smaller but similar in appearance to ping-pong balls (Figure 7). No air space is present in the eggs, and the shells, although calcareous, are soft and pliable (Ackerman 1980). Pore structure is absent in the mineralized layer of the turtle egg shell (Solomon and Baird 1976). The eggs range from 35 to 49 mm in diameter, averaging 42 mm (Caldwell 1959; Caldwell et al. 1959; Ehrhart 1977, 1979; Hirth 1980). Average egg weight is 38.4 g (Kaufmann 1968). Egg size tends to be smallest for eggs laid last within a nest (Caldwell 1959). Egg size in loggerheads apparently does not change substantially with body size, clutch size, or date clutch is laid (Frazer and Richardson 1986). Small, yolkless eggs 28 to 30 mm in diameter may also be laid (Caldwell 1959; LeBuff and Beatty 1971).

The eggs hatch in 46 to 65 days ($\bar{x}$ = 60 days) and hatchlings emerge from the nest 2-3 days later; much of the predation on hatchlings occurs during that 2-3 day period (Ackerman 1981; Yntema and Mrosovsky 1982; Fletemeyer 1983; Hopkins and Richardson 1984).

Figure 7. Exposed clutch of eggs being deposited by a loggerhead turtle.

In Florida, and probably other warmer climates, the incubation period tends to be shorter (53 days, SD = 2.6, Nelson et al. 1986). Hatching success or fertility rates in natural clutches are 80% to 90% (Ehrhart 1982) (Figure 8). Hatching success and incubation time can be affected by clutch size, ambient sand temperature, sand compaction, and other physical parameters of the sand surrounding the nest (Mann 1978; Fletemeyer 1979; Yntema and Mrosovsky 1982; Limpus et al. 1983b). As the clutch mass increases, the incubation time increases (Ackerman 1980). The higher the ambient sand temperature, the shorter the incubation time. However, eggs do not hatch when exposed to ambient sand temperatures outside the 24 to 34 °C range. Optimal hatching success occurs between 25 and 32 °C (Limpus et al. 1983b). During the critical period of 11 to 31 days of incubation, when incubation temperatures were laboratory-controlled and constant at 32 °C or above, all embryos developed into females, whereas at 28 °C or below all embryos developed into males; at 30 °C embryos developed into relatively equal numbers of males and females (Yntema and Mrosovsky 1982).

Eggs consume oxygen throughout their incubation. The rate of oxygen uptake increases rapidly during the second half of incubation and slows slightly just prior to hatching (Ackerman 1981). Adequate exchange of oxygen and other gases between the nest and surrounding sand is important to the rate of growth and viability of the embryos (Ackerman 1980). Gas exchange can be affected by grain size and moisture content of sand (Hillel 1971). Sands that range from fine to coarse (0.25- to 0.125-mm size grains) allow sufficient gas exchange for high hatching success (Schwartz 1982). Sand compaction may also affect gas exchange (Fletemeyer and Beckman, in press). Compacted sands, which may result from vehicular traffic on the beach and beach nourishment, may also inhibit the digging by hatchlings from

Figure 8. Hatching success being determined for a loggerhead nest in Delray Beach, Florida.

the nest cavity to the sand surface (Mann 1978; Fletemeyer 1979). Compacted sands may also cause direct egg loss when a nesting cavity cannot be adequately dug to a size to contain all the eggs or to a depth which will give the eggs protection from weather and crushing (Raymond 1984a).

Hatchlings

Hatchlings emerge as a group from the nest at night and orient seaward (Hopkins and Richardson 1984). They crawl upwards from the nest to just below the beach surface and remain there for 1-3 days before emerging (Figure 9). Those that hatch late or remain in the nest after others in the clutch have emerged usually die (Carr and Hirth 1961). Ehrhart and Raymond (1983) found 83% to 90% of the hatchlings in each clutch on some Florida beaches emerged successfully. Recently hatched turtles weigh 15 to 23 grams and measure 44 to 48 mm in carapace length and 35 to 40 mm in carapace width (Caldwell et al. 1955; Fletemeyer 1983) (Figure 10). After emergence, hatchlings must reach the water rapidly to avoid heat stress or predation from gulls, raccoons, and ghost crabs (Dean and Talbert 1975; Hosier et al. 1981); however, gulls and heat stress are not usually factors since most emergences occur at night. Orientation of hatchlings to the ocean has been attributed to geotaxis (no longer an acceptable hypothesis) (Parker 1922), reflected surf light (Daniel and Smith 1947a), and bright horizon pattern (Mrosovsky and Carr 1967; Kingsmill and Mrosovsky 1982). The seaward orientation can be disrupted when lights from structures are directly visible landward from a nest (Mann 1978). Confused by the light shining on the beach, the hatchlings may wander inland and onto adjacent roadways (Mann 1978; Fletemeyer

Figure 9. A marked loggerhead nest with depression in sand which occurs 1-3 days before hatchlings emerge from the nest.

Figure 10. Loggerhead hatchling.

1979; Raymond 1984b). They may also wander extensively along the beach or into the dunes until preyed upon or desiccated. Hatchling movement to water may also be inhibited by pedestrian and vehicle tracks on the beach, as hatchlings often follow tracks that run parallel to the beach for long distances (Hosier et al. 1981). After reaching the water, most hatchlings become pelagic (Hopkins and Richardson 1984). On the Atlantic coast they may become associated with sargassum rafts in the Gulf Stream (Caldwell 1968; Smith 1968; Fletemeyer 1978a, 1978b; Carr and Meylan 1980). Movement of hatchlings on the gulf coast is unknown.

Juveniles and Subadults

Carr (1986) presents evidence that juvenile loggerheads become driftline inhabitants spending a number of years in a transatlantic developmental stage in the gyres and eddies of the main Gulf Stream system. As they spend their time in a pelagic phase in areas which may include the North Atlantic gyre and Sargasso Sea, they feed at or near the surface (Carr 1986) on

pelagic tunicates, pelagic snails, gooseneck barnacles, and other high-seas organisms (van Nierop and den Hartog 1984).

Subadult loggerhead turtles use bays and estuaries from April through October in Georgia and South Carolina and year round in Florida (Mendonca and Ehrhart 1982, Hopkins and Richardson 1984). Subadults are also commonly seen in coastal waters and found dead on beaches in south Texas (Rabalais and Rabalais 1980). In Mosquito Lagoon of east-central Florida, loggerheads (12.8 to 97.7-kg weight, 44.0 to 92.5-cm SL carapace length) were found throughout the year (Mendonca and Ehrhart 1982). They did not appear to be active at night and probably were in this area to feed on the abundant invertebrates (Mendonca and Ehrhart 1982).

Testosterone levels of an immature loggerhead population at Cape Canaveral, FL, indicated a sex ratio of 1 male to 1.57 females, which differed significantly from the 1:1 ratio observed in some other species (Owens et al. 1984).

Adults/Movements/Migration

Adult loggerheads seem to prefer shallow coastal waters (Carr 1952; Ernst and Barbour 1972; Carr et al. 1979; Rabalais and Rabalais 1980). Most loggerheads have been observed floating on the surface in waters less than 60 m deep (Fritts and Reynolds 1981; Shoop et al. 1981; Fritts et al. 1983). Commercial trawlers incidentally captured adult loggerheads in water depths less than 40 m (Bullis and Drummond 1978). Water depth appears to be better correlated to adult loggerhead distribution than distance from shore. The Gulf Stream may also be responsible for distributions (Fritts et al. 1983). More loggerheads are sighted near midday, which is probably related to surface basking to increase body temperature (Sapsford and van der Riet 1979; Shoop et al. 1981).

Loggerheads that nest in Georgia move toward North Carolina and Virginia during summer and fall and move south when the water temperatures decline in late fall and winter (Bell and Richardson 1978; Shoop et al. 1981). Few remain on the Atlantic coast by the onset of winter (Bell and Richardson 1978; Lee and Palmer 1981; Shoop et al. 1981).

From Florida, following nesting, loggerheads disperse to islands in the Caribbean, the southeast coast of the United States, southern Florida, and the Gulf of Mexico (Meylan et al. 1983). Dispersal may be rapid. For example, one turtle tagged on the east-central coast of Florida was recovered 11 days later from the coastal waters of Cuba, indicating a minimum traveling speed of 70 km/day (Meylan et al. 1983).

In Texas, where loggerheads rarely nest, they are commonly seen throughout the summer around oil platforms, rock reefs, and obstructions (Rabalais and Rabalais 1980, Hildebrand 1982).

GROWTH

On the basis of observations of captive-reared animals, growth in sea turtles appears to be rapid from hatchling to subadult (Parker 1929; Uchida 1967, Frazer 1982), slowing from subadult to adult (75- to 80-cm SL carapace length at maturity), and very slow after the adult size is reached. However, the growth rate in sea turtles differs depending on the quality (Stickney et al. 1973) and/or the quantity of food (Nuitja and Uchida 1982). Determination of growth rate has also been confounded by the lack of an effective method of marking a hatchling and finding it at later life stages, as only three or four per thousand may survive to adulthood (Hirth and Schaffer 1974; Frazer

1982). A tremendous number of marked hatchlings will result in only a few marked adults for measurement. A new method of grafting carapace tissue with plastron tissue shows promise for solving mark retention problems (Hendrickson and Hendrickson 1981). Additional difficulties in measuring growth rate result from differences in growth rate of captive and wild turtles (Frazer 1982) and differences in the method of measurement (Figure 2) (Pritchard et al. 1983). Two measurement methods for sea turtles are used, over-the-curve (OC) carapace length measurement and straight-line (SL) carapace length measurement. For Florida turtles with OC >50 cm or SL >45 cm, SL carapace length can be calculated by applying the following formula: SL = 0.980 (OC) - 5.14 (Frazer and Ehrhart 1983).

The growth rates measured between captures of 13 wild immature loggerheads in Mosquito Lagoon, FL, indicated a mean rate of 5.90 cm/year (SL) (Mendonca 1981). The data, although not statistically significant, showed a trend of decreasing growth rate as body weight increased. Based on these data, it was predicted that it would take 10 to 15 years for loggerheads in this habitat to reach a mature size of 75-cm SL carapace length. This is the size of the smallest loggerhead found nesting on beaches near Mosquito Lagoon (Ehrhart 1980, Mendonca 1981). Florida loggerhead carapace measurements at capture and recapture and time intervals between capture and recapture, when fit to von Bertalanffy and logistic growth interval equations, had an asymptotic length of 94.6 cm (SE = 2.18) and an intrinsic growth rate of 0.120 (SE = 0.0364) for the von Bertalanffy equation and an asymptotic length of 94.6 cm (SE = 1.97) and an intrinsic growth rate of 0.143 (SE = 0.0456) for the logistic growth interval equation (Frazer and Ehrhart 1985). Frazer and Ehrhart (1985) used the mean SL carapace length of all nesting females on Merritt Island, FL, in 1978 (92.22 cm, SD = 5.12) to estimate a mean age at maturity from the von Bertalanffy model to be 30 years.

Growth rates of nesting female loggerheads are based on a number of tag and recapture programs along the southeast Atlantic coast of the United States, particularly in Florida. The growth rate in Florida ranged from about 0.6 cm/year SL (Bjorndal et al. 1983) to about 1.0 cm/year SL (Fletemeyer 1983). The mean carapace length of nesting females ranged from 92.0 cm SL (Bjorndal et al. 1983) to 99.4 cm SL (Fletemeyer 1983). Nesting females in Florida exhibit a relationship between weight and shell length (Ehrhart and Yoder 1978). Hirth (1982) calculated a weight-to-length log linear relationship for female Florida loggerheads, described by the equation: log weight (kg) = 2.341 log length (cm, OC carapace) -2.613.

The average growth per month of hatchling loggerheads reared in captivity was 90.7 g in weight, 16.4 cm in length, and 12.7 cm in width (Kaufmann 1967). Schwartz and Frazer (1984) found that growth in weight of male and female captive loggerheads best fit the following nonlinear logistic equations:

male:
$$W = 93.1/(1 + 1{,}796.8e^{-0.735t})$$
and female:
$$W = 77.5/(1 + 18{,}684e^{-0.960t})$$
where:
- W = weight in kilograms
- e = base of natural log
- t = age in years

In rearing experiments, hatchling weight and length ranged from 20 to 48 g and from 4.6 to 5.3 cm (Parker 1926, 1929; Kaufmann 1967; Rebel 1974; Schwartz 1981). Yearling weight and SL in captivity ranged from 0.8 to 1.2 kg and from 16.3 to 18.4 cm (Witham and Futch 1977; Schwartz 1981). At 2, 3, and 4.5 years, reared loggerheads weighed 2.5 kg, 4.3 kg (Schwartz 1981), and 37 kg (Parker

1929), respectively, and measured 26 cm, 30 cm (Schwartz 1981), and 63 cm (Parker 1929), respectively.

AGE AT MATURITY

Caldwell (1962) and Uchida (1967) predicted age at sexual maturity in captive loggerhead at 6-7 years. Limpus (1979) concluded that maturity in natural Australian populations was reached in about 30 years. Mendonca (1981) predicted 10-15 years to reach sexual maturity in free-living loggerheads. Zug et al. (1983) predicted 14-19 years to reach sexual maturity in free-living loggerheads while Frazer (1983c) predicted 22 years. Using data from captive animals Frazer and Schwartz (1984) predicted age at maturity for free-living loggerheads to be 16-20 years. Frazer and Ehrhart (1985) present evidence that the upper estimates of 30 years are more realistic indications of mean age at maturity.

EXPLOITATION

Historically, loggerheads in the United States were harvested until populations became depleted. From 1951 to 1971, loggerhead landings in Florida averaged 3,334 kg/year (range 96-12,391 kg/year). Although no longer commercially harvested in the United States, loggerheads are harvested in parts of the Caribbean for meat to make soups and other foods; for skin and shell to make shoes, boots, handbags, jewelry, etc.; and for eggs to eat and make bakery products (Rebel 1974; Gonzales 1982; Ross 1982). Many turtles harvested in the Caribbean are believed to be derived from U.S. nesting populations (Brongersma 1971).

MORTALITY

Egg and hatchling mortality can be caused by erosion of nests by waves and winds and by flooding of nests due to storm surge and heavy rain (Caldwell 1959; Anderson 1981; Andre and West 1981); predation (Stancyk 1982); and equipment traffic on the beach (Mann 1978; Fletemeyer 1979; Mapes 1985). Hatchlings also have died from heat stress when their orientation is disrupted (Mann 1978; Fletemeyer 1979; Raymond 1984b). Loggerheads have died from fouling by, or ingestion of, petroleum and plastic products and from diseases, chemical pollution, shark and killer whale predation, boat collisions, entanglement in fishing gear and other debris, impingement by dredges, and hypothermia (Joyce 1982; Fletemeyer 1979, 1983; Gordon 1983; Balazs 1985; Lutcavage and Musick 1985; Witherton and Ehrhart 1985; Meylan and Sadove 1986).

An additional problem has been the accidental capture of sea turtles in shrimp trawls (Ross 1982). An estimated 11,000 to 12,000 loggerhead deaths per year result from incidental capture in trawls (Ross 1982; Gordon 1983). Most of these loggerheads are subadults ranging in OC lengths from 55 to 70 cm (Richardson and Richardson 1982).

POPULATION DYNAMICS

Due to changes in habitat use during different life history stages and seasons, sea turtle populations are difficult to census (Meylan 1982). Because sketchy information is available about certain life history stages, particularly juveniles and adult males, population numbers have been derived from indices such as number of nesting females, number of hatchlings per kilometer of nesting beach, and number of subadult carcasses washed ashore (Hopkins and Richardson 1984).

Population estimates can be confusing, because they may be expressed either as number of nests (clutches) deposited per year, number of nesting

females per year, or total number of mature females. This is confusing because each nesting female may lay 1 to 7 nests per season ($\bar{x} = 2.5$), and an individual will migrate to nest only every second or third year (average 2.5 years between nesting seasons of an individual) (Gordon 1983). The following formula was used by Gordon (1983) to calculate the total number of mature females:

Tf = (Tn x ri)/ns
Tf = Total number of mature females
Tn = Total number of nests per year
ri = remigration interval (average time interval between nesting years, per individual)
ns = average number of clutches per nesting female per year

The number of nesting females per year was estimated to be between 6,000 and 25,000 by Lund (1974) and Carr and Carr (1978). An average 2.5-year nesting frequency per individual (ri) gives a total of 15,000 to 62,500 mature females based on the estimated number of total nests per year for recent years. Gordon (1983) more recently reported 28,310 to be the total number of U.S. nesting female loggerheads (Table 3). Powers (1981) estimated from aerial surveys that the number of nesting females was 18,297 (SE = 6,516) in 1980 for the southeastern United States (North Carolina, South Carolina, Georgia, and eastern Florida). Thompson (1983), who surveyed the same area and used the same methods as Powers (1981), estimated the number of nesting female loggerheads in 1982 to be 28,884 (SE = 6,572) which was not significantly different from Powers' (1981) estimate ($p \leq 0.05$). If we recalculate using

Table 3. Distribution and estimated population size of nesting female loggerhead sea turtles along the Atlantic and gulf coasts of the United States, 1983 (Gordon 1983).

	Coastline (km)	Number of nestings per season[a]	Percent of population per region	Nesting season
Texas	620	1	<0.1	Apr-Sep
Louisiana	710	Not recorded	---	---
Mississippi	120	4	<0.1	Jun
Alabama	75	1	0.1	Jul
Florida	2,037	23,897	84.4	Apr-Sep
Georgia	176	963	3.4	May-Aug
South Carolina	290	3,156	11.1	May-Aug
North Carolina	485	279	<1.0	May-Aug
Virginia	180	7	<0.1	Jun-Jul
Maryland	50	1	<0.1	---
Delaware	45	0	0.0	---
New Jersey	439	1	≤0.1	---
Total	**5,900**	**28,310**	**99.9**	**Apr-Sep**

[a]Compiled and computed from Gordon (1983)

Thompson's estimate and using Gordon's (1983) value of the average number of nests per nesting female per season (South Carolina and Georgia, 3.3 per year; North Carolina and eastern Florida, 2.5 per year) and a remigration interval of 2.5 years, the total number of mature females in the Southeastern United States population is estimated to be from 49,133 to 62,680. Murphy and Hopkins (1984), using areal and ground surveys, estimated the total number of nests for the Southeastern United States to be 58,016 and the number of nesting females for the 1983 season to be from 14,150 to 29,008. Using the average nesting frequency of 2 years (Gordon 1983), the total number of mature females is estimated to be from 35,375 to 72,520.

Using data from Little Cumberland Island, GA, a population model predicted annual recruitment at 39% for nesting females, mean longevity of a nesting female to be 3 years, and turnover of nesting females to be 6 years (Richardson and Richardson 1982). The model incorporated frequency of nesting (remigration intervals), probability of remigration, and fecundity. Survivorship and age to maturity were unknown (Richardson and Richardson 1982). It was suggested that a group of 1,000 nesting females is expected to lay 300,000 eggs a season, from which 389 females per season must survive to maturity to replace the original 1,000 females. Once a female turtle reaches nesting age (size) the annual survivalship in the wild is calculated to be 0.81 which indicates a maximum reproductive life span of 32 years (i.e. it is unlikely a female will survive for more than 32 years beyond her first nesting year and one adult in a thousand is likely to survive that long) (Frazer 1983c). From tag return data, a turtle at Little Cumberland Island, GA, is known to have survived for at least 16 years beyond the year she was first observed nesting (Frazer 1983a).

Frazer (1986) presents evidence that age at maturity is 15-30 years based upon loggerheads exhibiting a constant survivorship of eggs to age 1 year of 10%-30% and an annual survival of juvenile loggerheads of 70%-94%. Since the loggerhead population in the U.S. Atlantic is declining, the estimated proportion of eggs surviving to adult is between 0.0009-0.0018, rather than 0.0025 for a stationary population (Frazer 1986).

ECOLOGICAL ROLE

Food Habits

Loggerheads are primarily carnivorous (Mortimer 1982). They eat a variety of benthic organisms including mollusks, crabs, shrimp, jellyfish, sea urchins, sponges, squids, basket stars, and fishes (Brongersma 1972; Musick 1979; Hendrickson 1980; Mortimer 1982). Adult loggerheads, particularly females during the nesting season, can be observed feeding in reef and hard-bottom areas (Limpus 1973; Mortimer 1982; Stoneburner 1982; Williams-Walls et al. 1983). In the seagrass beds of Mosquito Lagoon, FL, subadult loggerheads fed almost exclusively on abundant horseshoe crabs. Some blue crabs and mullet were also eaten (Mendonca and Ehrhart 1982). Benthic feeding by juvenile loggerheads may also be inferred from their frequent capture in shrimp trawls at depths up to 55 m (Richardson and Richardson 1982; Meylan et al. 1983). Loggerheads may also eat animals discarded by commercial trawlers, which may contribute to the capture of turtles in trawls (Shoop and Ruckdeschel 1982).

Although food preferences in wild turtles have not been studied, loggerheads in laboratory experiments had short term food preferences but also adapted to new foods (Grassman and Owens 1982). Loggerheads have a well-developed olfactory system (Manton et al. 1972) and may use their sense

of smell to locate food (Grassman and Owens 1982).

Observations in Australia suggest that local availability of benthic invertebrates for food may be an important factor in selection of a loggerhead nesting beach. Availability of abundant food throughout the nesting season allows female loggerheads to produce eggs with a total weight equal to one-fourth of the turtle's body weight without substantial loss of body weight (Limpus 1973).

Predation

Eggs, hatchlings, juveniles, and adults are preyed upon by various animals. The most common predators of eggs and nests are raccoons, crabs, and hogs (Stancyk 1982). Predation occurs most often within a few hours or days after egg laying (McAtee 1934; Gallagher et al. 1972; Davis and Whiting 1977; Hopkins et al. 1978; Mapes 1985). The amount of predation decreases after the early stages of incubation and then increases again near hatching time (Klukas 1967; Hopkins et al. 1978). Higher predation rates at the beginning and end of incubation are believed to be related to olfactory cues (odors) released by females when laying the eggs and by pre-emergent hatchlings (Hopkins et al. 1978; Stancyk et al. 1980); these odors are detected by predatory mammals. Raccoons can be particularly destructive, taking up to 100% of the eggs in a nest and up to 96% of the nests on a beach (Klukas 1967; Davis and Whiting 1977; Stancyk et al. 1980; Talbert et al. 1980; Hopkins and Murphy 1981). Beaches with greater nesting densities tend to also have a greater percentage of predation (Hopkins et al. 1978) than more sparsely nested beaches.

Hatchlings are taken by mammals (fox and raccoon), birds, and crabs as they crawl to the water; however, predation by birds is minimized by their habit of nocturnal emergence (Caldwell 1959; Richardson 1978; Stancyk 1982). The greatest predation on hatchlings is likely to occur after they reach the water (Hendrickson 1958; Bustard 1979). Sharks, barracuda, snook, jacks, snapper, and other nearshore fish that can eat a 40 to 50 mm long hatchling are potential predators (Caldwell 1959; Witham 1974; Stancyk 1982).

Juvenile and adult sea turtle predation is believed to be minimized by their size, which exceeds the size range that can be taken by most predators. However, researchers have found up to a 21% incidence of cuts, bites, or lacerations on nesting turtles caused by sharks, which indicates a relatively high amount of predation (Hendrickson 1958, Hughes 1974). Sharks, grouper, and killer whales are reported to prey on adult and juvenile sea turtles (Caldwell 1959, 1969; Hirth and Carr 1970; Hughes 1974). The magnitude of this predation, however, is unknown. Caldwell (1959) reported that nesting turtles have been killed by dogs.

Commensals and Parasites

Sea turtles are repositories for a multitude of commensal and parasitic organisms. The most predominant of these are barnacles, amphipods, algae, and trematodes (Steinbeck and Ricketts 1941; Caldwell 1968; Frazier 1971; Carr and Stancyk 1975; Caine 1982). Other organisms associated with sea turtles include bryozoa, polychaetes (Caldwell 1968), tunicates (Caine 1982), parasitic crabs (Clark 1965), hydroids (Steinbeck and Ricketts 1941), remoras (Fretey 1978), leaches (Schwartz 1974), cestodes (Sey 1977), and nematodes (Lichtenfels et al. 1980). A number of diseases were found from post mortem examination of loggerheads (Wolke et al. 1982). Caine (1986) reported 48 epibiotic species which represented two distinct assemblages of carapace epibionts. He suggests that the presence of two dis-

tinct carapace communities may represent discrete northern and southern Atlantic coast populations of loggerheads.

WATER AND SAND TEMPERATURE EFFECTS

Temperature is a major factor influencing sea turtle life histories. Sand temperature may affect nest-site selection by adult females, the incubation time and hatching success of eggs, and the sex and emergence timing of hatchlings, whereas water temperature affects nesting activity and movements of adults.

Initiation of Nesting and Length of Nesting Season

On Hutchinson Island, FL, nesting begins in the spring when local water temperatures begin to reach 23 to 24 °C and intensifies with increased temperature and photoperiod (Williams-Walls et al. 1983). Another probable effect of temperature is the shortening of the nesting season at higher latitudes (Table 3) (Kraemer 1979). Once a turtle crawls ashore to nest, sand temperature may be a cue to nest-site selection (Stoneburner and Richardson 1981).

Incubation Time and Hatching Success

Under laboratory controlled conditions, the lower the ambient sand temperature, the longer the incubation time for turtle eggs. A 1 °C decrease adds about 5-8.5 days to incubation time (Mrosovsky and Yntema 1980), whereas eggs incubated in sand outside the 24 to 34 °C temperature range may not hatch. High hatching success occurs between sand temperatures of 25 and 32 °C (Limpus et al. 1983b). The length of incubation is determined by the overall temperature throughout development while sex is determined by the temperature during the middle third of development (Standora and Spotila 1985).

Sex Ratios of Hatchlings

When laboratory-controlled incubation temperatures remained at 30 °C, approximately equal numbers of male and female hatchlings developed; above 30 °C more females tend to be produced, whereas below 30 °C males predominate (Yntema and Mrosovsky 1982). Loggerhead nests which incubate at the 30 °C pivotal temperature may have female hatchlings at the center of the clutch and males along the periphery as a result of metabolic heating (Mrosovsky et al. 1984; Standora and Spotila 1985).

Sex ratios may vary because of temperature during the nesting season with cooler early season nests producing male hatchlings and more females being produced as the season progresses and temperature increases (Standora and Spotila 1985). Changes in meteorological conditions such as heavy rains and extensive cloud cover may affect incubation temperature and thus sex ratios (Standora and Spotila 1985).

Renesting Interval

As the nesting season progresses and the water temperature increases, time between nestings of an individual female decreases (Hughes and Brent 1972). However, if a cold front decreases ambient water temperature between subsequent nestings of an individual, the renesting interval may increase (Williams-Walls et al. 1983).

Hatching Synchrony and Hatchling Emergence

Temperatures in the nest rise toward the end of incubation, and may synchronize hatching (Hopkins et al. 1978). The hatchlings usually emerge as a group at night (Hopkins and Richardson 1984); the emergence seems to be cued by the lower nighttime temperatures (Hendrickson 1958). Above approximately 28.5 °C, hatchlings usually remain some distance above their

nests, but below the surface of the sand (Mrosovsky 1968).

Surface Basking

During aerial surveys, more loggerheads are sighted near midday, which is probably related to surface-basking behavior to increase body temperature (Sapsford and van der Riet 1979; Shoop et al. 1981).

Feeding and Overheating

Temperature can also affect feeding activity. Green turtles were found in shallow feeding areas of a lagoon in Florida in the morning and evening, a time when water temperatures were lower. During midday, when water temperatures in the shallows rose above 31 °C, these turtles moved to deeper water that was often 2 °C cooler. At dusk, the turtles moved to a sleeping site and remained there until morning (Mendonca 1983). This nocturnal inactivity may be in response to changes in temperature and/or light. Moving to cooler water and remaining inactive are probably responses that prevent overheating (Spotila et al. 1979; Mrosovsky 1980). Spotila and Standora (1985) proposed that the potential for lethal heat gain during the day on land is one factor that selects for nocturnal nesting of loggerheads.

Migration and Hibernation

In response to low water temperatures, turtles may migrate or hibernate. Turtles nesting in northern latitudes migrate south in the winter (Bell and Richardson 1978; Shoop et al. 1981). During the winter, loggerhead turtles have been discovered buried in the substrate at water temperatures averaging 14 °C in Florida (Carr et al. 1980); the same was found for green turtles below 15 °C in the Gulf of California (Felger et al. 1976). This hibernation may be either an emergency response to cold water or a normal part of the life cycle in specific populations (Mrosovsky 1980). Sudden cooling of water to temperatures below 14 °C can stun turtles, causing them to float on the surface in a lethargic state (Lutcavage and Musick 1985; Witherington and Ehrhart 1985; Meylan and Sadove 1986). Temperatures below 4.8-6.5 °C may be lethal (Ehrhart 1977; Schwartz 1978). The tolerance to cold water varies with turtle species, age, and population (Schwartz 1977; Mrosovsky 1980; Mendonca 1983). Hatchlings and young tolerate cold water longer than adults (Schwartz 1977). In outdoor tanks in North Carolina, adult Kemp's ridleys survived longer (20-24 h) at low temperatures than greens or loggerheads (9-12 h), although floating occurred at 10-13.5 °C in ridleys and 9.0-9.9 °C in greens and loggerheads (Schwartz 1977). Different populations of a turtle species may respond differently to a given temperature level, possibly because of acclimatization of the populations to different temperature regimes (Mendonca 1983).

CONTAMINANTS

Loggerheads have the potential for accumulating contaminants through their primary food source, benthic invertebrates (Stoneburner et al. 1980). Pesticides, heavy metals, and PCB's have been detected in sea turtles, but minimum levels that will have an adverse effect are unknown (Hillestad et al. 1974; Thompson et al. 1974; Clark and Krynitsky 1980; Fletemeyer 1980; Stoneburner et al. 1980; Witkowski and Frazier 1982; Coston-Clements and Hoss 1983; McKim and Johnson 1983).

Oil spills and subsequent tar balls can also affect loggerheads and other sea turtles (Coston-Clements and Hoss 1983). On the beach, oil and tar balls can deter nesting, reduce hatching success (Fritts and McGehee 1982), irritate eyes and respiratory systems of hatchlings (Bureau of Land Management 1981), and cause death of juve-

niles from ingestion (Witham 1978; Fletemeyer 1980, 1983).

MANAGEMENT

Predator Control

Nest predation by wild or feral animals can be reduced by removal or elimination of the responsible animals (Pritchard et al. 1983). Control of predators can be effective if conducted prior to the onset of nesting and continued throughout the season as needed (Hopkins and Richardson 1984). Trapping or shooting is especially effective for raccoons, dogs, and hogs (Caldwell 1959; Stancyk 1982). Other alternatives would be to cage nests with fixed screens to exclude predators or to relocate nests to a protected area (Stancyk 1982). Wire enclosures must be placed immediately after nest establishment and removed after hatching. The manpower and materials to protect a large number of nests may be a constraint of using wire enclosures.

Nest Relocation

To prevent or reduce loss of nests and eggs to predators, erosion, or human activities, nests are often relocated to safer spots on the beach (Ehrenfeld 1982; Stancyk 1982). Even though local nest transplantation is often considered an acceptable management practice when nests are in jeopardy, some concerns have been reported. Eggs may be damaged from their movement, thus reducing hatching success (Stancyk 1982). Poor site selection for relocated nests may cause them to be susceptible to erosion, flooding, or predation (Ehrenfeld 1982; Stancyk 1982; Witzell 1983).

Hatcheries

Movement of nests to hatcheries is another method used to prevent or reduce loss of nests and eggs to predators, erosion, or human activities (Richardson 1978; Talbert et al. 1980; Hopkins and Richardson 1984). The eggs are usually moved to a single protected site and buried in a fenced, sandy area on the beach or in boxes or buckets in a building. Some of the concerns with this method are (a) potential for break-ins by predators; (b) generally lower hatch rates reported for hatcheries; (c) variation in temperature and other physical variables negatively affecting hatchlings (temperature also determines their sex); (d) proper maintenance and monitoring to release emerging hatchlings; and (e) increased predation when hatchlings are released during the day instead of at night (Stancyk 1982). These concerns can be resolved by proper handling of eggs and hatchlings and proper design of the hatchery (Lund 1983, Pritchard et al. 1983).

Head-starting

Head-starting is the practice of raising hatchlings in captivity until they reach a size believed to be less vulnerable to predation before they are released. Some concerns expressed about head-started hatchlings are that they may become dependent on "captive" foods, become wounded and infected in crowded captive conditions, be removed from the sequence of natural conditions which may play a critical role in their life cycle, and have a percentage survival less than or equal to that of wild hatchlings (Ehrenfeld 1982; Mrosovsky 1983).

Dredging

To prevent impingement of sea turtles by a dredge, the operation may be restricted to a season when the turtles are absent, or use of a dredge that will have less effect on the turtles may be required.

In the maintenance dredging of the entrance channel at Canaveral Harbor, FL, an unusually large number of sea turtles was discovered. Most of the

turtles were loggerheads, but greens and Kemp's ridleys were also found (Joyce 1982). Since the turtles were discovered during the winter, were covered with mud, and were in a torpid condition, it was hypothesized that they were hibernating in the mud walls of the channel (Carr et al. 1980).

Approximately 1,250 loggerhead turtles were removed from the dredging area by trawling to prevent their impingement by the dredge. In addition, a California-type draghead, with a cage opening on the top of the draghead, was used to reduce capture and mortality of sea turtles (Joyce 1982). A recent dredging operation in the Canaveral channel, during the fall of 1985, used a clam-shell dredge which had minimal effect on the turtles.

Beach Nourishment

While the adding of sand to a beach, referred to as beach nourishment, benefits turtles by creating nesting beach, concerns have been expressed about the effects on nesting turtles (Ehrhart and Raymond 1983; Raymond 1984a).

Beach nourishment can affect sea turtles directly by burying nests or by disturbing nesting turtles and hatchlings during their spring and summer nesting season (Lund 1983). Indirectly, beach nourishment or replenishment has the potential for affecting sea turtle nest site selection, clutch viability, and hatchling emergence by altering the physical makeup of the beach. Sand grain size, grain shape, structure, moisture content, temperature, color, and the density of the sand may be altered. However, these changes can be managed by selection of fill material comparable to the natural sand, by placement of the sand seaward of the existing beach and at a gentle slope, and by the timing of sand placement so as not to interfere with the nesting season (Nelson and Pullen 1985).

Another concern is the compaction of the beach which may result from a shift to a finer grain size, layering of sand grains, and an increase in density from equipment operation on the beach and the weight of fill material. A compact beach will inhibit nest excavation by sea turtles (Fletemeyer 1980; Ehrhart and Raymond 1983; Raymond 1984a) and limit emergence of hatchlings (Mann 1977; Fletemeyer 1979). If sands are too coarse, the nest collapses and the hatchling turtles are unable to emerge to the surface (Mann 1978; Sella 1982). A compacted beach can be mediated by using a coarser sized sand and by operating only wide-tracked equipment on the beach. A compacted beach can be softened by tilling (Nelson 1986).

Clutch viability may be affected by changes in the physical properties of a nesting beach. Mortimer (1982) and Schwartz (1982) reported that an optimum range of grain size for hatching success was medium to fine (0.063-2.0 mm). Even though sand particle size for nesting turtles varies greatly from one nesting beach to another (Hirth and Carr 1970; Hirth 1971; Hughes 1974; Stancyk and Ross 1978), when sands are too fine, gas diffusion required for embryonic development is inhibited (Ackerman 1977; Mortimer 1979, 1982; Schwartz 1982). In studies of two beach nourishment projects, hatching success and number of hatchlings were not affected by the project (Raymond 1984a; Nelson et al. 1986). Investigators studying aragonite sand as a nesting substrate found an increase in the number of piped dead hatchlings; evidence indicated that the nasal passages of the hatchlings were clogged with aragonite sand (Nelson et al. 1986).

Effect of Light on Turtles

Lights from beachfront buildings, streetlights, vehicular lights, and any other type of shorelight can potentially interfere with the orientation of hatchlings toward the ocean

(McFarlane 1963; Philobosian 1976; Mann 1977; Fletemeyer 1979; Bandre and MackMakin 1983; Raymond 1984b) and may discourage adults from nesting. Hatchling orientation depends largely on a visual response to natural seaward light (Daniel and Smith 1947a, 1947b). The shorter wavelengths of light (the blue end of the spectrum) have been implicated as attractants to hatchlings (Hooker 1911; Parker 1922; Mrosovsky and Carr 1967); however, other studies have suggested that hatchlings respond to a higher intensity of light rather than a response to color hues (Ehrenfeld and Carr 1967; Ehrenfeld 1968; Mrosovsky and Shettleworth 1968). Mrosovsky (1978), Ehrenfeld (1979), and Raymond (1984b) provide excellent reviews of the literature on the water-finding ability of sea turtles.

Problems with disorientation of hatchlings by lights can potentially be solved by eliminating the light during the nesting season; by preventing light from reaching the beach by shading the light; by blocking the light from the beach with vegetation or other barriers; by using lights which focus away from the beach; and by reducing the intensity of the lights (Raymond 1984b).

Accidental Capture of Turtles in Trawls

Accidental capture of sea turtles in fish and shrimp trawls results in an estimated 11,000 to 12,000 loggerhead deaths per year (Ross 1982; Gordon 1983). To prevent turtles from being trapped in shrimp trawls, the National Marine Fisheries Service developed a turtle excluder device, (TED), which is installed into a trawl (Oravetz 1983; Oravetz and Watson 1983). In addition to extruding turtles from nets, the device increases the efficiency of the trawl by reducing the by-catch and the drag on the net (Oravetz 1983).

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50272-101

REPORT DOCUMENTATION PAGE	1. REPORT NO. Biological Report 88(23)*	2.	3. Recipient's Accession No.

4. Title and Subtitle

Life History and Environmental Requirements of Loggerhead Turtles

5. Report Date August 1988

6.

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8. Performing Organization Rept. No.

9. Performing Organization Name and Address

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10. Project/Task/Work Unit No.

11. Contract(C) or Grant(G) No.

(C)

(G)

12. Sponsoring Organization Name and Address

National Wetlands Research Center
Fish and Wildlife Service
U.S. Department of Interior
Washington, DC 20240

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Environmental Laboratory
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13. Type of Report & Period Covered

14.

15. Supplementary Notes

* U.S. Army Corps of Engineers Report No. TR EL-86-2 (Rev.)

16. Abstract (Limit: 200 words)

In the United States scattered nestings of loggerhead sea turtles (*Caretta caretta*) may occur in most of its range from Texas to Florida and Florida to New Jersey; however, nesting concentrations occur on coastal islands of North Carolina, South Carolina, and Georgia and on the coasts of Florida. The greatest portion of a loggerhead's life is spent in ocean and estuarine waters where it breeds in shallow waters adjacent to nesting beaches, feeds on a variety of fish and shellfish, and migrates generally north in the spring and summer and south in the fall and winter. The other part of its life is spent on coastal beaches where the female digs a nest, lays her eggs (average 120 eggs), the eggs hatch (in 46 to 65 days), and the hatchlings emerge from the nest as a group and orient seaward to become part of the aquatic system again. Nesting activity begins in the spring, peaks in midsummer, and declines until completion in late summer. A loggerhead female generally nests every other or every third year. Beach sand temperatures may affect nest site selection by females, the incubation time and hatching success of eggs, and the sex and emergence timing of hatchlings. Most management of sea turtles has been directed toward increasing hatching and hatchling success through predator control, egg relocation, and raising captive hatchlings.

17. Document Analysis a. Descriptors

Feeding Habits
Turtles
Life Cycles
Contaminants
Animal migrations
Temperature

b. Identifiers/Open-Ended Terms

Loggerhead turtle
Caretta caretta
Predation
Management

c. COSATI Field/Group

18. Availability Statement	19. Security Class (This Report)	21. No. of Pages
Unlimited distribution	Unclassified	vii + 34
	20. Security Class (This Page) Unclassified	22. Price

(See ANSI-Z39.18)

OPTIONAL FORM 272 (4-77)
(Formerly NTIS-35)
Department of Commerce