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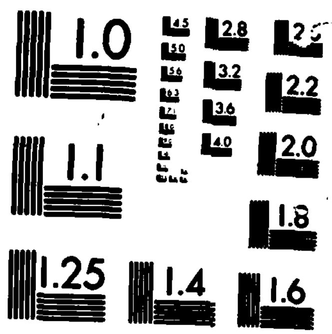

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LIFE HISTORY AND ENVIRONMENTAL REQUIREMENTS OF LOGGERHEAD SEA TURTLES

by

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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 the coasts of Florida. The greatest portion of a loggerhead's life is spent in ocean and estuarine waters where they breed, feed, migrate, and hibernate. The remainder of their life is spent on coastal beaches where the female digs a nest and lays her eggs, the eggs hatch, and the hatchlings crawl to the water to become part of the aquatic system again.

Mating is believed to occur in shallow water adjacent to nesting beaches just prior to nesting and egg laying. Nesting activity begins in the spring, peaks in midsummer, and declines until completion in late

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summer. A loggerhead female generally nests every other year or every third year. A small percentage nest at intervals less than 2 years or more than 3 years. When a loggerhead nests, it usually lays two to three clutches of eggs per season (range one to five). These interseasonal nestings are generally 12 to 14 days apart (range 11 to 20 days). Loggerheads may return to the same vicinity to nest between or within seasons, but they are not as site specific as green sea turtles (*Chelonia mydas*).

Loggerhead eggs are similar in appearance to ping-pong balls, although slightly smaller and leathery, soft, and pliable. The eggs hatch in 46 to 65 days (x = 60 days). Hatchling success/fertility rates in natural clutches are 80 to 90 percent. Hatch 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.

Hatchlings emerge from the nest as a group at night and orient seaward. The seaward orientation can be disrupted when lights from structures are directly visible from a nest. After reaching the water, hatchlings probably become pelagic.

Juvenile loggerhead turtles utilize bays and estuaries for feeding. Adult loggerhead seem to prefer shallow coastal waters that are less than 60 m deep. Adults move north in summer and fall and move south when water temperatures decline in late fall and winter.

Growth in sea turtles appears to be rapid from hatchling to young adult, becoming very slow at maturity. The rate of growth of sea turtles differs depending on quality and quantity of food.

Although no longer commercially harvested in the United States, loggerheads are harvested in parts of the Caribbean for meat, skin, shell, and eggs. Loggerheads have died from fowling by, or ingestion of, petroleum and plastic products and from disease, chemical pollution, shark and killer whale predation, boat collisions, hypothermia, and accidental capture in shrimp and fish trawls.

Sea turtle populations are difficult to census. The total number of mature females in the United States in 1983 was estimated to be between 28,000 and 73,000. It has been suggested that a group of 1,000 nesting females is expected to lay 300,000 eggs a season, from which 389 females must survive to maturity to replace the original 1,000 females.

Loggerheads are primarily carnivorous. They eat a variety of benthic organisms including molluscs, crab, shrimp, jellyfish, sea urchins, sponges, squids, basket stars, and fishes.

Eggs, hatchlings, juveniles, and adults are preyed upon by various animals. The most common predators of eggs and nests are raccoons, crabs, and hogs. Hatchlings are taken by mammals, birds, and crabs as they emerge from the nest and crawl to the water. The greatest predation is likely to be by nearshore fish after the hatchlings reach the water. Because of their size, predation on juvenile and adult sea turtles may be minimal; however, they have been taken by sharks, groupers, and killer whales.

Temperature is a major factor influencing sea turtle life histories. Sand temperature affects 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.

Loggerheads have the potential for accumulating contaminants through their primary food source, benthic invertebrates. Oil spills and tar balls can also affect loggerheads.

Most management of sea turtles has been directed toward increasing hatching and hatchling success. Nest predation can be reduced by removal or elimination of the responsible animal. To prevent or reduce loss of nests and eggs to predators, erosion, or man's activities, nests may be relocated to safer spots on the beach or to hatcheries. Hatchlings may be raised in captivity until they reach a size believed to be less vulnerable to predation before they are released. This practice is referred to as head-starting.

PREFACE

This report was sponsored by the Office, Chief of Engineers (OCE), US Army, as part of the Environmental Impact Research Program (EIRP), Work Unit 31533, entitled Beach and Foredune Ecology. The Technical Monitors for the study were Dr. John Bushman and Mr. Earl Eiker of OCE and Mr. David B. Mathis, Water Resources Support Center. The literature search and preparation of a draft final report were accomplished during the time period October 1983 to February 1985.

This report was prepared by Mr. David A. Nelson, Coastal Ecology Group, US Army Engineer Waterways Experiment Station (WES). Mr. Nelson was principal investigator for this report, under the general supervision of Mr. E. J. Pullen, Chief, Coastal Ecology Group; Dr. C. J. Kirby, Jr., Chief, Environmental Resources Division; and Dr. John Harrison, Chief, Environmental Laboratory. Dr. Roger T. Saucier, WES, was the Program Manager of EIRP. The report was edited by Ms. Jessica S. Ruff of the WES Publications and Graphic Arts Division.

At the time of publication, COL Allen F. Grum, USA, was Director of WES and Dr. Robert W. Whalin was Technical Director.

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LIFE HISTORY AND ENVIRONMENTAL REQUIREMENTS OF LOGGERHEAD SEA TURTLES

NOMENCLATURE/TAXONOMY/RANGE

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

1. In the United States, loggerhead sea turtles may be encountered along coastline from Texas to Florida on the Gulf of Mexico and from Florida to New Jersey 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, major nesting concentrations occur 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). During warmer months loggerheads are usually found close to shore in marine and estuarine waters, and as the water turns cooler most move offshore to the Gulf Stream and/or south to warmer water (Lee and Palmer 1981).

MORPHOLOGY/IDENTIFICATION AIDS

Adult

2. The adult loggerhead sea turtle is slightly elongate with a heart-shaped carapace that tapers posteriorly (Figure 2) (Pritchard et al. 1983). It has a very large triangular-shaped head that may be as wide as 25 cm. Loggerheads normally weigh up to 140 kg and attain a carapace length up to 110 cm. 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 characters: a hard shell, two pairs of scales on the front of the head (prefrontal scutes), five pairs of lateral scales on the carapace, plastron (ventral) with three pairs of enlarged scales (inframarginals) connecting to the carapace, two

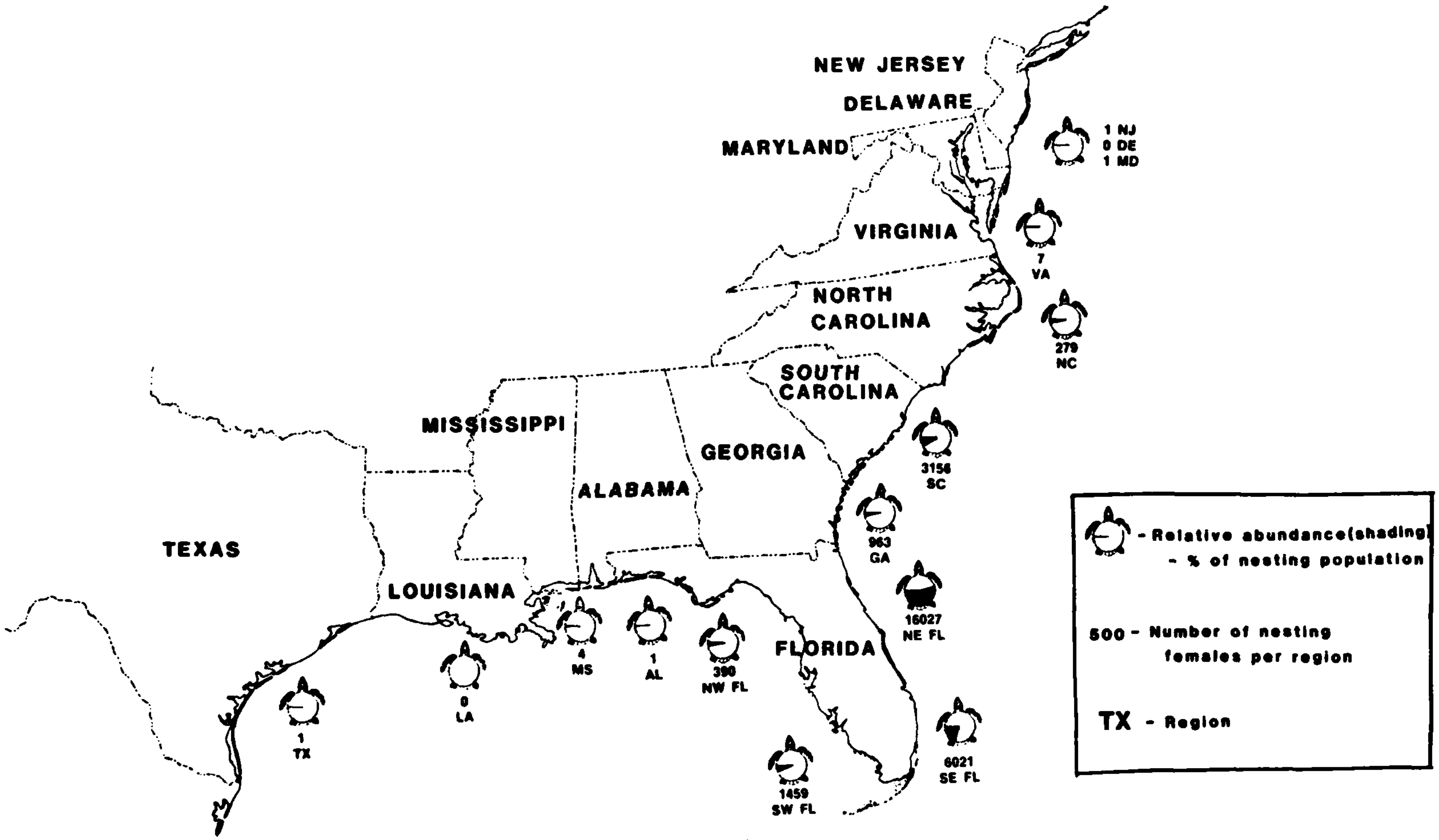


Figure 1. Distribution and relative abundance of nesting female loggerhead sea turtles along the Gulf of Mexico and Atlantic coasts (adapted from Gordon 1983)

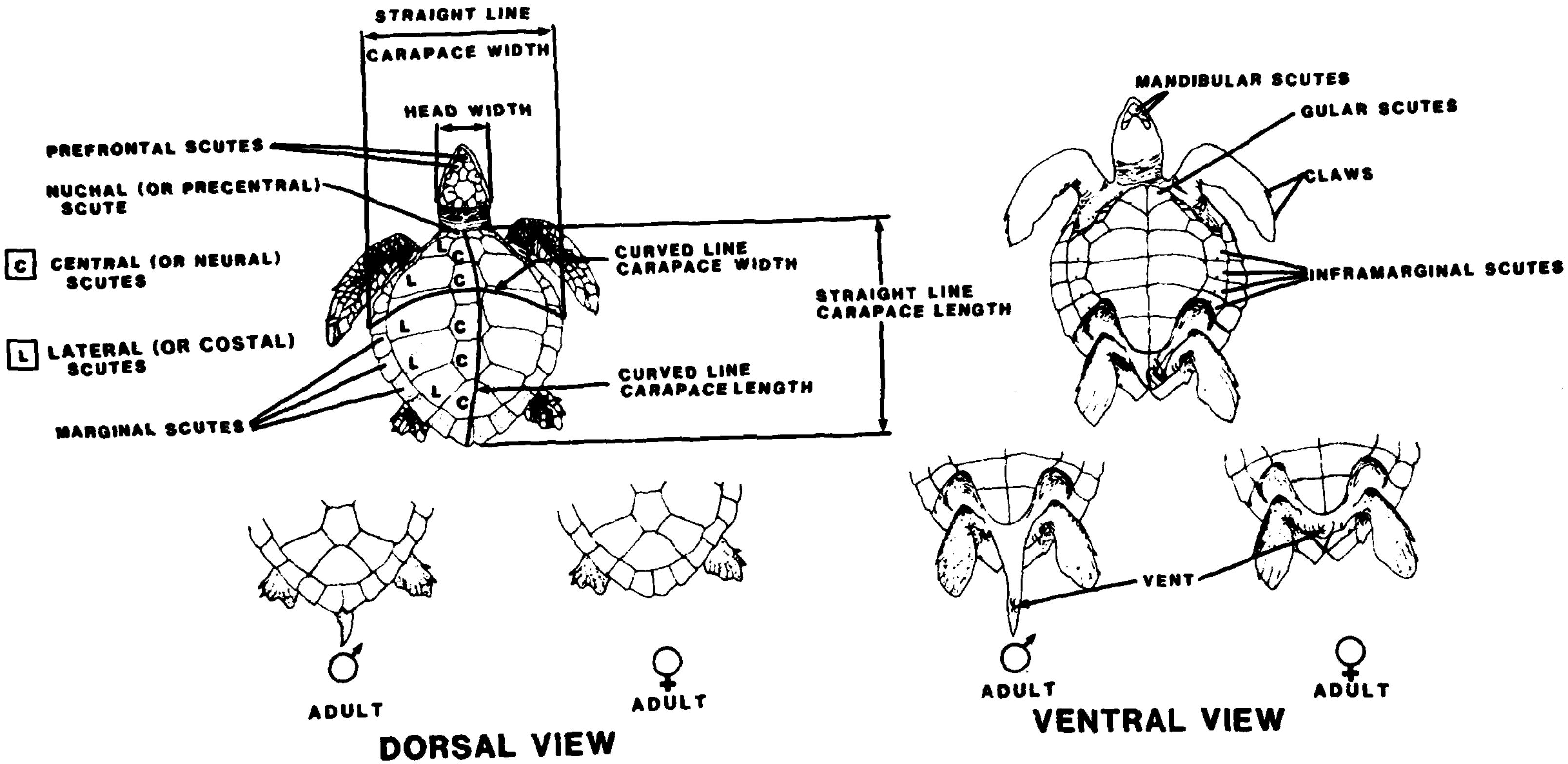


Figure 2. General external morphology of sea turtles (adapted form Pritchard et al. 1983)

claws on each flipper, and the typical brownish-red coloration (Figure 3 and Table 1) (Marquez 1978).

Hatchlings

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

Tracks and nests

4. When loggerheads crawl up on a beach, they leave an alternating 90- to 100-cm-wide (asymmetrical) pattern of 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 body (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

5. 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 its life is spent on beaches where the female digs a nest and lays her eggs, the eggs hatch, and the hatchlings crawl to the water to become part of the aquatic system again (Figure 6).

Mating

6. Mating is believed to occur in shallow water 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 just prior to the nesting season (Caldwell et al. 1959) and occurs only once a season for each female (Ehrhart 1982). Matings have been observed during daylight hours and probably occur at

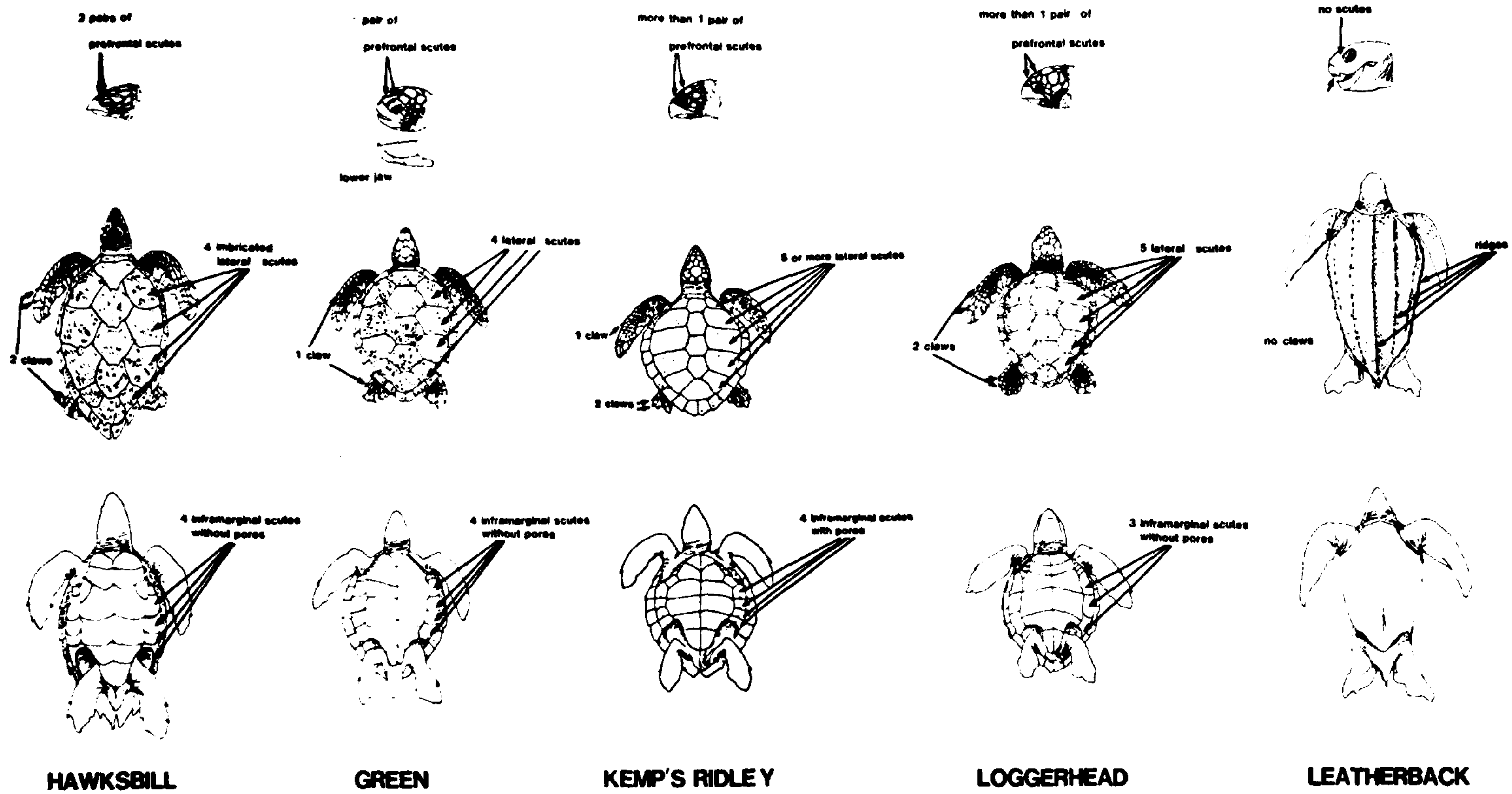


Figure 3. Morphological features used to distinguish between different sea turtle species (adapted from Marquez 1978)

Table 1

Adult Sea Turtle Characteristics

Species	Length* cm	Weight* kg	Carapace Shape	Carapace Color	Plastron Color	Head Size and Shape	Head Width, cm
Leatherback	155-183 (140)	272-725 (300)	elongate, triangular	blue-black	white	medium round	25
Green	51-105 (90)	113-140 (100)	broad, oval	olive, dark brown mottled	white-yellowish	small round	15
Loggerhead	79-125 (110)	77-140 (105)	heart-shaped	reddish-brown	cream-yellow	very large triangular	25
Kemp's ridley	59-73 (70)	36-45 (42)	circular	olive green	yellow	medium pointed	13
Hawksbill	76-90 (80)	43-120 (60)	shield-shaped	greenish-brown mottled	yellow	narrow pointed	12

Species	No. Costal Scutes	Scutes on Bridge	No. Prefrontal Scutes (pair)	1st Nuchal Touching	No. Claws Front	No. 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	alternating
Kemp's ridley	5	4 (5 rarely)**	2	yes	1	2	80	alternating
Hawksbill	4	4	2	no	2	2	75-80	alternating

SOURCE: Conant (1975), Zwinenberg (1977), Marquez (1978), Limpus et al. (1983a), Pritchard et al. (1983), Hopkins and Richardson (1984).

* Common length or weight given in parentheses.

** With pores in inframarginal scutes; other species without pores.

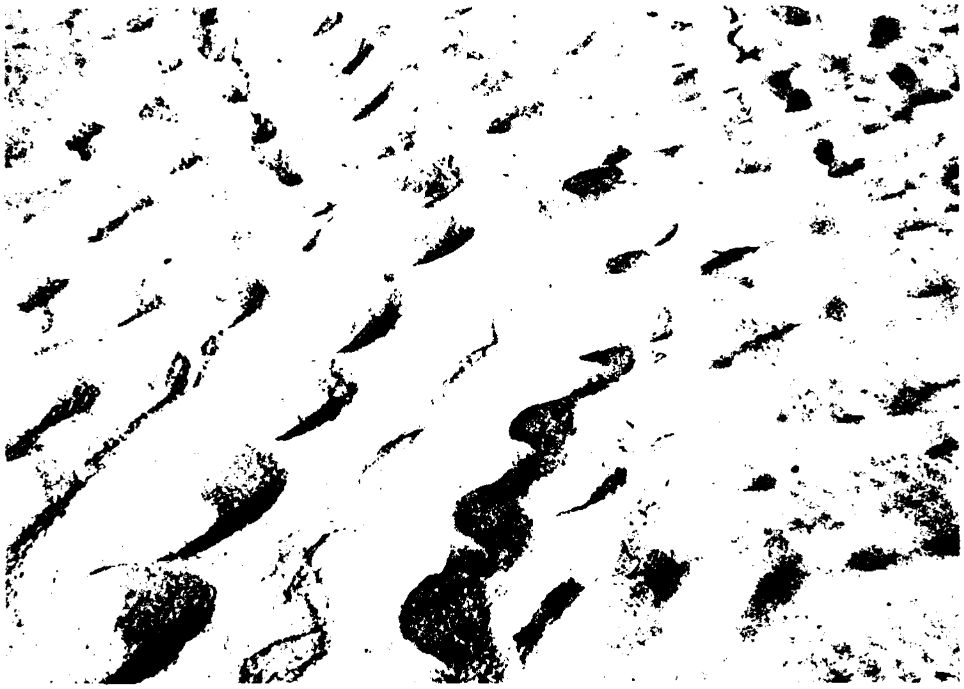
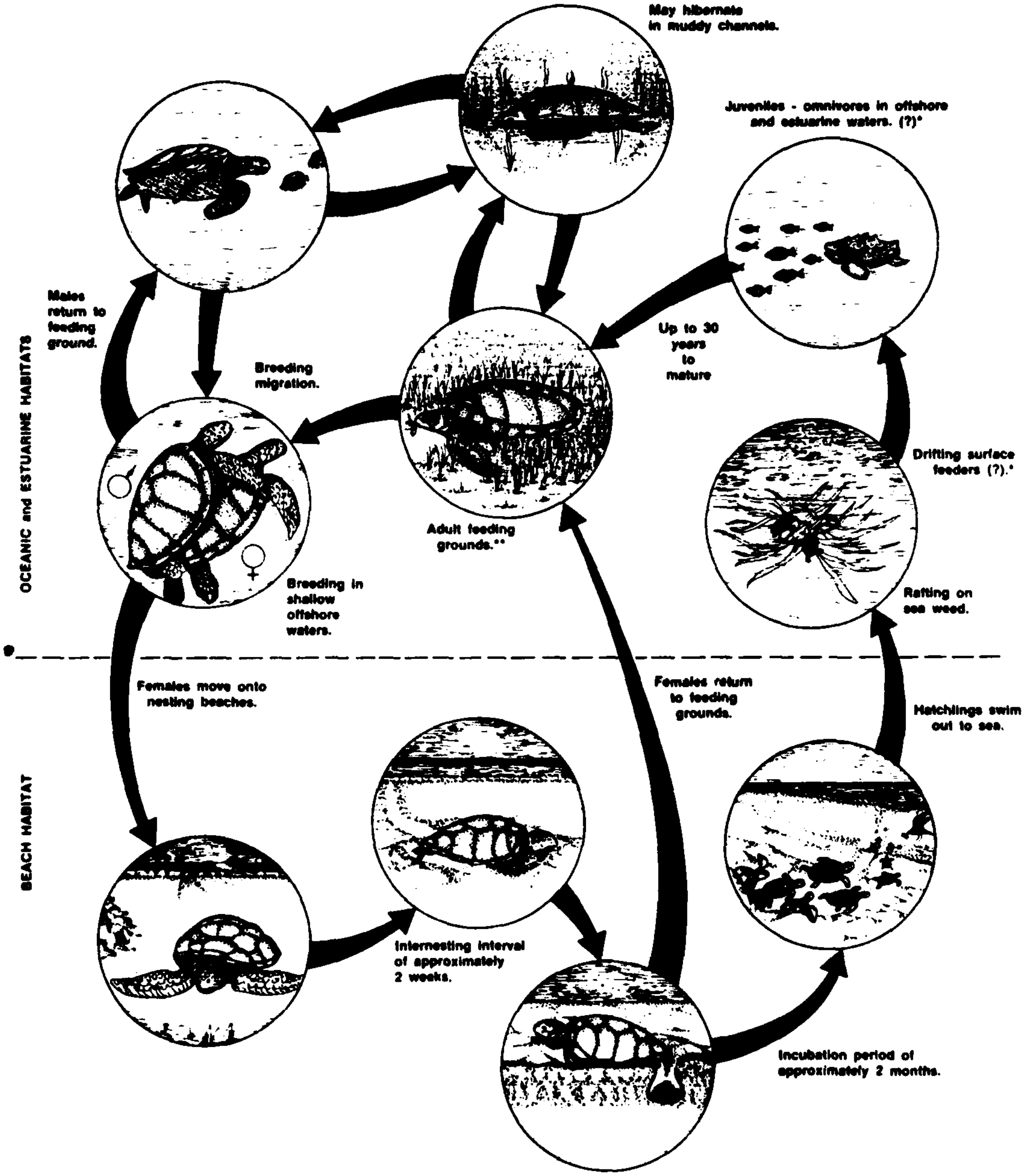


Figure 4. Alternating tracks of female loggerhead crawl

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)

night as well (Caldwell 1959). During mating the male mounts the female, holding onto the female's carapace with his four limbs. The male's 8-in. (20-cm) or longer tail, which is much longer than the female's, is bent downward, thereby pressing the male's cloacal opening against the female's cloaca (Caldwell 1959).

Nesting

7. Nesting begins in the spring (April) when local water temperatures begin to reach 23° to 24° C (Williams-Walls et al. 1983), increasing with increased temperatures and photoperiod to a peak in June and July, and declines until completion in late summer (August-September) (Fletemeyer 1981, 1982, 1983; Stoneburner 1981; Richardson and Richardson 1982).

8. Loggerhead females generally nest every other year or every third year, although a small percentage nest at intervals 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 two to three clutches (range, one to five) of eggs per season (Table 2) (Ehrhart 1979, Talbert et al. 1980, Fletemeyer 1981, Richardson and Richardson 1982). These interseasonal nestings are generally 12 to 14 days apart (range 11 to 20 days) (Fletemeyer 1983, Williams-Walls et al. 1983). Interseasonal nesting intervals vary in duration with ambient water temperature. As water temperature increases, the interval between clutches decreases (Hughes and Brent 1972). A 2-week-long coldwater intrusion off Hutchison Island, Fla., lowered the mean surface temperature 3.7° C, from 29.4° to 25.7° C. The mean 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 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).

9. The selection of a beach for nesting may be based on nest site fixity (Carr 1967, Richardson and Richardson 1982, Fletemeyer 1983, Hopkins and Richardson 1984), learned behavior (Hendrickson 1958), position of beach rocks

Table 2

Summary of Breeding Information on Sea Turtles

Species	Egg Diameter, cm	No. Eggs	No. Clutches	Nest Depth, cm	Hatchling Carapace Length, cm	US Season
Leatherback	5.1-6.3	50-170 (?)*	1-9 (6-7)	75-100	5.5	Mar-Sept
Green	4.5-5.0	100-200 (100)	1-8 (3-7)	75-100	5.0	Jun-Sept
Loggerhead	3.5-4.9	35-180 (120)	1-7 (2-3)	45-90	4.5	May-Jun
Kemp's ridley	3.8-4.0	50-185 (110)	2-3	?	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 No. Nests/Year**
Leatherback	50-70	9-17 (10)†	2-3	?	43
Green	45-60	10-15 (14)	2-4 (2)	20-30 (4-13)††	204
Loggerhead	46-65	11-20 (12-14)	2-3 (2.5)	6-20	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

SOURCES: Conant (1975), Marquez (1978), Marquez et al. (1982), Hopkins and Richardson (1984).

* Common number of eggs in a clutch.

** US continent. Information from Gordon (1983).

† Common number of days between nests.

†† Common age at maturity.

(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 imprinting at birth to that particular beach (Carr 1967), or through social facilitation by following other nesting females to a nesting beach (Hendrickson 1958). Rock outcrops on the shoreline may serve to guide turtles to a certain beach (Hughes 1974) or when the rocks are narrowly spaced may reduce the use of a beach for nesting (Mann 1978). Beaches in close proximity to offshore reefs are utilized more frequently for nesting. Offshore reefs are used for resting and feeding areas between egg-laying sessions (Stoneburner 1982, Williams-Walls et al. 1983).

10. Loggerheads emerge from the surf at night and crawl ashore, usually during high tide (Frazer 1983). Approximately 30-50 percent of the time they crawl onto the beach (sometimes excavating an area, 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 are influenced by a turtle's "readiness" to lay, physical properties of the beach, temperature of the beach sand, and disturbance of the emerging turtles (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 (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).

11. Loggerheads usually locate their nest 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 seven spots before finally laying (Ehrhart and Raymond 1983). The digging of a nest and egg-laying usually take about 1 hr. Between 35 and 180 eggs ($\bar{x} = 120$) are deposited into the nest hole (Fletemeyer 1983, Hopkins and Richardson 1984). The nest site has a very shallow or nonexistent 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 $\pm$ 7.92 cm). The vertical thickness of egg mass ranges from 10 to 40 cm ($\bar{x} =$ 23 cm $\pm$ 6.7 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 eggs ranges

from 12.7 to 55.9 cm, but most often is 27.9 to 40.6 cm.

Eggs

12. 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). Solomon and Baird (1976) report the absence of a pore structure in the mineralized layer of the turtle egg shell. 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 smaller for eggs laid last within a nest (Caldwell 1959) and for eggs in larger clutches (Ehrhart 1982). Small yolkless eggs 28 to 30 mm in diameter may also be laid (Caldwell 1959, LeBuff and Beatty 1971).

13. The eggs hatch in 46 to 65 days ($\bar{x}$ = 60 days) (Ackerman 1981, Yntema and Mrosovsky 1982, Fletemeyer 1983, Hopkins and Richardson 1984). Hatching success/fertility rates in natural clutches are 80 to 90 percent (Ehrhart 1982). Hatching success and incubation time can be affected by clutch size,

Figure 7. Exposed clutch of deposited loggerhead sea turtle eggs (pencil included as an indication of 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, if the incubation temperature is 32° C or above, all embryos develop into males, whereas at 28° C or below all embryos develop into females; at 30° C embryos develop into relatively equal numbers of males and females (Yntema and Mrosovsky 1982).

14. Eggs consume oxygen throughout their incubation. The rate of oxygen uptake increases rapidly during the second half of incubation, slowing 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). The exchange of gas 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 good hatching success (Schwartz 1982). Sand compaction may also affect gas exchange. Fletemeyer and Beckman (in press) found nests in highly compacted sands contained about 5 percent higher levels of carbon dioxide near the end of incubation than nests in uncompacted sands. This may have caused premature egg pipping among hatchlings, thus reducing the number of successful hatchling emergences. Compacted sands, which may result from vehicular traffic on the beach, may also inhibit the digging by hatchlings from the nest cavity to the sand surface (Mann 1978, Fletemeyer 1979).

Hatchlings

15. Hatchlings emerge from the nest as a group at night and orient seaward (Hopkins and Richardson 1984). 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 percent of the hatchlings in each clutch on Florida beaches emerged successfully (Figure 8). 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

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

1983). After emergence, hatchlings must reach the water rapidly to avoid heat stress or predation from gulls, raccoons, and ghost crabs (Figure 9) (Dean and Talbert 1975, Hosier et al. 1981). Orientation of hatchlings to the ocean has been attributed to geotaxis (Parker 1922), reflected surf-light (Daniel and Smith 1947), 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 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 1979). 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 probably become pelagic (Hopkins and Richardson 1984). On the Atlantic coast they swim until they encounter sargassum rafts in the Gulf Stream (Caldwell 1968; Smith 1968; Fletemeyer 1978a, 1978b; Carr and Meylan 1980). However, at Cumberland Island, Ga., hatchlings moved from the beach to open water and then moved to

Figure 9. Hatchlings emerging from nest and crawling rapidly toward open water

protected backwaters and tidal creeks (Stoneburner and Richardson 1982). Movement of hatchlings on the Gulf Coast seems to be unknown.

Juveniles

16. Juvenile loggerhead turtles utilize bays and estuaries from April to 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 stranded 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 straight-line carapace length) were found throughout the year (Mendonca and Ehrhart 1982). They did not appear to be active at night and probably were present in this area to feed on the abundant invertebrates (Mendonca and Ehrhart 1982).

17. Investigation of an immature loggerhead population at Cape Canaveral, Fla., using testosterone levels indicated a sex ratio of 1 male to 1.57 females, which differed significantly from the expected 1:1 ratio observed in

many species of sea turtles (Owens et al. 1984). It was found in this study that tail measurement was not accurate in differenting subadult male and female loggerheads (Owens et al. 1984) as it is in adults.

Adults/movements/migration

18. 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 which are 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).

19. 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).

20. From Florida, following nesting, loggerheads disperse to the Bahamas, Cuba, Dominican Republic, 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).

21. 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

22. Growth in sea turtles appears to be rapid from hatchling to young adult (Parker 1929, Uchida 1967, Frazer 1982), slowing from young adult to

mature adult (75- to 80-cm straight-line carapace length at maturity) and becoming very slow at maturity. However, the rate of growth in sea turtles differs depending on the quality (Stickney et al. 1973) and/or the quantity of food (Nuitja and Uchida 1982). The determination of growth rate has also been confounded by the inability of researchers to mark and periodically measure turtles from hatchling to adult. 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 turtles with OC >50 cm or SL > 45 cm, straight-line carapace length can be calculated by applying the following formula: SL = 0.980 (OC) - 5.14 (Frazer and Ehrhart 1983).

23. The growth rate measured between captures of 13 wild immature loggerheads in Mosquito Lagoon, Fla., indicated a mean rate of 5.90 cm/year (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 to be found nesting on beaches near Mosquito Lagoon (Ehrhart 1980, Mendonca 1981). Estimates of age at maturity exceeded 20 years for Australian populations of loggerheads (Limpus 1979).

24. Growth rate of nesting female loggerheads is based on a number of tag and recapture programs along the southeast Atlantic coast of the United States, particularly in Florida. The rate of growth in Florida ranged from about 0.6 cm/year (Bjorndal et al. 1983) to about 1.0 cm/year (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 ratio for female Florida loggerheads of 2.34 kg to 1 cm.

25. Kaufmann (1967) found the average growth per month of hatchling loggerhead reared in captivity to be 90.7 g in weight, 16.4 cm in length, and 12.7 cm in width. 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, $W = 77.5/(1 +$

$18,684e^{-0.960t}$) (W = weight in kilograms, e = base of natural log, and 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 length 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 3.7 kg (Parker 1926), respectively, and measured 26 cm, 30 cm (Schwartz 1981), and 63 cm (Parker 1926), respectively. (Adult loggerheads usually weigh less than 140 kg with a carapace length little more than 77 cm (Rebel 1974).)

EXPLOITATION

26. Historically, loggerheads in the United States supported a fishery until populations became depleted. From 1951 to 1971 loggerhead landings in Florida averaged 3,334 kg per year (range 96-12,391 kg per 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 of the turtles harvested in the Caribbean are believed to be derived from US nesting populations (Brongersma 1971).

MORTALITY

27. Juvenile and adult 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 and hypothermia (Fletemeyer 1979, 1983; Gordon 1983).

28. 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 older juveniles ranging in OC lengths of 55 to 70 cm (Richardson and Richardson 1982).

POPULATION DYNAMICS

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

30. Population estimates can be confusing because they may be expressed either as number of nests (clutches) a year, number of nesting females a year, or total number of mature females. This is confusing because each nesting female lays 1 to 7 nests in a 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) uses the following formula to calculate the total number of mature females:

$$\frac{\text{Number of nests per year} \times \text{Average nesting frequency per individual}}{\text{Average number of clutches per female per year}} = \begin{array}{l}\text{Total number of}\\ \text{mature females}\end{array}$$

31. Lund (1974) and Carr and Carr (1978) estimated the number of nesting females a year to be between 6,000 and 25,000. An average 2.5-year nesting frequency per individual gives a total number of mature females of 15,000 to 62,500. More recently, Gordon (1983) reported 28,310 to be the total number of US nesting female loggerheads based on the estimated number of total nests per year for recent years (Table 3). Murphy and Hopkins (1984) estimate 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. Based on the average nesting frequency of 2.5 years (Gordon 1983), the total number of mature females is estimated to be from 35,375 to 72,520, somewhat higher than Gordon's estimate.

32. Based on data from Little Cumberland Island, Ga., a population model predicted annual recruitment at 39 percent 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

Table 3

Distribution and Estimated Population Size of Nesting Female Loggerhead Sea Turtles Along the Atlantic and Gulf Coasts of the United States, 1983

Region	Coastline km	No. of Nestings per Season*	Percent of Population per Region	Nesting Season
Texas (TX)	620	1	<0.1	Mar-Sep
Louisiana (LA)	710	Not recorded	--	--
Mississippi (MS)	120	4	<0.1	Jun
Alabama (AL)	748	1	0.1	Jul
Florida (FL)	2,037	23,897	84.4	Apr-Sep
NW coast		390	1.4	May-Aug
SW coast		1,459	5.2	Apr-Aug
SE coast		6,021	21.3	Apr-Sep
NE coast		16,027	56.6	May-Sep
Georgia (GA)	176	963	3.4	May-Aug
South Carolina (SC)	290	3,156	11.1	May-Aug
North Carolina (NC)	485	279	<1.0	May-Aug
Virginia (VA)	180	7	<0.1	Jun-Jul
Maryland (MD)	50	1	<0.1	--
Delaware (DE)	45	0	0	--
New Jersey (NJ)	439	1	<0.1	--
TOTAL		28,310	99.9	Apr-Sep

* Compiled and computed from Gordon (1983); where number of females = (T)/(ns) × (ri), T = total number of nests in 1 year, ns = number of nests per season, ri = nesting females in the population, ns = 2.5 for all regions except SC and GA, where ns = 3.3, ri = 2.5 for all regions.

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 must survive to maturity to replace the original 1,000 females.

ECOLOGICAL ROLE

Food habits

33. Loggerheads are primarily carnivorous (Mortimer 1982). They eat a variety of benthic organisms including molluscs, 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, Fla., subadult loggerheads fed almost exclusively on abundant horseshoe crabs (*Limulus polyphemus*). 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). Shoop and Ruckdeschel (1982) found evidence that loggerheads may also eat animals discarded by commercial trawlers, which may contribute to the capture of turtles in their trawls.

34. Although food preferences in the wild turtles have not been studied, loggerheads have shown in laboratory experiments that they do have short-term food preferences but will also adapt 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).

35. Study observations in Australia suggest that local availability of benthic invertebrates for food may be an important factor in selection of a loggerhead nesting beach. Abundant food may also enable female loggerheads over a nesting season 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

36. 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). The amount of predation decreases after the early stages of incubation and then increases again near hatching time (Klukas 1967, Hopkins et al. 1978). The higher predation rates at the beginning and end of incubation are believed to be related to olfactory cues released by females when laying the eggs and by preemergent hatchlings (Hopkins et al. 1978, Stancyk et al. 1980) that are detected by predatory mammals. Raccoons can be particularly destructive, taking up to 100 percent of the eggs in a nest and up to 96 percent 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. Egg mortality is also 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).

37. Hatchlings are taken by mammals, birds, and crabs as they crawl to the water; however, this predation 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).

38. Juvenile and adult sea turtle predation is believed to be minimal because they exceed the size range that can be taken by most predators. Sharks, grouper, and killer whales (*Orcinus orca*) are reported to be predators of adult and juvenile sea turtles (Caldwell 1959, 1969; Hirth and Carr 1970; Hughes 1974). The magnitude of this predation, however, is unknown. Researchers have found up to a 21-percent incidence of cuts, bites, or lacerations on nesting turtles caused by sharks, which is indicative of a relatively high amount of predation (Hendrickson 1958, Hughes 1974). Caldwell (1959) reported that nesting turtles have been killed by dogs.

Commensals and parasites

39. 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), and remoras (Fretey 1978).

WATER AND SAND TEMPERATURE EFFECTS

40. Temperature is a major factor influencing sea turtle life histories. Sand temperature affects 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

41. 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

42. The lower the ambient sand temperature, the longer the incubation time for turtle eggs. A 1° C decrease adds about 5 to 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. Good hatch success occurs between sand temperatures 25° and 32° C (Limpus et al. 1983b).

Sex ratios of hatchlings

43. If incubation temperatures remain at 30° C, approximately equal numbers of male and female hatchlings develop; above 30° C more males tend to be produced, whereas below 30° C females predominate (Yntema and Mrosovsky 1982).

Renesting interval

44. As the nesting season progresses and the water temperature increases, time between nestings of an individual female decreases in duration (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

45. Temperatures in the nest rise toward the end of incubation, which may synchronize hatching (Hopkins et al. 1978). The hatchlings usually emerge as a group at night (Hopkins and Richardson 1984), which seems to be cued by the cooler nighttime temperatures (Hendrickson 1958). Above approximately 28.5° C, hatchlings remain in their nests (Mrosovsky 1968).

Surface basking

46. 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

47. Temperature can also affect feeding activity. Turtles were found in shallow feeding areas of a lagoon in Florida in the morning and evening, a time when water temperatures were cooler. During midday, when water temperatures in the shallows rose above 31° C, turtles moved to deeper water that was often 2° C cooler. At dusk, 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. Movement to cooler water and remaining inactive are probably responses that prevent overheating (Spotila et al. 1979, Mrosovsky 1980).

Migration and hibernation

48. In response to cold 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, sea turtles have been discovered buried in the substrate at water temperatures averaging 14° C in Florida (Carr et al. 1980) and below 15° C in 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. Temperatures below 4.8° to 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 are able to tolerate cold water longer than adults (Schwartz 1977). In outdoor tanks in North Carolina, adult Kemp's ridleys survived longer (20 to 24 hr) at lethal temperatures than greens or loggerheads (9 to 12 hr), although floating occurred at 10° to 13.5° C in ridleys and 9.0° to 9.9° C in greens and loggerheads (Schwartz 1977). Different populations of a turtle species may respond differently to a given temperature level, possibly due to acclimatization of the populations to different temperature regimes (Mendonca 1983).

CONTAMINANTS

49. Loggerheads have the potential for accumulating contaminants through their primary food source, benthic invertebrates (Stoneburner et al. 1980). Pesticides, heavy metals, and PCBs 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).

50. 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 system of hatchlings (Bureau of Land Management 1981), and cause death of juveniles from ingestion (Witham 1978; Fletemeyer 1980, 1983).

MANAGEMENT

Predator control

51. 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 will need to be placed immediately after nest establishment and must be removed after hatching. The manpower and materials to protect a large number of nests may be a constraint of using wire enclosures.

Nest relocation

52. To prevent or reduce loss of nests and eggs to predators, erosion, or man's activities, nests are relocated to safer spots on the beach (Ehrenfeld 1982, Stancyk 1982). Even though local nest transplantation is 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 then to be susceptible to erosion, flooding, or predation (Ehrenfeld 1982, Stancyk 1982, Witzell 1983).

Hatcheries

53. Movement of nests to hatcheries is another method used to prevent or reduce loss of nests and eggs to predators, erosion, or man's activities (Richardson 1978, Talbert et al. 1980, Hopkins and Richardson 1984). The eggs are usually moved to a single protected site and are usually 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, (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).

Head-starting

54. 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, may become wounded and infected in crowded-captive conditions, may be removed from the sequence of natural conditions which may play a role in their life cycle, and may have a percent survival less than or no better than wild hatchlings (Ehrenfeld 1982, Mrosovsky 1983).

Dredging

55. 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.

56. In the maintenance dredging of the entrance channel at Canaveral Harbor, Fla., 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).

57. 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 that had minimal effect on the turtles.

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