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**Summary of Loggerhead Sea Turtle Research
Cumberland Island National Seashore
1984-1986**

Final Report

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Summary of Loggerhead Sea Turtle Research

Cumberland Island National Seashore

1984-1986

The nesting activity of the loggerhead sea turtle (*Caretta caretta*) has been monitored intensively on Georgia barrier islands each summer since 1964. The data gathered over the duration of this 24-year study provides unique insight into survivorship and recruitment of the loggerhead, a threatened species. The beaches contained within the boundary of the Cumberland Island National Seashore represent the most important nesting habitat for loggerheads in Georgia.

A rather extensive description of the loggerhead population biology study on Cumberland Island may be found in National Park Service Research/Resources Management Report No. 39 (Stoneburner 1980). Since then, a series of elaborate analyses of the accumulating life history data of the nesting loggerheads has been completed (Crouse 1984, Eckert 1987, Frazer 1983, Richardson 1982). It is the overall purpose of the Cumberland study (1984-86) to continue an uninterrupted flow of population data collected over a very long period of time in order to permit continuing analyses. Of particular interest is the positive effect of the new turtle excluder device

(TED) program on increasing survivorship of Cumberland Island nesting adult female sea turtles over the next few years.

The data summarized in this report are stored in the long-term data base housed at the Institute of Ecology, University of Georgia. The Cumberland results for 1984-86 have been merged with data from other Georgia islands (1984-86) and with overall state records gathered from 1964-1986 and in the following years. It is anticipated that the next major analysis phase for Georgia loggerhead population data will occur in the vicinity of 1990, a period of approximately ten years since the last analysis phase.

METHODS & MATERIALS

The Georgia loggerhead population study was initiated by the author in 1964 on Little Cumberland Island (Figure 1) with a program to mark and record the behavior of nesting females. Tagging studies were also begun adjacent to Little Cumberland on Jekyll Island (1971) and Cumberland Island (1973), thereby adding additional information concerning the dispersal of nesting effort around the Little Cumberland study area. Tagging programs initiated on distant islands (Figure 2) within Georgia [Ossabaw Island (1972), Wassaw Island (1972), Blackbeard Island (1979)] and neighboring states (Cape Lookout, NC; Kiawah Island, SC; Cape Canaveral, FL) have added to the comprehensiveness of the Georgia data.

Cumberland Island National Seashore is approximately 17 miles long. A five mile study area, divided into 20 quarter mile sections, is intensively monitored for nesting female loggerhead turtles (Figure 3). The study area is bounded by Christmas Creek

Figure 1. A map locating the Little Cumberland Island (GA) nesting beach and the adjacent beaches of norther Cumberland Island and southern Jekyll Island, where tagging programs of nesting female loggerhead sea turtles are conducted.

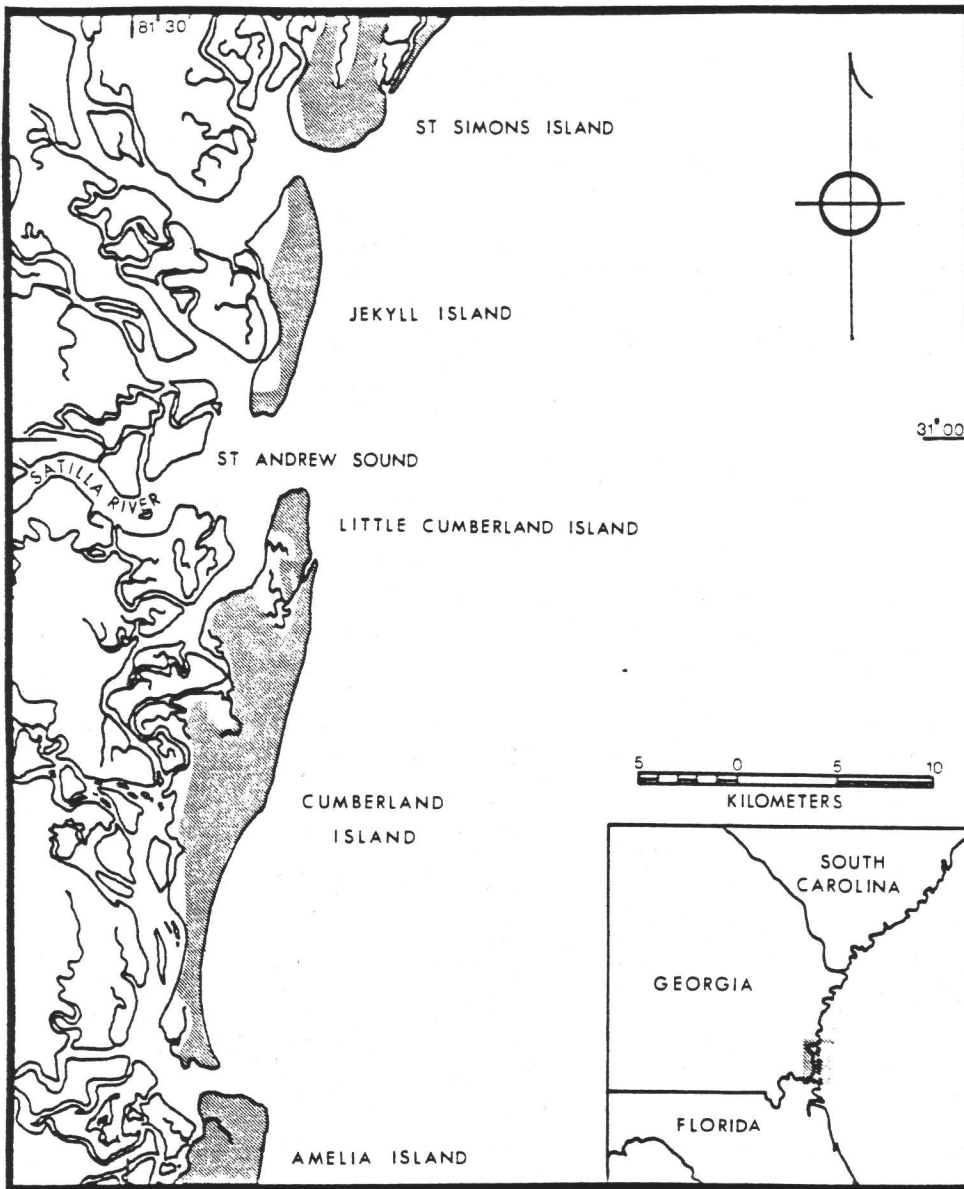


Figure 2. A map of coastal Georgia locating Blackbeard, Ossabaw, and Wassaw Islands, where tagging studies of nesting female loggerhead sea turtles are conducted at distances greater than 10 km from the Little Cumberland Island study site.

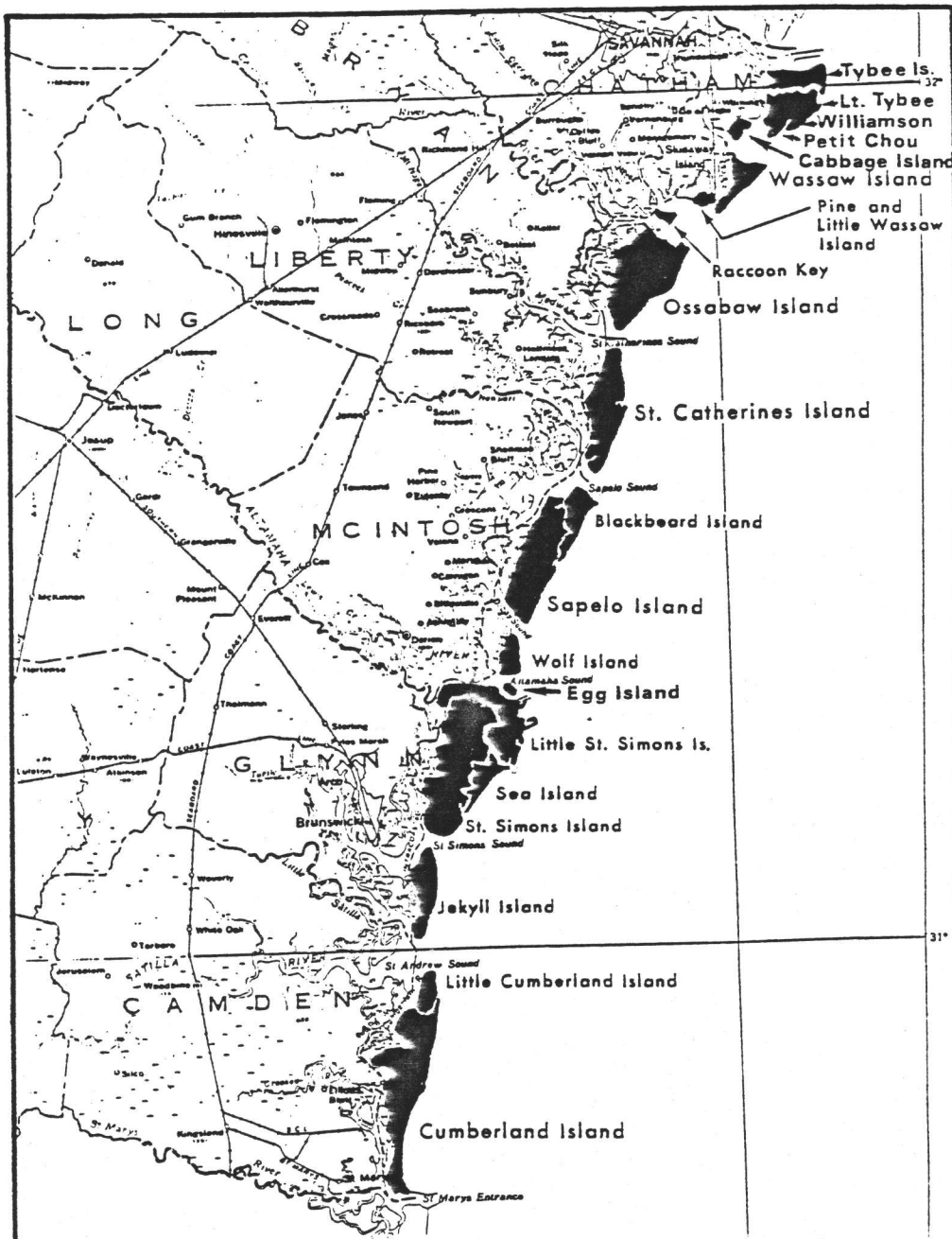
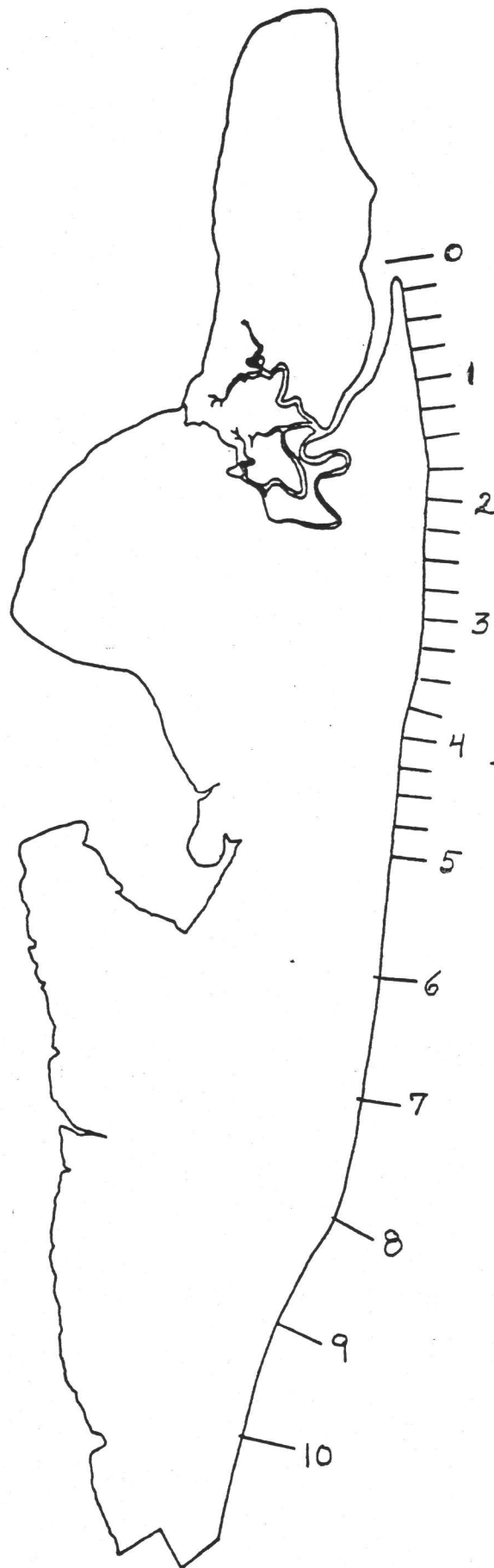


Figure 3. A map of Cumberland Island National Seashore, indicating mile posts for the primary study area (Marker posts 0 to 5) and the secondary study area (Marker posts 5 to 10 (mapped) and 11 to 18 (not mapped)). Crawls are located to the nearest 0.25 miles in the primary and to the nearest 1.00 miles in the secondary study areas.



← Mile
section numbers

CUMBERLAND ISLAND
NATIONAL SEASHORE

to the north and the continuation of the Cumberland beach (12 miles) to the south. North of Christmas Creek is the Little Cumberland Island loggerhead nesting beach that is monitored by another research project in cooperation with the National Park Service project. South of the study area (Post #20), the beach is divided into 1-mile sections and patrolled for the presence of nesting turtles on an opportunistic basis.

Georgia turtle taggers pride themselves on the efficiency of their beach coverage. Thus, it is the mission of this study to intercept each and every nesting female loggerhead sea turtle within the primary five-mile study area on Cumberland Island. The beach is patrolled by Honda ATV or on foot as least hourly throughout each night of the 80-day nesting season (20 May - 10 August). The objective of this intensive approach to sampling is to intercept, tag and record the females responsible for at least 90 percent of the nests in the study area. The Cumberland beach survey efficiency has remained above 90 percent within the study area for each of the 1984-86 seasons.

A second important aspect of Georgia population sampling methodology is replication. The areas patrolled and frequency of coverage have remained consistent on Little Cumberland since 1964 and on Jekyll and Cumberland Islands since 1973. This fact has provided an unprecedented opportunity to compare numbers of nesting females from year to year, equalled only by a similar loggerhead project on the east coast of South Africa (Hughes, 1974). The system of precise replication of experimental method has continued through the 1984-86 seasons on Cumberland Island for the data gathered and presented in this report.

Adult females are tagged with a variety of monel steel and plastic tags when they appear on the nesting beach. Unfortunately, it is extremely difficult to design a tag that

will stay with a turtle for several years and remain readable on the turtle's return. Since loggerheads nest every second or third season, it takes 4 - 6 years to notice a fault in tag structure, to design and produce a replacement, and to test the replacement in the field. Tagging technology improved from 1964 to 1970, but a hidden change in manufacturer's design caused another tag loss problem (1971-1975) that has only recently (1976-1981) being corrected. Individual turtles may receive up to four tags of three types to minimize the tag loss problem.

The duration of Little Cumberland's tagging program has resulted in a valuable population measure, the percentage of untagged turtles that have not ever been tagged before. Piercing a front flipper pad with a tag causes a scar or swelling which is clearly identifiable and permanent. It is possible to separate turtles never before tagged (Neophyte) from turtles that have lost their tags (Calloused). Thus, a remigrant is a turtle returning to nest from a previous season; it may be either calloused or bearing a readable tag. Turtles on Cumberland Island and adjacent nesting beaches have been carefully inspected for callouses (tag scars) since 1967.

The Cumberland population data presented here (1984-86) have been added to records from the Little Cumberland, Cumberland, and Jekyll Island tagging studies (1964-1987). The 10,000 record computerized file for sea turtle observations is housed at the Institute of Ecology. The combined data set from Little Cumberland, Cumberland and Jekyll contains approximately 6500 records of tagged turtles emerging to lay within the St. Andrew Sound study region, including about 3500 successful nesting attempts.

Crawl records and tag numbers are entered into the computerized data storage file after they are rigorously scrutinized for possible recording errors. The propensity for errors in sea turtle tagging data appears greater than for most other tagging studies. Field records are gathered at night, often with poor lighting and under the stress of inclement weather and noxious insects. A single misread digit on any one of four 6-digit tags placed on turtles appearing from two to ten times during the nesting season will cause the animal's nesting records to be combined with another's nesting records. This results in the generation of anomalous behavior patterns in the computer file. Such errors, if unchecked, will soon destroy the reliability of data. The Georgia data are rigorously combed for recording errors, probably more efficiently than any other similar set of data in existence.

RESULTS

The distributions of nests and total crawls (nesting crawls plus false/unsuccessful nesting crawls) by season (Figures 4-7) and by mile of beach (Figure 8-9) are provided. The numbers of nests per season (212 in 1984, 201 in 1985, and 211 in 1986) are surprisingly constant from year to year, given the usual tendency for numbers of nests and nesting females to fluctuate dramatically from year to year. Approximately 75% of all nesting activity is found in the most northerly portion of Cumberland Island, a five mile stretch that coincides with the five mile study area. However, taken together, the lower 13 miles of beach represent an important 25% of overall nesting on Cumberland Island and should not be dismissed as unimportant sea turtle nesting habitat, even though nest density is much lower than in the study area.

Figure 4 Total nests deposited on Cumberland Island (1984-86) according to Julian date. Figure covers a period from May 10 (JD = 130) to June 28 (JD = 179) except for 1984 (leap year) when all Julian dates advance by one for each corresponding date.

Nests "1984-86 Day 1-50"

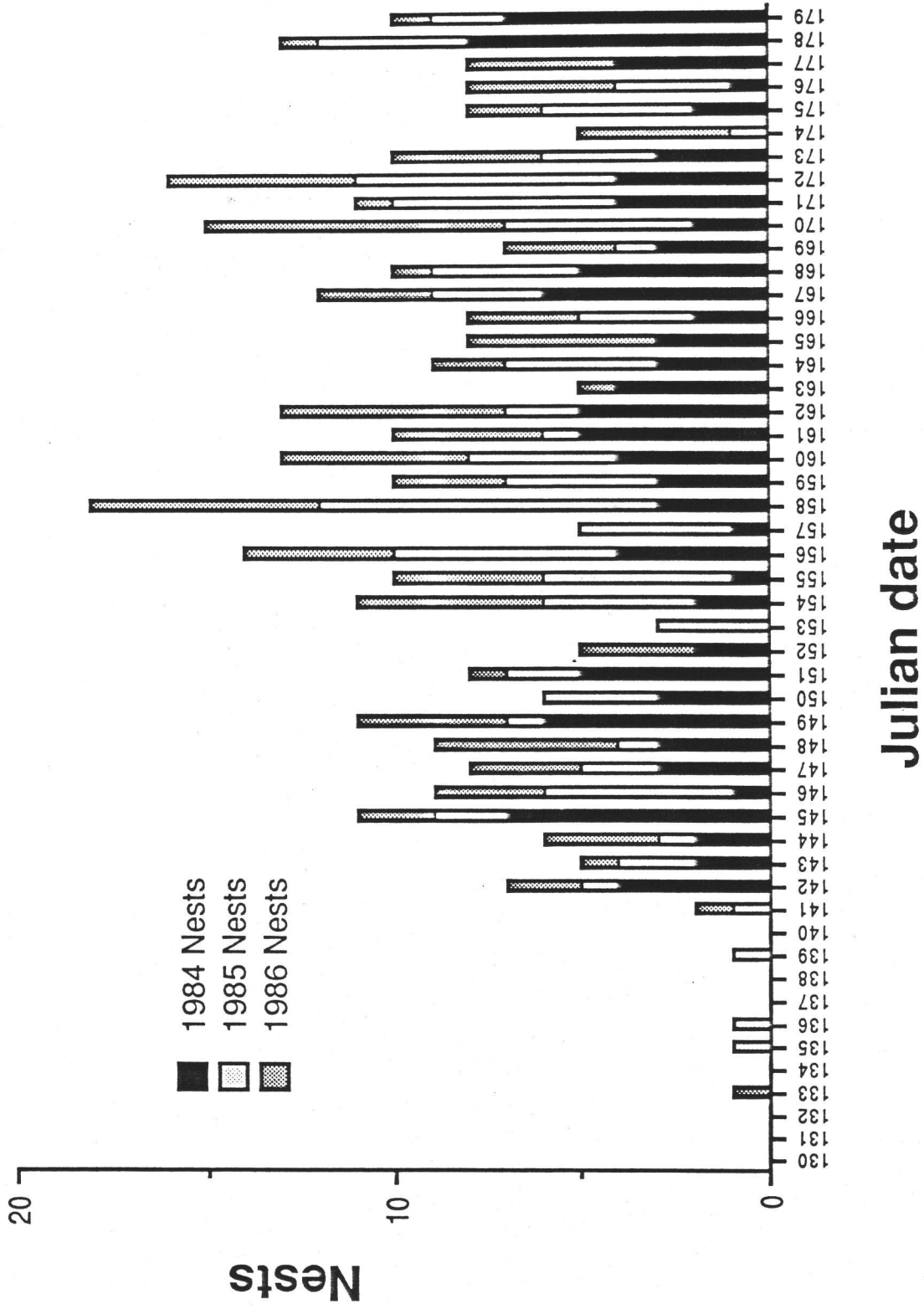


Figure 5 Total nests deposited on Cumberland Island (1984-86) according to Julian date. Figure covers a period from June 29 (JD = 180) to August 16 (JD = 229) except for 1984 (leap year) when all Julian dates advance by one for each corresponding date.

Nests "1984-86 Day 51-100"

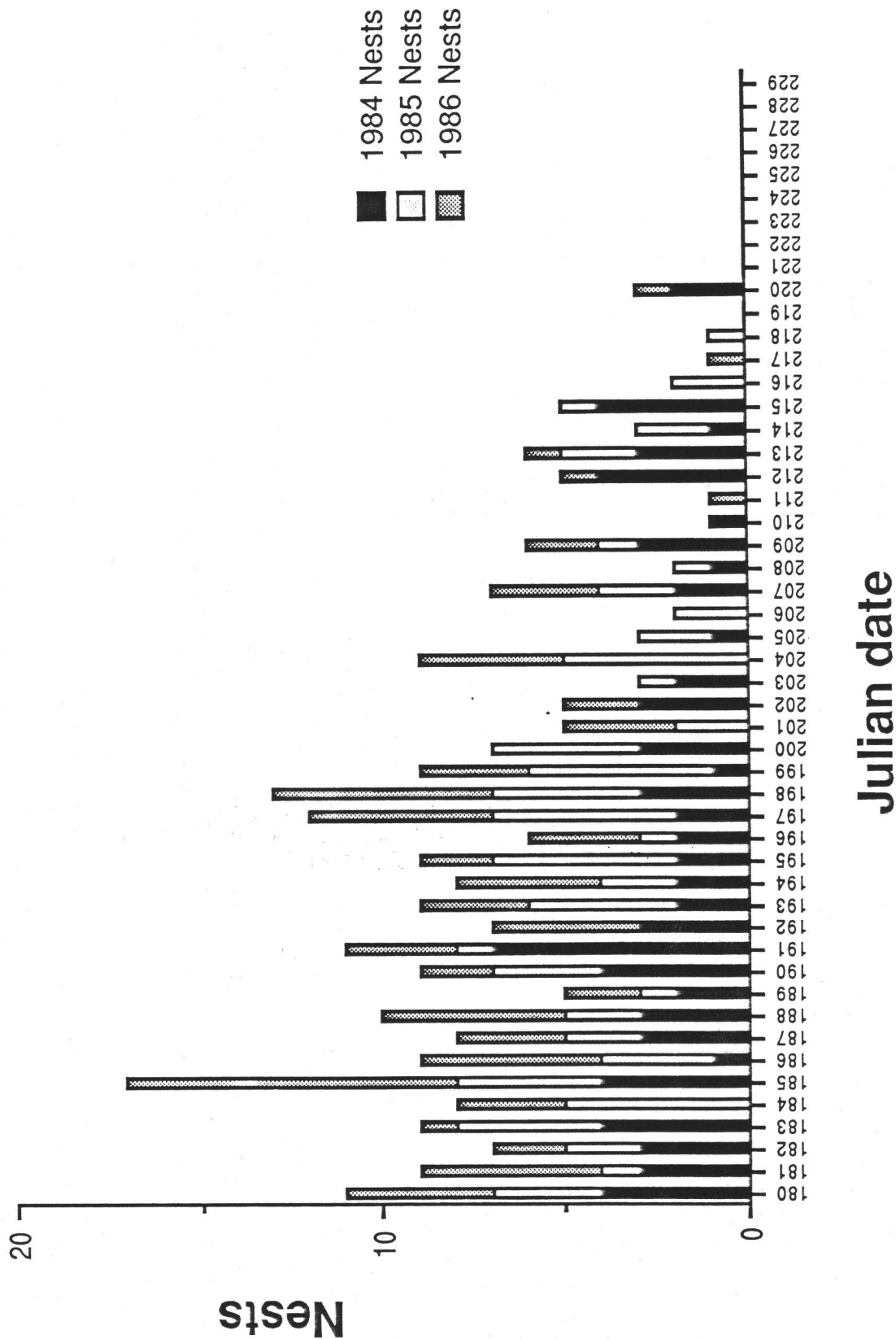


Figure 6 Total crawls (nesting crawls and false nesting crawls) deposited on Cumberland Island (1984-86) according to Julian date. Figure covers a period from May 10 (JD = 130) to June 28 (JD = 179) except for 1984 (leap year) when all Julian dates advance by one for each corresponding date.

Total Crawls "1984-86 Day 1-50"

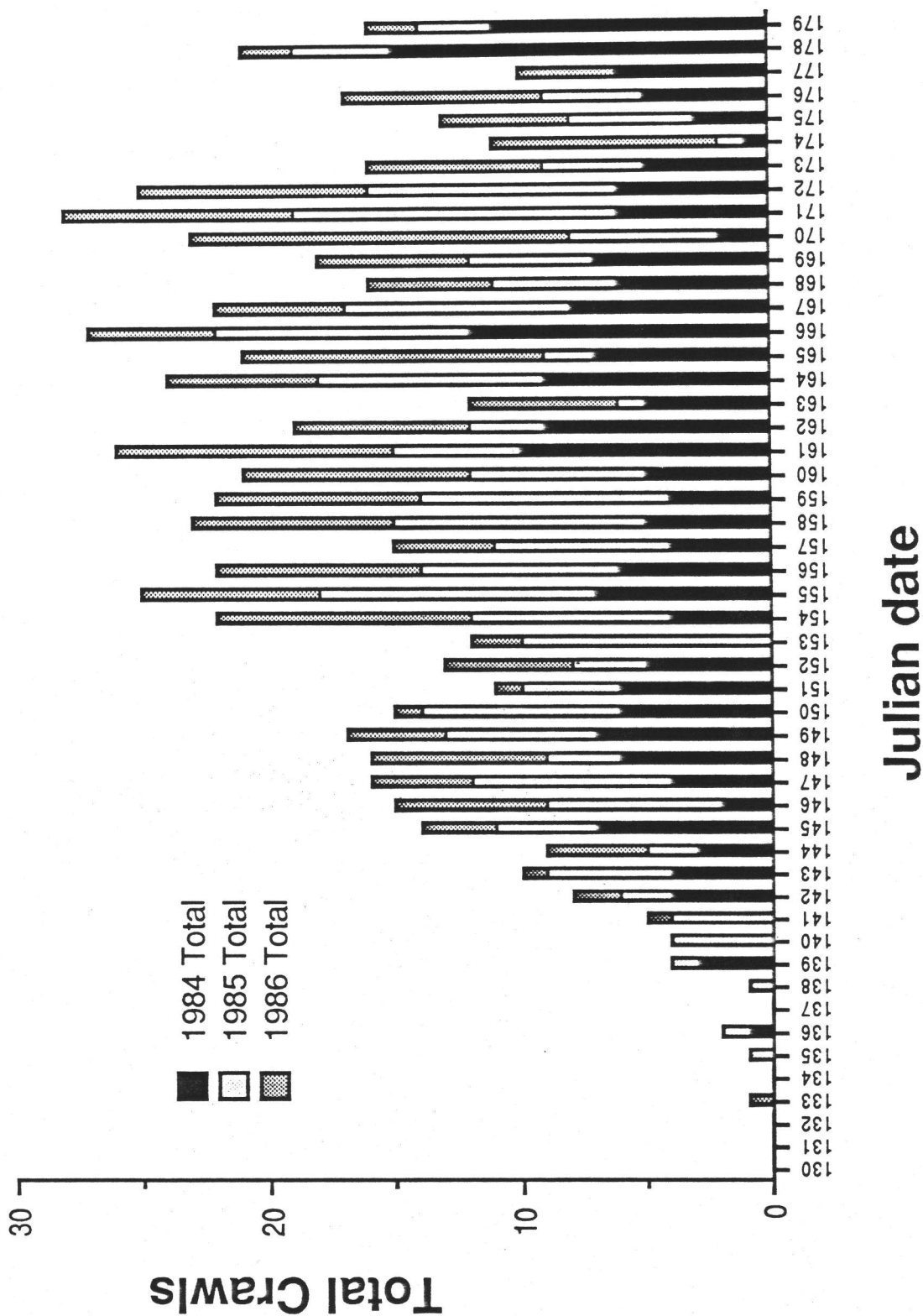


Figure 7 Total crawls (nesting crawls and false nesting crawls) deposited on Cumberland Island (1984-86) according to Julian date. Figure covers a period from June 29 (JD = 180) to August 16 (JD = 229) except for 1984 (leap year) when all Julian dates advance by one for each corresponding date.

Total Crawls "1984-86 Day 51-100"

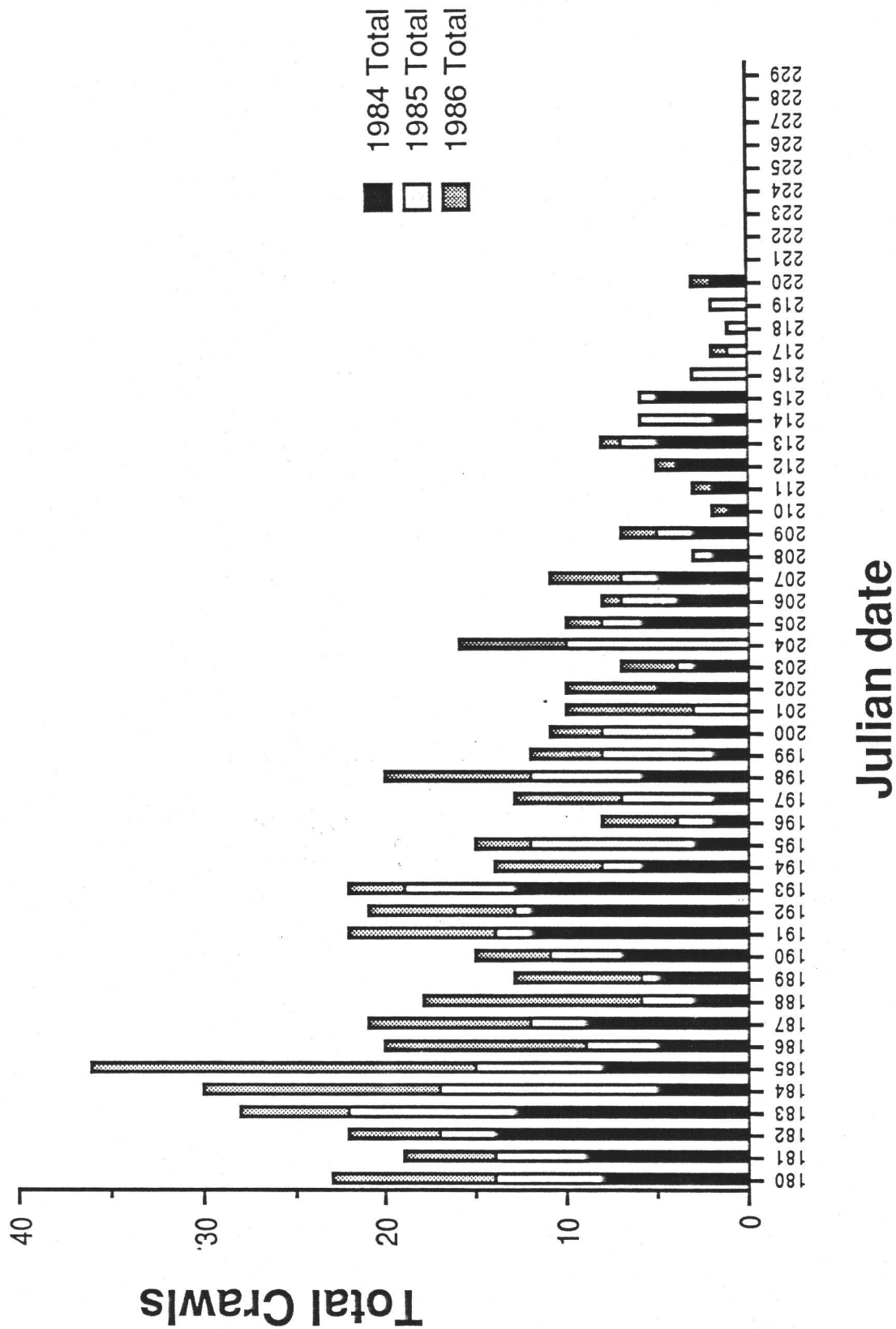


Figure 8 Spatial distribution of nests along Cumberland Island (1984-86) according to mile sections. Section 1 corresponds to the north end of Cumberland at Christmas Creek, while Section 18 ends south of the jetty. Note: Nests from 1984 have not been mapped south of Section 5.

Nests "1984-86 by Mile Section"

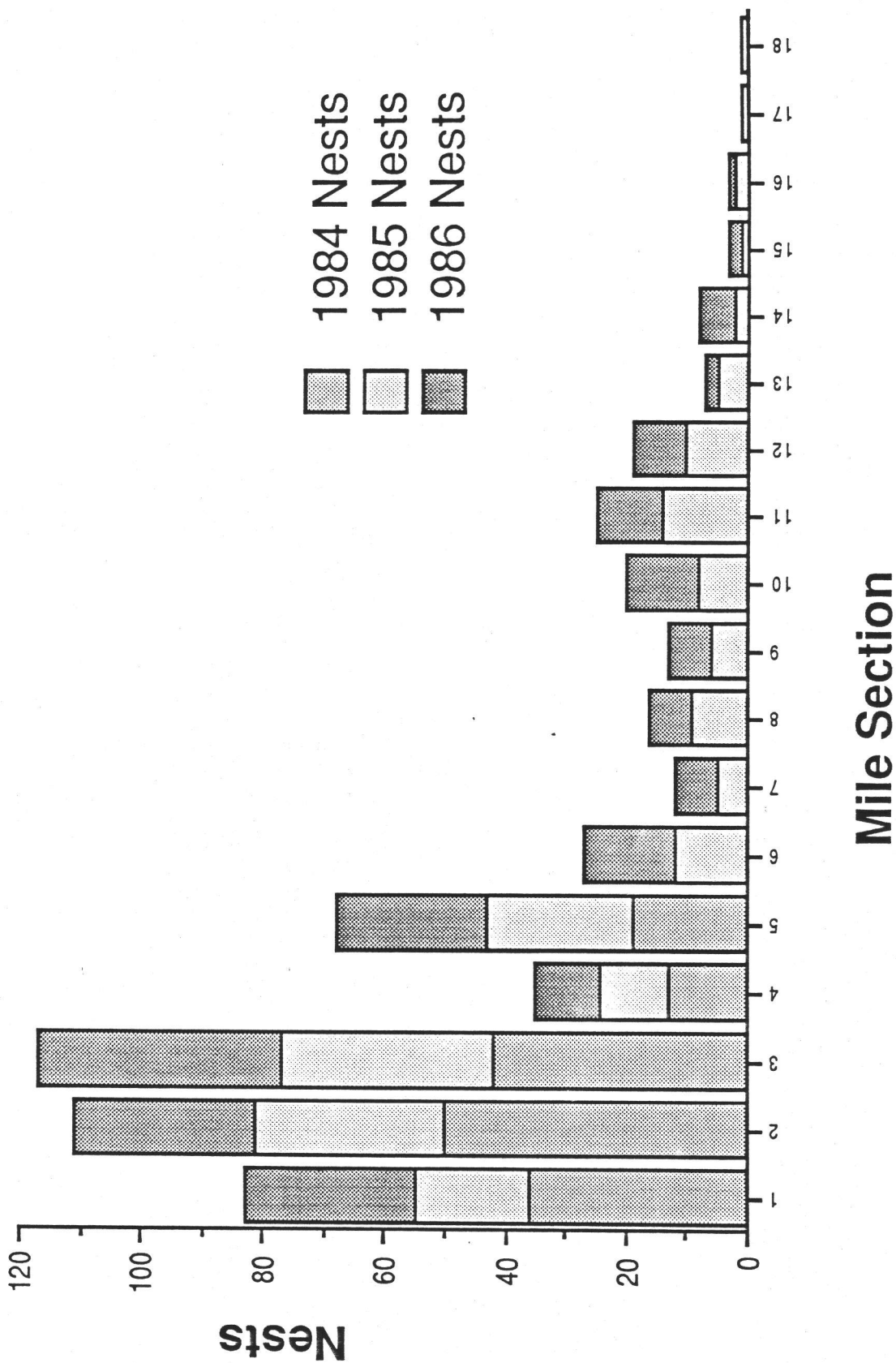
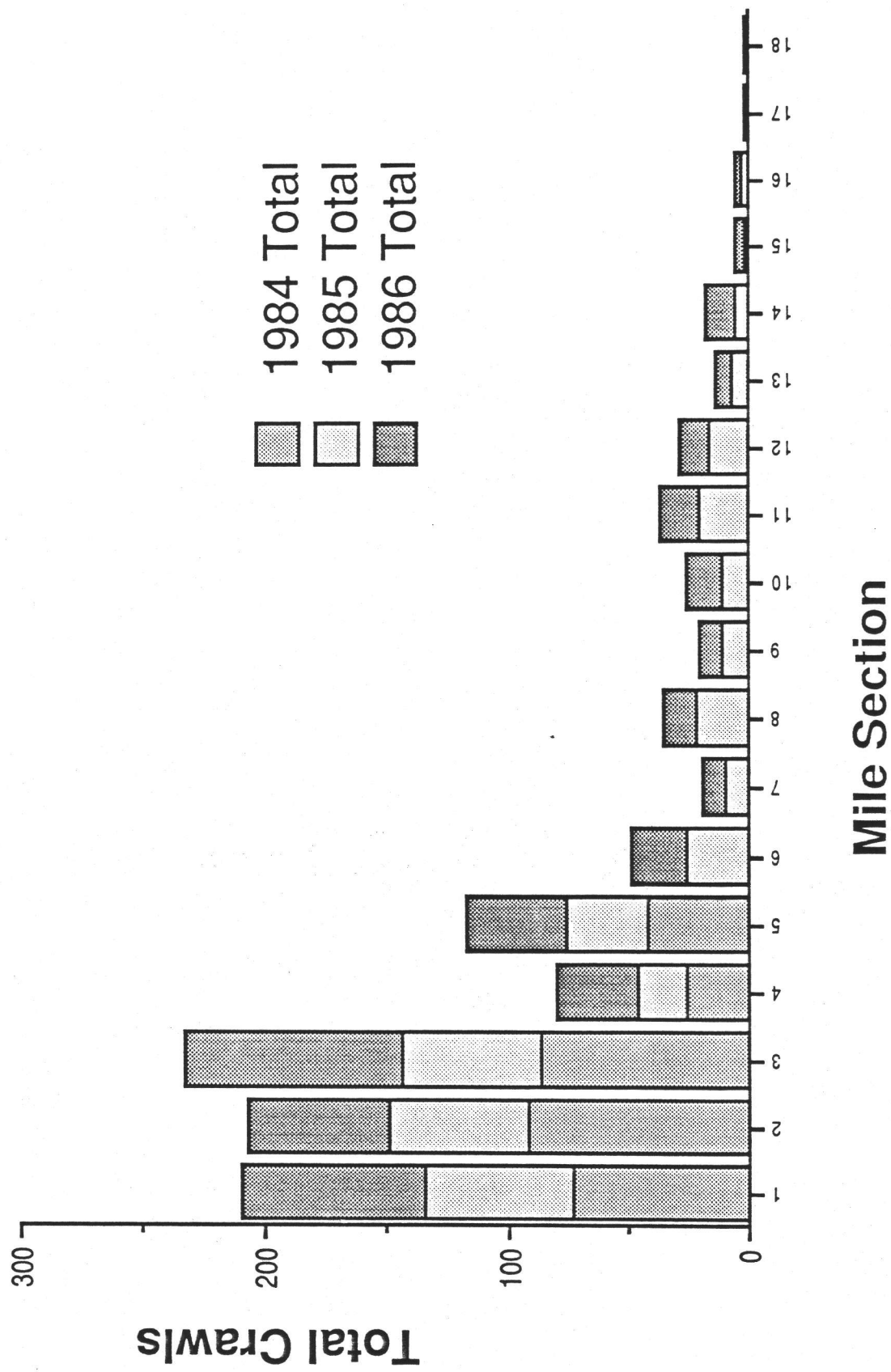


Figure 9 Spatial distribution of total crawl activity (nesting crawls and non-nesting crawls) along Cumberland Island (1984-86) according to mile sections. Section 1 corresponds to the north end of Cumberland at Christmas Creek, while Section 18 ends south of the jetty. Note: Crawl activity from 1984 have not been mapped south of Section 5.

Total Crawls "1984-86 by Mile Section"



DISCUSSION

As stated previously, the population analysis of the 1984-86 Cumberland Island data will be merged with data from other Georgia islands and other years. In order to provide an idea of overall loggerhead population biology, a summary is provided here. It is important to remember that our understanding at this time has been derived from data collected for 20 years prior to 1984. The Cumberland Island 1984-86 data will be utilized in detailed population analyses anticipated by 1990.

The life cycle of a loggerhead turtle, like all sea turtles, is simple to conceptualize (Figure 10) but difficult to observe. The terrestrial phase begins when adult females appear on nesting beaches to deposit their eggs. Incubation takes two months, and the hatchlings, upon emerging, crawl directly to the water and disappear at sea. Thus, the terrestrial stage represents one percent or less of the duration of the life cycle if a loggerhead lives for 20 years or more. All other segments of the life cycle occur within the pelagic phase.

A number of terms are commonly used to describe sea turtle biology. A brief definition of these terms is essential for understanding the discussion which follows.

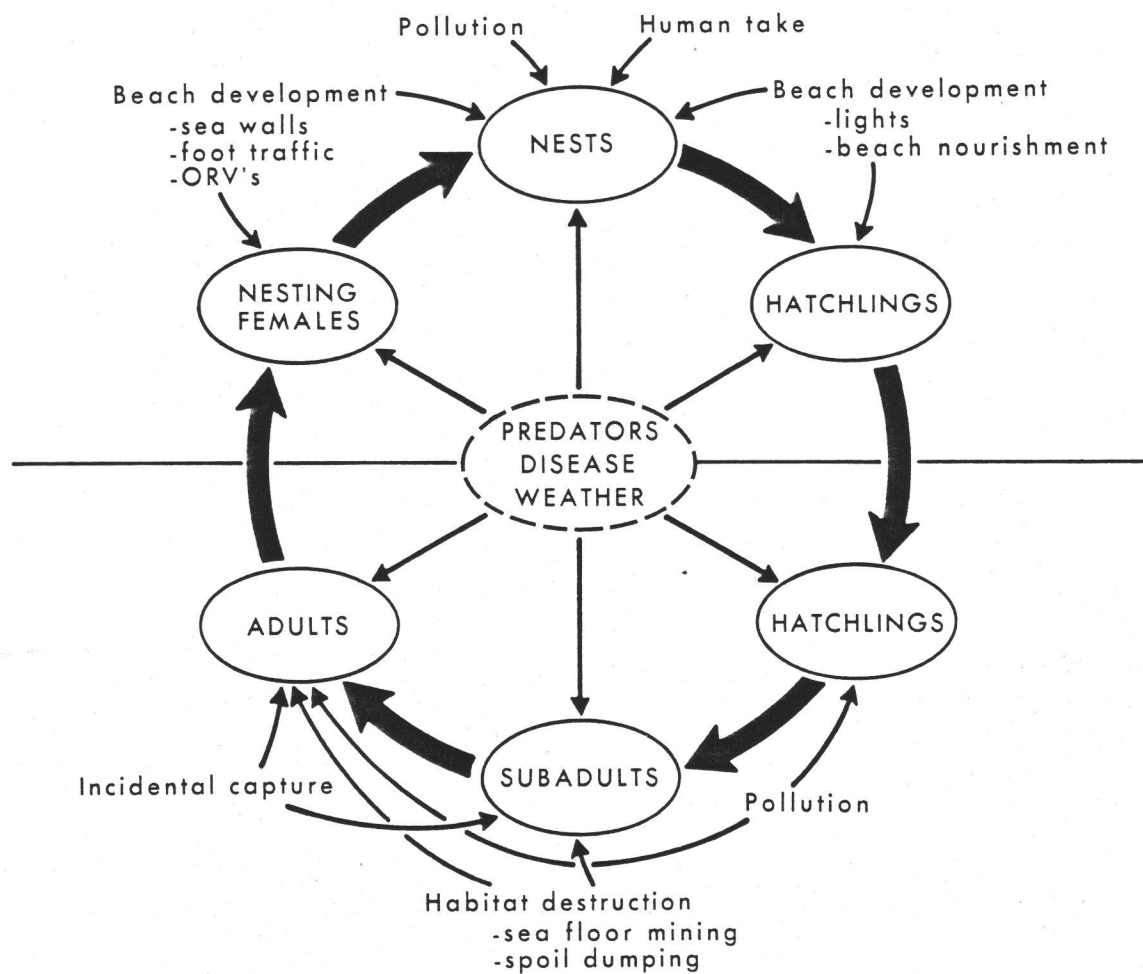
Neophyte: an adult female that has not been seen on a nesting beach in previous years. Neophytes are derived from recruitment and immigration.

Recruit: a neophyte that is believed to be a young animal just entering the nesting population.

Immigrant: an adult female that returns to nest from a previous nesting year. Remigrants consist of calloused and tagged individuals.

Figure 10 A schematic diagram of the life cycle of a loggerhead sea turtle depicting terrestrial and pelagic portions of the cycle and the types of human-induced and natural mortality sustained by the loggerhead at various stages of the life cycle.

LOGGERHEAD TERRESTRIAL STAGES



PELAGIC STAGES

Calloused: an untagged animal that shows evidence (tag scars) of having been tagged on a previous nesting season.

Tagged: a remigrant that bears a readable tag from previous nesting season.

Remigration: the tendency for sea turtles to nest for two or more years.

Remigration rate: the probability that a nesting turtle will return to nest another year, regardless of the elapsed time between nesting years.

Remigration interval: the length of time between nesting years (usually 1 - 5) by an individual turtle.

Remigration interval probability: the probability that a remigrating turtle will return on a specified remigration interval to nest.

Nest beach fidelity: the tendency for a sea turtle to focus its nesting effort within a specified range of coastline.

Interesting interval: the number of days between the laying of two consecutive clutches of eggs by a single individual within a season.

False crawl: a nesting attempt that does not result in a successful clutch of eggs.

Aborted nesting attempt: an incomplete clutch of eggs that is abandoned without being covered (buried) by the turtle before departure from the nesting beach.

Nesting crawl: a nesting attempt resulting in a clutch of eggs that is covered (buried) by the turtle before departure from the nesting beach.

Fecundity: A loggerhead can nest up to seven times in one season (Lenarz et al. 1981). A mean clutch size of 119 eggs and upper limit (3s) of 194, calculated from 105 clutches laid in 1978 on Little Cumberland Island, is representative. Thus, fecundity of an individual turtle could be as high as 1358 eggs per laying season, but a population average is much less, closer to 4.2 clutches per turtle (T. Murphy, pers comm.) and 120 eggs per clutch, or approximately 500 eggs per turtle per nesting season.

Potential for misinterpretation: Average clutch size and clutches per season are parameters not easily measured, particularly the latter. The greater problem is the inability of sea turtle scientists to accept inadequate sampling as a source of error.

Remigration Intervals: All sea turtles, with the apparent exception of the annual nesting ridley species, usually nest on 2-year or 3-year intervals, varying between species and between populations within species (T. Richardson et al., 1978; Hughes, 1974). A sample of 186 remigration intervals by loggerheads nesting on Little Cumberland and Cumberland are distributed according to the following proportions:

<u>Interval</u>	<u>Proportion</u>
Annual	.04
2 years	.43
3 years	.36
4 years	.13
5 or more years	.04

The population average remigration interval at these rates would be 2.7 years between nesting seasons. Thus, returning to the previous section where average population fecundity was estimated at 500 eggs per adult female turtle during the nesting season, the equivalent average annual production of eggs by an individual female would be 185 eggs.

Potential for misinterpretation: If beach sampling efficiency is low, such that nesting females are missed during an entire season, unusually long intervals

(5 years instead of a 3 and 2-year cycle, 4 years instead of two 2-year cycles, etc.) will be observed. Intense beach coverage on LCI and adjacent islands has reduced this error to a minimum.

Nesting Cycle: The first clutches of the nesting season are deposited usually after 20 May and the last not later than 10 August. A typical interval between clutches is 12 days, but this varies within seasons (long intervals of 15-18 days early in the season when water temperatures are colder), between seasons (intervals are shorter when average summer temperatures are warmer) and according to the nesting behavior of the individual turtle (Bennett and Richardson, 1978). A nesting interval is dependent on the time elapsed from the last successfully deposited clutch of eggs; a turtle that fails to nest on several consecutive nights will delay deposition of the next clutch accordingly. The actual number of clutches is not limited physiologically but by the meteorological constraints of the 3-month nesting season and by the individual behavior of adult females within the nesting season.

Potential for misinterpretation: Loggerhead sea turtles nest on regularly scheduled 12-day intervals and rarely skip intermediate visits, but inadequate beach surveys frequently miss nesting turtles. Investigators who do not accept this fact are prone to include double (24 day) and triple (36 day) intervals in their calculations of mean internest interval.

Incubation, Hatching Success and Predation: Observed incubation (egg laying to hatchling emergence) ranges from 55 to 70 days, depending on ambient sand

temperatures that are, in turn, modulated by regional weather patterns (Kraemer, 1979). Actual incubation (egg laying to egg hatching) may be a week less than observed incubation, because the hatchlings spend several days in the nest before they emerge (Kraemer and Richardson, 1979). Digging to the surface requires a combined effort by the hatchlings; groups of ten or fewer hatchlings do not have the strength to tunnel through the overlying layers of sand. The timing of dispersal from the nest cavity is temperature controlled and usually occurs at 2200-2400 hours. The time required for all hatchlings to exit the nest cavity is usually under 3 minutes, while transit time from nest to water's edge takes 5-15 minutes under normal conditions.

Hatching success on unmanaged beaches ranges from near zero (Hopkins and Murphy, 1981) to .60 (S. Hopkins, pers. comm.), depending on predation pressures (raccoons, feral hogs, man), the occurrence of torrential rains (Kraemer and Bell, 1980) or extreme tides and the physical instability of the dunes. Hatching success under ideal conditions usually ranges from .70 to .85.

Potential for misinterpretation: Natural hatching success varies dramatically between nesting beaches and between seasons within a nesting beach. Loggerheads are iteroparous animals, undoubtedly adapted to the unpredictability of such conditions (Cole, 1954). The net hatching success (production of hatchlings that reach the water) required to sustain a population, averaged over many years, is unknown.

Sex Ratios: Sex ratios of loggerheads may be modulated in the laboratory by

controlling incubation temperatures (Mrosovsky and Yntema, 1980; Yntema and Mrosovsky, 1980); temperatures 32°C and above produce females while temperatures 28°C and below produce males. Naturally incubated clutches from Little Cumberland Island tended to be high in males early and late in the season and high in females toward the middle of the season (Mrosovsky et al. 1984). However, the season average appeared to approach a 1:1 male/female sex ratio.

Potential for misinterpretation: Most population models assume a 1:1 sex ratio, because field data are lacking. Additional determinations of hatchling sex ratios will accumulate slowly, since destructive sampling from threatened species is discouraged, and a nondestructive means for sexing hatchlings has not been devised. The population mean for percent females from naturally incubated nests probably falls close to 0.5 for Cumberland loggerheads, but more data are needed before a conclusive statement can be made on this parameter.

Hatchling Dispersal at Sea: Upon entering the water, loggerhead hatchlings disappear from the Georgia coast for an undetermined length of time. This period represents the "lost year" or years discussed in many publications (Carr, 1980; Hughes, 1982; Witham, 1980). The current paradigm places the hatchlings in a semi-planktonic relationship within the Sargasso Sea during the early years of development, and recent evidence of neonate loggerheads associated with convergences at the edge of the Gulf Stream supports this hypothesis (Carr 1986). The appearance of small "dinner plate" loggerheads in the Azores off the African coast

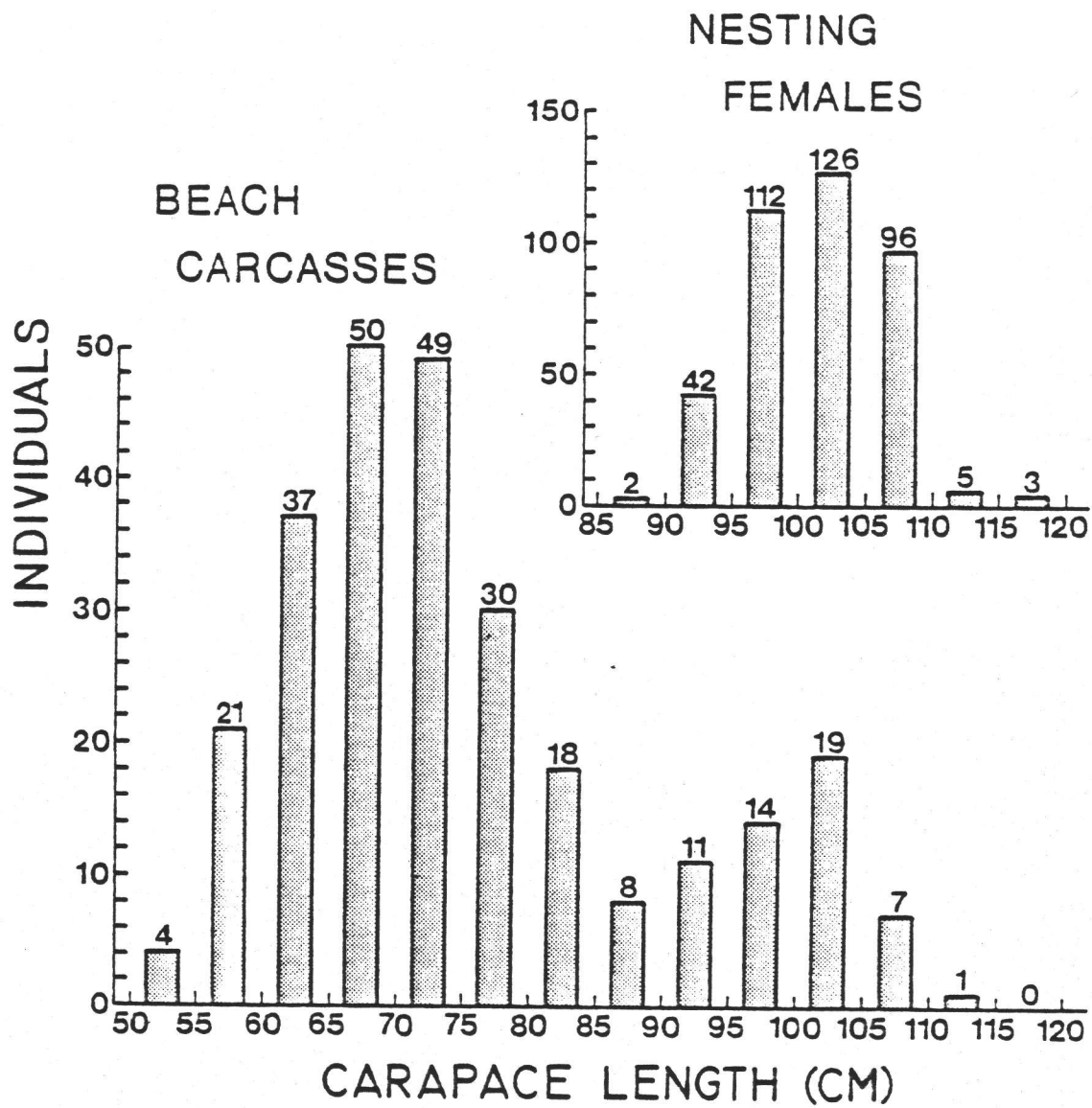
imply a possible circum-North Atlantic Ocean route using oceanic gyres as a transport mechanism. Many years would be required for an individual turtle to return to the Georgia coast by this method.

The duration of the "planktonic stage" is unknown. Juvenile loggerheads first reappear on the Georgia coast with a carapace length of approximately 50 cm. Captive loggerheads reared under ideal conditions reach this size in two (Uchida, 1967) to four or five (Parker, 1929) or more (Hildebrand and Hatsell, 1927) years. Carapace lengths of wild Australian loggerheads have been measured in the field (Limpus, 1979). Growth rates of these animals were very much slower than for captive animals; carapace length increments ranged from one to two cm per year, indicating that wild populations could take as long as 20 years to reach the 50 cm carapace size (Limpus, 1979).

Potential for misinterpretation: Survivorship during the "missing years" is completely unknown. Hatchling production cannot be compared to numbers of juveniles (carapace length > 50 cm) appearing in Georgia waters, because the latter cannot be identified with a particular nesting beach or geographical region, and juvenile numbers cannot be censused with confidence. Age corresponding to a 50 cm carapace length probably falls within the range of 4-10 years and may vary widely from individual to individual (Frazer 1983).

Nearshore Juveniles: Loggerhead carcasses, distributed according to the size classes depicted in Figure 11, wash onto Georgia beaches each summer. These dead

Figure 11. A size distribution (over-the-curve carapace lengths) of 269 loggerhead carcasses washed onto Georgia beaches, 1979, compared to 386 female loggerheads nesting on Cumberland Island, 1973-1979 (Hillestad et al., 1982).



animals probably are killed in shrimp trawler nets (Hillestad et al., 1977; Hillestad et al., 1982) and, in lieu of better data, may be assumed to be an unbiased sample of size classes occurring in nearshore Georgia waters. Loggerheads account for nearly all individuals in the 45-90 cm carapace length classes. These large juveniles probably overlap in size with nesting females in the 90-105 cm classes.

Potential for misinterpretation: There is an estimated annual population of somewhat less than 10,000 loggerheads nesting each year in the southeastern U.S. , based on unpublished data (Hopkins and Richardson 1984). Seventy percent of these animals nest in South Florida; the Georgia population is currently less than 500 adult females annually. The thousands of large juvenile loggerheads appearing in Georgia and South Carolina waters each summer may be predominantly recruits from the Florida nesting populations, since similar high concentrations of subadults are apparently not found near the Florida nesting beaches. Thus, there is no known way to estimate the proportion of nearshore juvenile loggerheads which originate from the Georgia nesting population.

Age to Maturity: There have been insufficient tagging studies of Georgia juvenile loggerheads to get growth estimates on these animals. Similar animals in semi-enclosed lagoons in southern Florida grew approximately 6 cm per year in carapace length (Mendonca, 1981). Wild populations in Australia grew 1-2 cm per year in carapace length (Limpus, 1979). There are sufficient fragments of information to suggest a typical sigmoid growth curve for a loggerhead from hatching to

reproductive maturity (Parker, 1929). Estimates of age to maturity range from 6-7 years for the maximum growth rate of one captive reared turtle (Uchida, 1967) to 13-15 years for turtles in semi-enclosed Florida lagoons and 20-50 years for wild Australian loggerheads (Limpus, 1979).

Potential for misinterpretation: A realistic appraisal of the available data would suggest that a range of 10-30 years should be considered when applying age-to-maturity estimates to population models at this time (Frazer and Ehrhart 1985).

Adult Males: Copulation occurs from nearshore waters to the Gulf Stream. There are no known gathering areas where males may be censused. They appear as a small portion (10 percent) of the Georgia beach carcasses in the 90-120 cm carapace length classes (Figure 11). It is not known if adult male loggerheads enter nearshore Georgia waters in proportions similar to the adult females.

Potential for misinterpretation: Identifying accurately the sex ratio of adult Georgia loggerheads is not possible at this time.

Adult Females: Nesting females appear on Georgia beaches from 20 May to 10 August. They are absent from nearshore waters for the remainder of the year, and it is assumed from tag returns that Georgia female loggerheads restrict their range to the continental shelf from Long Island, NY, to Cape Canaveral, FL. They may utilize hard bottom habitat up to 100 m in depth for feeding and hibernation. Florida nesting

loggerheads, however, appear quite frequently in the Bahamas, Caribbean, and Gulf of Mexico (L. Ehrhart, personal communication).

Adult females represent a .10 to .15 proportion of Georgia beach carcasses (Figure 11). This ratio is highest in May and June and falls to near zero in August, when subadults are still common in Georgia waters (J. Richardson, unpublished data). Therefore, it is assumed that the adult females (and males) represent a distinct population that mixes with the subadults at certain times of the year but does not constitute a fixed proportion of animals observed at all seasons.

Potential for misinterpretation: Subadults are not used to indicate potential recruitment to the Georgia nesting population since they cannot be linked to discrete natal beaches (J. Avise, personal communication). Furthermore, nesting Georgia females represent an unknown proportion of the adult females observed in carcass distributions, and these carcasses, though adult in size, may not represent reproducing females. Most Georgia carcasses are not examined internally for the presence of eggs to estimate the proportion of reproductive adults in the population. Fertile adults could not be linked to specific nesting beaches, if their numbers were known.

Nesting Beach Fidelity: Individual loggerheads, as well as all other species of sea turtles, frequently return for season after season to the same nesting beach, and, frequently, to the same section of a nesting beach; they are capable of precise navigation in this matter. However, a considerable proportion (.50) of the nesting

females is never seen again after the first nesting season. This behavior, universal among sea turtle species, is considered incongruous for a long-lived animal (Carr, 1980; Hughes, 1982). Only 25 of 1107 Cumberland loggerhead nesting histories (2 percent) include an appearance on a nesting beach more distant than 10 km from the Cumberland tagging site, in spite of excellent tagging programs on many of the major nesting beaches in South Carolina, Florida, and Georgia. Thus, the failure of half the Cumberland population to return to nest in subsequent years cannot adequately be explained by the theory of nesting females moving to adjacent beaches. Furthermore, no Cumberland loggerhead has ever been recorded nesting twice on each of two distant (> 10 km) beaches, reinforcing the concept that Georgia loggerheads do not shift their preferred nesting beach within season or between seasons. Loggerhead nesting dispersal from the LCI beach has not been quantified but is expected to be a decreasing exponential function of distance from the island.

Potential for misinterpretation: Inadequate sampling of nesting populations has been frequently used to explain the apparent failure of half or more of nesting turtles to return on following years. The longevity and increased sampling efficiency of the Cumberland population study reduce the uncertainty of this variable in Georgia loggerhead population statistics.

Natal Origin of Nesting Females: The question of natal origins for nesting female loggerheads was investigated but failed to produce conclusive results, due to methodological difficulties (J. Avise, personal communication). A correlation may

exist between intensive predator control (protection of eggs) and numbers of nesting females at Cape Romaine, SC, with an appropriate time lag of 20-25 years between the variables (Hopkins and Murphy, 1981; S. Murphy, personal communication).

There is no other hard evidence touching on this subject, and 24 years of significantly enhanced propagation of hatchlings from Little Cumberland Island have not caused a noticeable increase in recruitment to the Cumberland nesting population. Hatchlings could return with the precision of salmon to their exact natal beach, or they could disperse as adults throughout the southeastern U.S. range and fix on a nesting beach only when they make their first nesting attempt as a neophyte member of the reproducing population.

Potential for misinterpretation: The potential for recruits to focus their nesting effort at or near their natal beach is central to development of a sea turtle population model. Determining the accuracy of a predictive model is almost impossible until the question of nesting female natal origin is resolved. It is the consensus of sea turtle biologists that turtles do return to nest at or near their natal beaches. Morphological variation among nesting groups of adult female loggerheads in the Southeast supports this view (Stoneburner, 1980):

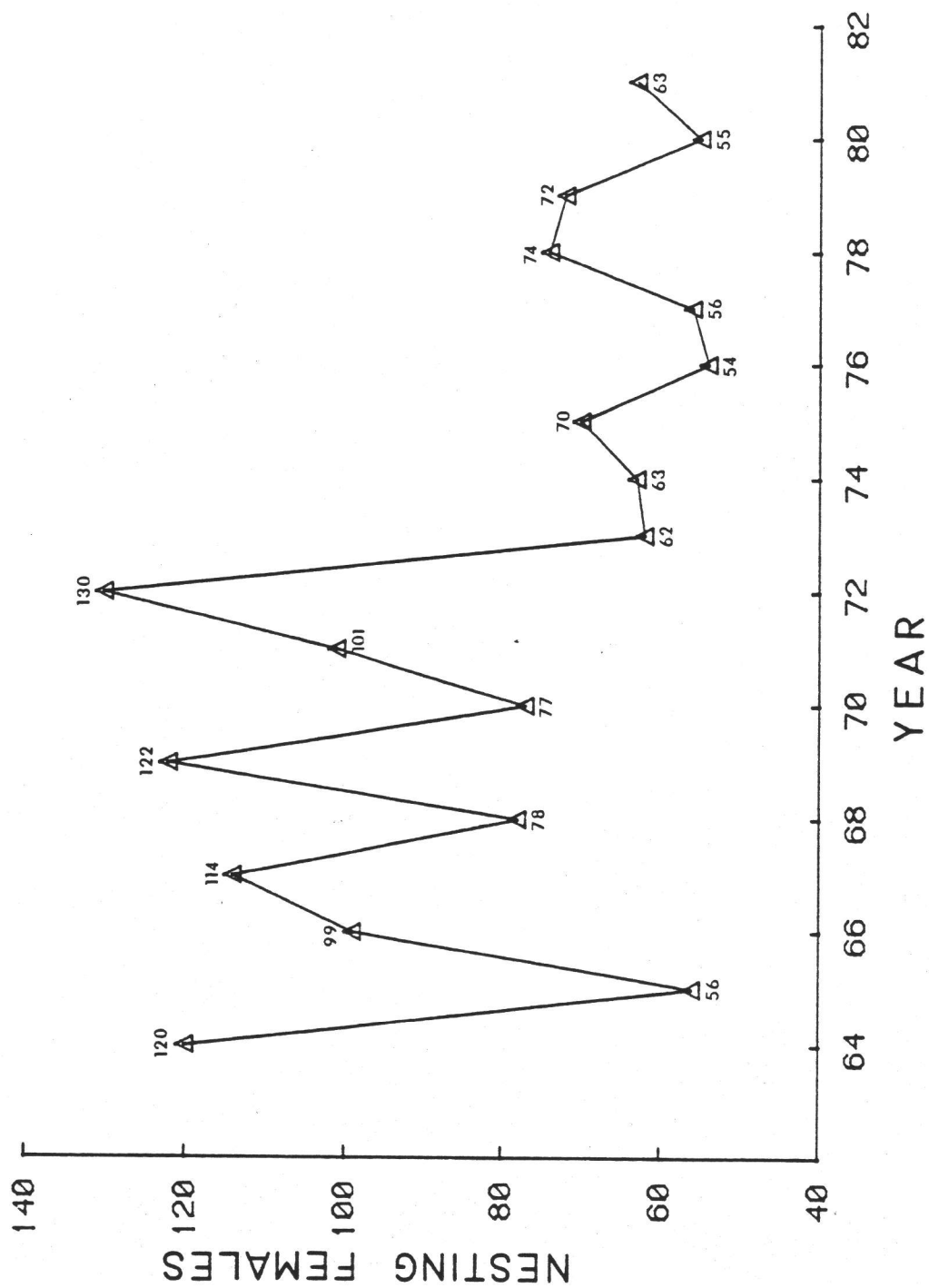
Variation in Annual Numbers of Nesting Females: There is inherent in several sea turtle species a tendency for number of nesting females to cycle from season to season, usually on a 2- or 3-year cycle. From 1964 until 1973, annual counts of Little Cumberland nesting loggerhead females (Figure 12) indicated that a high count year

would be followed, with one exception (1978), by a low count year and a low followed by a moderate or high count year. There is no proven reason for these cycles, but off-season nutritional effects and inherent physiological constraints have been suggested (Hughes, 1974). The possibility of dominant year classes, commonly observed for fish (Lawler, 1965), has been ruled out (Hughes, 1974; Richardson and Richardson, 1982). Since 1973, year-to-year variation has been significantly reduced.

Observed annual fluctuations cannot be simulated without a perturbation factor in addition to inherent physiological characteristics (Richardson and Richardson, 1982). Any imbalance of 2-year and 3-year cycles will soon balance during the simulated run, regardless of initial conditions. There is one observation that would support a density-dependent perturbation factor, relating to the reduction in total turtles that was observed at LCI circa 1973 (Figure 12). The mean and coefficient of variation for the number of annual nesting females on Little Cumberland Island from 1964 to 1973 ($n = 10$ years) are 95.90 and .27, respectively, while the same values for 1973 to 1981 ($n = 9$ years) are 63.22 and .12. Furthermore, the standard errors for these numbers are significantly different ($\alpha = .05$). If the magnitude of annual cycles is directly correlated to population size, the preceding relationship would be expected.

Potential for misinterpretation: Annual numbers of nesting females must be averaged over six or more years to obtain a realistic population mean. Two or three year surveys of nesting females may indicate precipitous increases or declines in population numbers, entirely dependent on survey misinterpretation and not related to actual population growth.

Figure 12. Cumberland Island (GA), 1964-1981. The figure depicts the annual fluctuations in numbers of nesting females (1964-1973) and the overall reduction in total numbers which occurred circa 1973.



Mortality: There is no direct measure of mortality in sea turtles, as is possible for humans and many other animal species. If trawler-killed carcasses that appear on Georgia beaches (Figure 11) represent an unbiased sample of the large juvenile population, then mortality can be inferred from the change in numbers from one age class to the next. Tagged females which disappear from the nesting population are considered to be terminated reproducers (ecological mortality) and not dead, per se. It is assumed from tag recoveries on adjacent and distant nesting beaches that missing Cumberland females are not nesting elsewhere in significant numbers, nor are they being overlooked on Cumberland as turtles that have lost their tags. Tag loss is a measurable factor incorporated in survivorship figures.

Potential for misinterpretation: Disappearance of tagged females from the nesting population is a valid measure of mortality for modeling purposes, as long as the concept is clearly defined. Pelagic surveys of adult female loggerheads cannot differentiate between active reproducing individuals and non-reproducing individuals.

Conclusion to Overview of Existing Life History Data: The loggerhead population data presented here provide a foundation for meaningful population models describing the behavior of loggerhead sea turtles. Population models with predictive capability are useful tools necessary for the recovery and management of the species. Most of the hard data presented in the preceding discussion have been gathered from the sea turtle studies within the Cumberland Island National Seashore (Cumberland and Little Cumberland Islands). As such, models derived from the

Cumberland data (Crouse 1985) utilize the best available information and, therefore, provide the best opportunity to understand and measure at least one aspect of loggerhead life history, the nesting females. Population models built on pelagic life history assumptions provide valuable insight into theoretical aspects of sea turtle life history but are presently limited in their ability to predict accurately population numbers at all life history stages.

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