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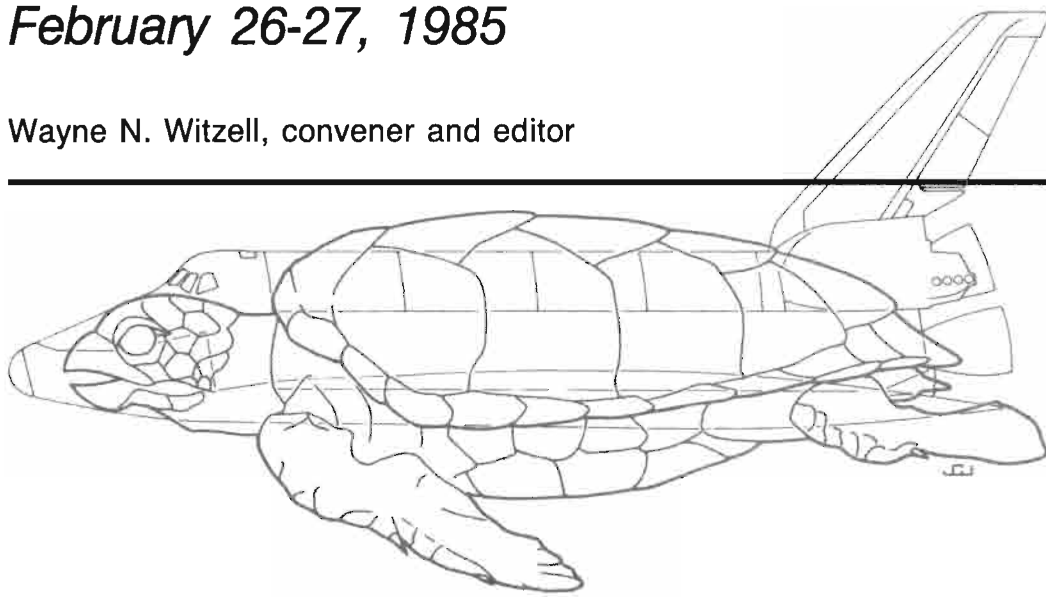
Ecology of East Florida Sea Turtles

Proceedings of the Cape Canaveral, Florida Sea Turtle Workshop Miami, Florida February 26-27, 1985

Wayne N. Witzell, convener and editor



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U.S. DEPARTMENT OF COMMERCE
Malcolm Baldrige, Secretary
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PREFACE

The Cape Canaveral, Florida, marine ecosystem is unique. There are complex current and temperature regimes that form a faunal transition zone between Atlantic tropical and subtropical waters. This zone is rich faunistically and supports large commercial fisheries for fish, scallops, and shrimp. Canaveral is also unique because it has large numbers of sea turtles year-round, this turtle aggregation exhibiting patterned seasonal changes in numbers, size frequency, and sex ratio. Additionally, a significant portion of this turtle aggregation hibernates in the Canaveral ship channel, a phenomenon rare in marine turtle populations.

The Cape Canaveral area has the largest year-round concentration of sea turtles in the United States. However, the ship channel is periodically dredged by the U.S. Army Corps of Engineers in order to keep Port Canaveral open to U.S. Navy vessels, and preliminary surveys showed that many sea turtles were incidentally killed during dredging operations. In order for the Corps of Engineers to fulfill its defense dredging responsibilities, and comply with the Endangered Species Act of 1973, an interagency Sea Turtle Task Force was formed to investigate methods of reducing turtle mortalities. This Task Force promptly implemented a sea turtle research plan to determine seasonal abundance, movement patterns, sex ratios, size frequencies, and other biological parameters necessary to help mitigate dredging conflicts in the channel. The Cape Canaveral Sea Turtle Workshop is a cooperative effort to comprehensively present research results of these important studies.

I gratefully acknowledge the support of everyone involved in this Workshop, particularly the anonymous team of referees who painstakingly reviewed the manuscripts. The cover illustration was drawn by Jack C. Javech.

Wayne N. Witzell, Workshop Convenor and Editor

CONTENTS

Marine Turtle Mortality in the Vicinity of Port Canaveral, Florida, 1977-84

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ABSTRACT

A total of 634 marine turtle carcass strandings were recorded in the three-county area surrounding Port Canaveral, Florida, from November 1977 through December 1984. The great majority (95%) were loggerhead turtles (*Caretta caretta*); however, green turtles (*Chelonia mydas*), Kemp's ridleys (*Lepidochelys kempi*), leatherbacks (*Dermochelys coriacea*), and a single hawksbill (*Eretmochelys imbricata*) were included in the total. A prominent peak in the distribution of strandings occurred in the late fall-early winter period of each year from 1977 through 1980 and coincided with heightened shrimp trawling activity. In 1979, 1980, and 1982 prominent peaks in turtle mortality occurred during the summer nesting season; each year, adult females that had been tagged earlier while nesting were among the carcasses. Many loggerheads exhibiting a so-called "diseased turtle syndrome" stranded in the spring of 1980, 1981, and 1982. The syndrome includes a profusion of small barnacles on the integument of the neck, head, shoulders, and front flippers, a massively depressed and concave plastron, eyes sunken in their sockets, and rotting, peeling skin. In 1980, 1981, and 1984, substantial numbers of loggerheads were killed by dredges being used to maintain specified depths in the Port Canaveral ship channel. In the last three years of the study there was a marked reduction in overall numbers of strandings, but the numbers of strandings in the Indian River Lagoon system increased. Most of the dead turtles in the lagoon had been struck by boat propellers or hand-held instruments. The great majority of loggerheads in the sample had straight carapace lengths (CLSL) of 60-80 cm. Only in June and July were adult turtles well represented. There were no loggerheads smaller than 45.8 cm CLSL. Green turtles resident in the area are much smaller than loggerheads, with virtually none larger than 60 cm CLSL.

INTRODUCTION

Since November 1977, I have kept records of marine turtle carcass strandings on the coast of Volusia, Brevard, and northern Indian River Counties, Florida. Port Canaveral, with its large aggregation of loggerhead turtles, is located approximately in the center of this area. Also, there are beaches in the northern part of this region that support moderately high nesting densities (Provancha and Ehrhart 1987) and a stretch of beach just 45 km to the south of Port Canaveral, near Melbourne Beach, that supports more nesting than any other in the United States (Bjorndal et al. 1983; Groombridge 1982; Ehrhart and Raymond 1983; Murphy and Hopkins 1983). It is clear that activities at Port Canaveral are directly or indirectly involved in many of the turtle carcass strandings, although pathological indications of cause of death are generally impossible to specify.

Stranding records compiled here include not only those from the port itself and nearby ocean beaches, but also many from the Indian River Lagoon system and Intracoastal Waterway, just west of the barrier strand. For most purposes records in these two categories are considered separately, and henceforth the former will be designated "ocean/port," the latter "lagoon."

Five species of sea turtles, *Caretta caretta*, *Chelonia mydas*, *Lepidochelys kempi*, *Dermochelys coriacea*, and *Eretmochelys imbricata*, are included in the total of 634 stranding records cataloged here, although 95% are *Caretta caretta* (Table 1). What follows, then, is an account of the chronological and morphological distribution of sea turtle carcasses stranded in the vicinity of Port Canaveral from November 1977 to the end of December 1984.

METHODS

Most sea turtle carcass strandings are reported to me by the Florida Marine Patrol office at Titusville. I attempt to substantiate each report, when possible, by examining the carcass and removing the entire animal or its skull to our laboratory. Most of the carcasses are in advanced stages of decomposition and not suitable for necropsy. I attempt to collect the carcasses or to remove the skull and bury the body for the following three reasons: in order to (1) examine them for cause of death; (2) have voucher specimens on hand for as many of our records as possible; and (3) avoid counting the same carcass twice (they can wash in and out and move laterally along the beach and be reported by more than one person).

Not all strandings can be investigated, however, and reports are received from a variety of sources. The records, therefore, are of various levels of verification. As a result, we classify each one according to the following scheme:

(1) specimen (skull and/or carcass) or photographs in our possession (usually have measurements and computed weight);
(2) carcass reported by reliable source, known to have been disposed of by burying or removal from beach;
(3) carcass reported by reliable source, confirmed by follow-up phone call, disposition uncertain;
(4) carcass reported by reliable source but not secondarily confirmed, disposition uncertain.

Skulls obtained are left outside for partial cleaning by carrion-feeding insects and then brought in for detailed cleaning and labeling. They are stored and curated in the vertebrate collection of the University of Central Florida. A number of the freshest specimens are frozen and kept in that condition for future research use.

Carcasses are often badly decayed or in pieces. Where possible, however, I have computed estimates of loggerhead live weights and most of the values for weight in Appendix Tables 1-10 were derived as follows. For subadult loggerheads, i.e., those <75 cm CLSL, these values are computed from a regression equation developed from weights and measurement of normal, healthy turtles captured in Mosquito Lagoon, Brevard County, between 1976 and 1979. Weights of adult loggerheads (>90 cm CLSL) were computed by using an equation based on weights and measurements from over 900 adult females nesting on the beaches of the Kennedy Space Center between 1976 and 1979. There is no reliable way to judge externally the maturity of loggerheads between 75 and 90 cm CLSL, and I regard them simply as intermediates. The equation for adult loggerheads was used to estimate their weights. The regression equations for both CLSL and overcurvature carapace length (CLOC), are as follows.

Adult loggerheads:

$$(\text{Wt., kg}) = 196.7 + 3.36\ (\text{CLSL, cm})$$
$$(\text{Wt., kg}) = 223.2 + 3.41\ (\text{CLOC, cm}) \qquad (1)$$

Subadult loggerheads:

$$(\text{Wt., kg}) = 79.9 + 1.8\ (\text{CLSL, cm})$$
$$(\text{Wt., kg}) = 83.7 + 1.8\ (\text{CLOC, cm}). \qquad (2)$$

Table 1—Species distribution of marine turtle carcass stranding records in Brevard, Indian River, and Volusia Counties, Florida, 10 November 1977 to December 1984.

Species	Number	%
Caretta caretta	602	95.0
Chelonia mydas	23	3.6
Dermochelys coriacea	4	0.6
Eretmochelys imbricata	1	0.2
Lepidochelys kempi	4	0.6
Total	634	

Table 2—Distribution by "report class" of marine turtle carcass stranding records in Brevard, Volusia, and Indian River Counties, Florida, November 1977 through December 1984. Report class numbers increase as record verification levels decrease.

Report class	*Caretta*	*Chelonia*	*Dermochelys*	*Lepidochelys*	*Eretmochelys*
1	442	22	2	4	1
2	92	1	2	—	—
3	40	—	—	—	—
4	28	—	—	—	—
Total	602	23	4	4	1

RESULTS AND DISCUSSION

General

The records of all carcass strandings in the seven-year period are compiled in Appendix Tables 1-10. Of the 634 records, only 26 (4.4%) are of the class 4 type (Table 2). That is to say that I am reasonably certain of the species identification of over 95% of them. Over 74% (471) records) are class 1 records, implying virtual certainty of identification and accompanied in many cases by skulls, photographs, or other tangible evidence. The distribution of carcass stranding records by species is given in Table 1. Totals given here for *Caretta caretta* include the 28 class-4 records that were assumed to be loggerheads, usually for good reason. That small possible error notwithstanding, Table 1 shows that the great majority (95%) of the carcasses stranded in the Port Canaveral area were loggerheads. Only 3.6% were green turtles, *Chelonia mydas*, and many of those were "lagoon" strandings. The small numbers and percent occurrences of stranded *Dermochelys coriacea*, *Lepidochelys kempi*, and *Eretmochelys imbricata* are also given in Table 1.

Chronology

The chronological distribution of ocean/port loggerhead carcass strandings for the entire seven-year period is shown in Figure 1. Lagoon strandings are summarized by month in Table 3. Over the four-year period prior to 1977, during which I was conducting sea turtle research in Brevard County, I knew of fewer than five stranded carcasses in the area. Of the 34 loggerheads that stranded in November and December 1977, most were from Patrick Air Force Base and Satellite Beach (ca. 15-25 km south of Port Canaveral), but the first five were from Cape Canaveral Air Force Station, immediately to the north of the Port (Appendix Table 1).

The frequency of carcass strandings subsided markedly in early 1978 and continued to be quite low through August (Fig. 1). That period was followed, however, by a mass mortality episode in September, October, and November. Eighty-five loggerhead carcasses (72.3% of the total for the year) stranded during that period, with most of the records concentrated in the month of October. Most were from the ocean beaches immediately to the south of Port Canaveral, within the city limits of Cape Canaveral and Cocoa Beach (Appendix Table 2).

There is a qualitative but definite relationship between the incidence of turtle carcass strandings and activity of the shrimp fishing fleet out of Port Canaveral. Ulrich (1978) in South Carolina and Hillestad et al. (1977) in Georgia have shown that similar mass carcass strandings were due primarily to drownings in shrimp trawls. They had observers onboard some of the trawlers. That was not done at Port Canaveral, to my knowledge, but the implication is clear enough. In 1978 and at various other times during the period of this study, stranding record peaks coincided with increased shrimp fishing activity.

Only three strandings were from the Indian River Lagoon system (Appendix Table 9), all three had been struck by boat propellers. One of them, a March juvenile, was the first green turtle to appear in our records. Another green turtle, a female and the only fully adult *Chelonia* seen in seven years, stranded in northern Indian River County in June. She was probably in the area to nest.

Carcass stranding frequency subsided again in the first five months of 1979 (Fig. 1), but from 20 June to 23 July of that year a new and significant aspect surfaced (Appendix Table 3). Many of the carcasses stranded on the beaches of the Kennedy Space Center and Cape Canaveral Air Force Station (KSC-CCAFS), immediately to the north of Port Canaveral, and it was the first time in at least seven years that markedly increased mortality coincided with the nesting season on those beaches. I had been surveying sea turtle nesting and tagging turtles on these beaches since 1973. Never before had loggerhead carcasses been so commonplace on KSC-CCAFS beaches in the summer. Never before had adult females that had been tagged during nesting emergences in current or previous years been among the dead turtles observed. In 1979 six such turtles were observed.

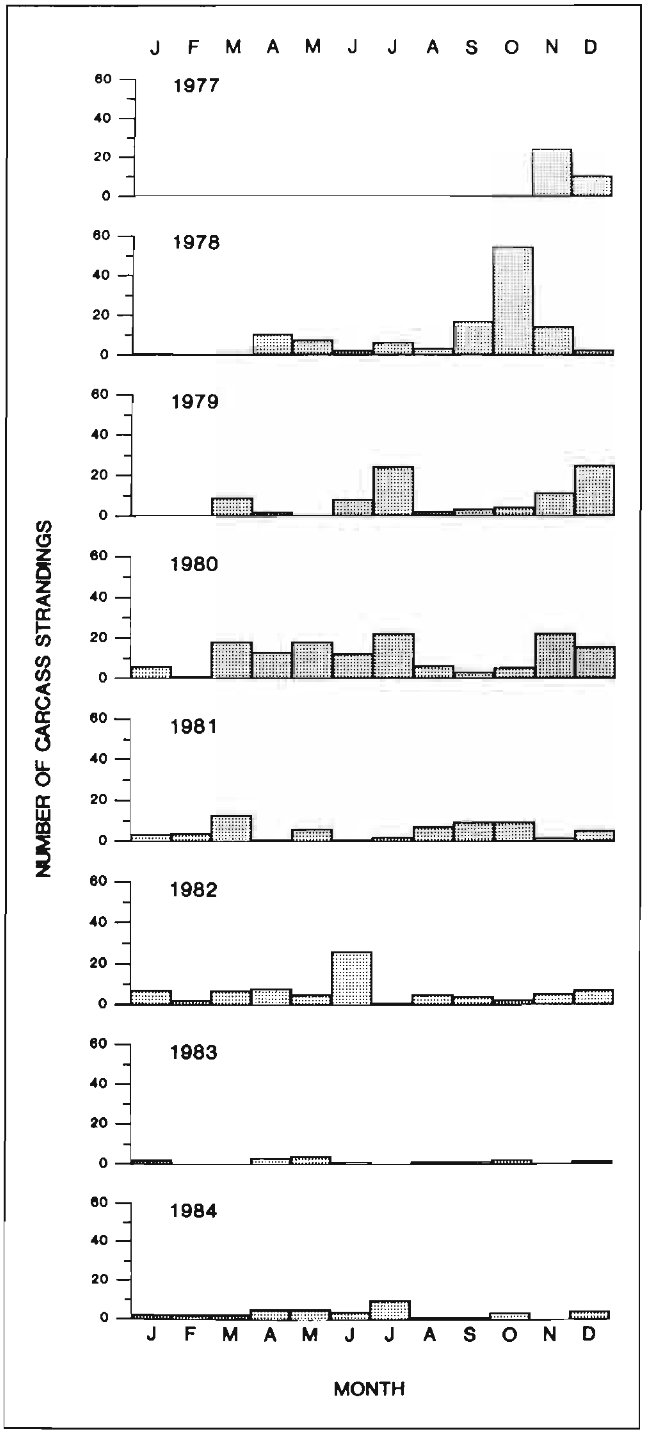

Figure 1—Chronological distribution of loggerhead turtle carcass strandings in Volusia, Brevard, and northern Indian River Counties, Florida, November 1977 through December 1984.

Three of the six had been tagged at KSC-CCAFS. The first one, H2640, was tagged on 18 June 1979, re-emerged to nest on 4 July, and was found dead ("very fresh") on 18 July. The second one, P1105, was tagged on 25 May 1979, nested again on 28 June and 13 July, and was found dead ("broken up and decomposed") on 23 July. The third turtle, A3044, was tagged at KSC-CCAFS on 19 July 1976. It emerged there again on 27 June and 11 July 1979, and was found "well decayed" on 23 July 1979.

Table 3—Monthly distribution of lagoon loggerhead turtle carcass stranding records from Brevard, Volusia, and Indian River Counties, Florida, 10 November 1977 to 31 December 1984.

Month	Number	%
January	2	5.3
February	—	—
March	4	10.5
April	6	15.8
May	7	18.4
June	6	15.8
July	3	7.9
August	3	7.9
September	2	5.3
October	—	—
November	2	5.3
December	3	7.9

Three of the loggerheads had been tagged nearby by other workers. The first, FL0468, was tagged on or about 8 July 1979 by National Parks Service personnel at Canaveral National Seashore in Volusia County. Its carcass washed up at Jetty Park, Cape Canaveral, on 14 July. Another one, B3410, was tagged in south Brevard County in 1977 and was found dead at Cocoa Beach, 25 July 1979.

The last tagged carcass is an interesting case. It was tagged (H1343) after nesting in north Brevard County in 1976. It was captured on 20 July 1979 by National Marine Fisheries Service (NMFS) biologists aboard the trawler *Lady Weesa* in the Port Canaveral navigation channel. They described it as "sick, emaciated, and feeble," but alive when released on 20 July. Just three days later its carcass was discovered on the beach at CCAFS. It was "well rotted," with the bones of the carapace becoming disarticulated. Needless to say, this gave us some new insights into the matter of carcass decomposition. I would have assumed that such a turtle had been dead for a week or two, when actually it had been alive three days before.

Two other carcasses, one from March and one from December, that had been trawled and tagged by NMFS were also included in this year's total. Also for the first time, three carcasses came from within the confines of Port Canaveral itself.

Slightly more than 36% of carcass strandings for the entire year occurred in June and July; and of the 30 for which sex and age class could be determined, 13 were adult females. It seems clear that many, if not all, of these were recent migrants to the area for the purpose of nesting.

Carcass strandings were relatively infrequent in August through October, 1979, but the number rose again in November and December (40.9% of the total for the year). The trend carried over into January of 1980 (Fig. 1). This peak was analogous to the major one in the fall of 1978, but shifted to a slightly later period in the year and involved fewer stranding records (42, including those from January 1980). Only about two-thirds of the records from this late fall-early winter peak were from the vicinity of Port Canaveral. Most of the others were from Volusia County, in the vicinity of Ponce Inlet. The shrimp fleet was quite active out of both ports at this time.

Two small green turtles were included in the reports for 1979 (Appendix Table 9). Neither stranding seemed related to activities at Port Canaveral.

Carcass stranding frequency was characteristically low in February 1980 (Fig. 1), but from that point on, 1980 was a very unusual year. Two mortality factors previously undetected in the Port Canaveral area became prominent features in our records during that period.

The first was a phenomenon that prevailed primarily from 15 March until about 10 June. It involved turtles that exhibited the following syndrome:

(1) an abundance of small barnacles on the integument of the neck, head, shoulders, and front flippers, where barnacles are nearly absent in other loggerheads;

(2) a massively depressed and concave plastron;

(3) eyes that appear sunken in their sockets;

(4) skin that was rotting and peeling, even in specimens that were still alive; and

(5) a tendency for carcasses to be much fresher than those we have dealt with at other times, or even alive.

Whether these turtles were infected by some pathogen or affected by some pollutant, they appeared to have languished without feeding at sea for some time. They undoubtedly washed up when they became too weak to counteract the wind and tide. D. O. Beusse and I performed a necropsy on one of these animals at Sea World of Orlando. The animal had been found crashing helplessly against a sea wall in Port Canaveral and was alive the day before the necropsy. The muscle and viscera appeared grossly anemic, the alimentary tract was empty throughout its length, and the indication was that the turtle died of some chronic wasting disease. Pathologic examination revealed enteritis, granulomatous pneumonia, and trematodiasis, the former being the probable cause of death. Approximately one-third of the 64 loggerhead carcasses examined from March through June exhibited this "diseased turtle syndrome."

Carr et al. (1980) reported that loggerheads (apparently from the same population as these) trawled from the Port Canaveral Ship Channel in 1977 were listless and generally in poor condition. In what they referred to as "desperate condition" was a group of 150-200 seen floating about 60 km offshore. They appeared sick and made no attempt to escape when a boat approached. Some were blind, some had lost flippers, and there were areas of bare bone on their heads and shells. The authors concluded that, "There was little doubt that the plight of these turtles was terminal." It is reasonable to assume that the sickly turtles seen by Carr et al. were suffering from the same "diseased turtle syndrome" as those in our records. At least eight more of these diseased animals were seen between February and June 1981, and there were nine others in 1982. After that the malady seemed to disappear, with just two "diseased turtles" appearing in 1983 and none in 1984.

A second previously unseen factor was the cause of considerable sea turtle mortality at Port Canaveral in July and August. On or about 12 July an extensive dredging operation, necessary for the maintenance of the navigation channel, began at Port Canaveral. On 20 July I documented the strandings of 12 carcasses on a 6 km stretch of the Cape Canaveral AFS beach (Appendix Table 4), immediately adjacent to the part of the channel where one of the largest dredges of its kind in the world was operating. Here too, as in the case of "diseased turtles," there was a distinct difference in the appearance of carcasses observed. They showed clear signs of having been crushed and broken, or even cut completely in two. Several specimens were represented only by bits and pieces. The breaks in the shells of these turtles were not along the sutures, as is the case in carcasses breaking up simply as the result of decay.

The dredging operation continued well past 31 August and most of the mortality observed in July and August was due to that. Nevertheless, no single episode with an abundance similar to 20 July recurred. These results suggest that the distribution of loggerheads is concentrated in certain parts of the Port Canaveral Channel and, consequently, that there is great potential for harm when the dredge operates in those areas. I suspect that the relative spatial distribution of turtles in the channel will be brought out by Henwood and, perhaps, others at this symposium.

The late fall-early winter peak in carcass strandings occurred again in 1980. It was similar to that of 1979 in terms of numbers of carcasses (42 in the October to December period) but slightly different from both 1978 and 1979 in that the greatest frequency occurred in November (Fig. 1). About 30% of the total complement of carcass strandings for the year were reported in this period, which coincided with the shrimping season.

Among the totals for 1980 were five loggerheads that had been tagged by NMFS at Port Canaveral. Four of them were from April and May; only one was involved in the dredge-related stranding episode of late July. Records for 1980 also include two green turtle and one leatherback strandings (Appendix Tables 9, 10). One of the green turtles (from 16 March) was alive, though very weak. Its right anterior flipper had been severed at the shoulder. It learned to swim well, however, and after several months of recuperation at Sea World in Orlando, it was released in Mosquito Lagoon.

The leatherback that stranded at New Smyrna Beach on 7 January 1980 was the first of that species to appear in our records. It was apparently a subadult turtle (120.4 cm straight carapace length) and had several deep propeller wounds in the lower carapace and bridge on the left. A second one stranded at Daytona Beach in November.

Only two of the 1980 loggerhead carcasses were not from the ocean beach or port. Both were from the Intracoastal Waterway in Mosquito Lagoon. When the one from 27 March was necropsied, a bullet fell out of the carcass. Further examination revealed that it had been shot on the side of the head. The other turtle, from 22 April, had propeller wounds in the carapace which, without doubt, caused its demise.

There were fewer carcass strandings in 1981 than in any previous year studied (Fig. 1). There were only 61 ocean/port loggerhead records for the entire year (Appendix Table 5). The slight bulge on the graph in March (Fig. 1) was primarily the result of "diseased turtle" strandings mentioned earlier. The records indicate that the modest increase in the August-October period had dual origins. A few, including a previously-tagged nesting adult female, were killed by another dredge in the Port. The later records coincided with an apparent increase in trawling activity. Thirteen of the 25 ocean/port loggerhead carcasses seen in the period were from Volusia County.

The first *Lepidochelys kempi* in our records stranded at Daytona Beach Shores, Volusia County, on 3 March 1981. Another significant event was the stranding of a 13.2 cm CLSL green turtle with its pharynx and esophagus plugged by petroleum tar. Witham (1978) has provided records of a number of such victims from south Florida. The records from 1981 include only one carcass found within the actual confines of Port Canaveral and none that had been tagged by NMFS at the Port.

As expected, stranding frequency was relatively low during the first five months of 1982 (Fig. 1). About half of the carcasses examined during that period exhibited the "diseased turtle syndrome."

The most significant peak in the distribution for the entire year came in June. Most of the strandings, which made up 33% of the total for the year, were from late in the month and virtually all were from the immediate vicinity of Port Canaveral (Appendix Table 6). About 45% of these June turtles were adult females. At one point in time (29 June) no fewer than 17 carcasses lay on the beaches just north and just south of the Port. There were many trawlers working offshore each time we went there to examine carcasses, and residents of the area reported substantial activity of the shrimp fleet in the preceding weeks.

Eleven of the 1982 loggerhead carcasses were lagoon strandings. This was a much larger proportion (17.5%) than in previous years. Six of these appeared to have been struck by boat hulls or propellers. The remainder appeared to have been injured by clubs, axes, and other "hand-held" instruments and most were from the Sebastian Inlet region. In the Indian River turtles are sometimes captured by hook and line sport fishermen, by crab fishermen, and by commercial fin fishermen.

There was a vestige of the late fall-early winter peak, which spilled over into January 1983 (Fig. 1). It involved only 14 ocean/port loggerheads, continuing the trend for reduction in carcass numbers at this time of year that began in 1981.

The records for 1982 included five green turtles, one of which came from inside Port Canaveral. Another Kemp's ridley stranded on 3 January, and a third leatherback was recorded on 20 November. Both were stranded on ocean beaches in Volusia County (Appendix Table 10).

In 1983 carcass stranding totals fell to the lowest levels seen in the period of study (Fig. 1). Only 21 loggerheads were reported, and six (30%) of those were lagoon strandings (Appendix Table 7). This followed a trend for increased mortality in the Indian River and Intracoastal Waterway that was begun in 1982. The totals for the year included two green turtles, an especially fresh leatherback from Melbourne Beach, and two more Kemp's ridleys, both from Volusia County early in the year (Appendix Table 10).

On 14 July 1983, a 19 cm hawksbill turtle, *Eretmochelys imbricata*, became the first and only ocean/port stranding of that species in our records. It was alive but greatly weakened by entanglement in discarded synthetic line. After rehabilitation for two months at Sea World of Orlando, it was tagged and released at Sebastian Inlet (see Redfoot et al. 1985 for details). I have previously reported the stranding of a small hawksbill on the shore of Mosquito Lagoon in 1974 (Ehrhart 1983).

It is worthy of note that only one "diseased turtle" was seen in 1983 and that only one adult turtle (a male) was recorded during the summer nesting season.

The overall number of carcass strandings rose only slightly, to 53 in 1984. A relatively large proportion of them (20%) were lagoon strandings, including six loggerheads and five green turtles (Appendix Tables 8, 9). This was the culmination of a trend that took shape in the later years of this study. Most of the lagoon carcasses had been struck by boat propellers or bludgeoned by clubs, axes, etc.

The overall proportion of green turtles (15%) was also somewhat higher, but there were no leatherbacks, ridleys, or hawksbills in 1984. There was no trace of a late fall-early winter peak (Fig. 1) and no carcasses exhibiting the "diseased turtle syndrome." There was a dredge operating at the Port in the spring and that produced a small group of dredge kills in mid-April. The records for the summer months included, once again, at least four adult females. There were three carcasses from within Port Canaveral proper and three others that had been tagged earlier by NMFS.

Population structure

It appears that the factors causing marine turtle mortality in east-central Florida affect all sectors of the population that are present in the area. Consequently, the sample of specimens examined in this study should constitute an adequate cross-section of the structure of coastal loggerhead populations and provide some insight to the structure of green turtle populations as well.

Annual summary statistics for loggerhead carapace lengths (straight-line and overcurvature) and weight are presented in Appendix Tables 1-8. Annual means of straight carapace length varied from 68.4 cm to 75.2 cm and mean weights from 45.0 kg to 63.7 km. The monthly frequency distributions of straight carapace lengths of ocean/port loggerheads measured in this study are shown in Figure 2, and the age-class distribution for all loggerhead records is given in Table 4. Figure 2 shows clearly that the population of loggerheads resident on the Florida coast consists primarily of turtles between 60 and 80 cm straight carapace length. Table 5 gives morphometric distributions for all lagoon stranding records and shows that here, too, over 70% of the specimens were in the 60-80 cm range. In every month of the year except June and July, the great majority of loggerhead carcasses fall within that range (Fig. 2). Even in June and July, approximately 40% of the animals are in that size range. The proportions of loggerheads in the 50-60 cm range are generally not large (Fig. 2), especially for those months, such as October, where *N* is large. Even more scarce, of course, were carcasses with carapace lengths under 50 cm (Fig. 2). The smallest loggerhead seen over the seven-year period had a shell length of 45.8 cm CLSL and a body mass of 16.0 kg.

It has become essentially axiomatic that loggerheads under 45 cm shell length do not occur along the Atlantic Coast of North America. It seems incredible that we have so little information concerning the whereabouts of Atlantic loggerheads in the 15-45 cm range. After conversations with Archie Carr and Leo Brongersma, I suggested (Ehrhart 1984) at the Western Atlantic Turtle Symposium that part or all of the answer might lie with that size class of loggerheads known to inhabit the waters off Madiera and the Azores, in the eastern Atlantic. Archie Carr has also informed me that numbers of small loggerheads are now being tagged there; to my knowledge, however, there has not been a North American recovery of a loggerhead tagged in the eastern Atlantic.

It is also difficult to decide whether or not these 45-50 cm loggerheads arrive off the Southeast coast seasonally. The five specimens in that range seen in this study were widely distributed throughout the year (one each in July, October, and January, and two in March). There would undoubtedly be some variation in the size of these subadult migrants, and the relatively larger proportions of 50-60 cm loggerheads seen here in August and September (Fig. 2) may suggest a late summer arrival.

Loggerheads in the 80-90 cm carapace length class are also not well represented in this seven-year sample (Fig. 2). It is in this range, I believe, that reproductive maturity of the animals is impossible to determine on the basis of size alone. The relative paucity of loggerheads in size classes above 90 cm, except in June and July (see below), is understandable since Meylan et al. (1983), Ehrhart (1982), and others have established, through remote tag recoveries, that adults in this population emigrate to remote foraging grounds after the nesting season. It is possible that the small number of loggerheads in the 80-90 cm range seen here, by Carr et al. (1980) at Port Canaveral, and in nearby lagoonal populations (Mendonca and Ehrhart 1982) results from the fact that individuals of about 80 cm abandon the coastal population and join the adults on the

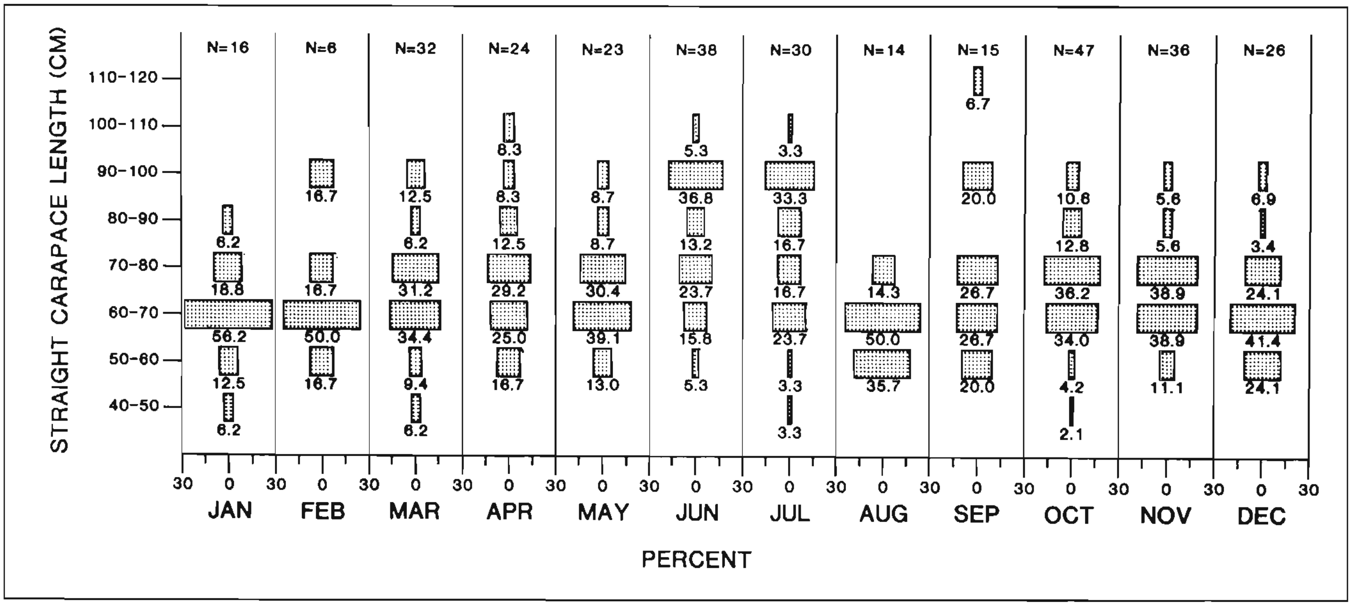

Figure 2—Size-class distribution (straight carapace length) by month for stranded ocean/port loggerhead carcasses, November 1977 through December 1984.

Table 4—Age-class distribution of loggerhead, green, and Kemp's ridley turtle carcass strandings in Brevard, Indian River, and Volusia Counties, Florida, 10 November 1977 to 31 December 1984.

Age class	Number	%
Caretta caretta		
Immature	254	65.6
Immature-Young adult	58	15.0
Adult	75	19.4
Total	387	
Chelonia mydas		
Immature	21	91.3
Immature-Young adult	1	4.3
Adult	1	4.3
Total	23	
Lepidochelys kempi		
Immature	4	100.0
Immature-Young adult	—	—
Adult	—	—
Total	4	

Table 5—Size and weight class distributions for all lagoon loggerhead turtle carcass stranding records in Brevard, Volusia, and Indian River Counties, Florida, 10 November 1977 to 31 December 1984. CLSL = straight carapace length; CLOC = overcurvature carapace length.

CLSL (cm)	*N*	%	CLOC (cm)	*N*	%	Wt. (kg)	*N*	%
50-60	8	25.8	50-60	2	7.1	10-20	3	9.7
60-70	12	38.7	60-70	11	39.3	20-30	7	22.6
70-80	10	32.2	70-80	10	35.7	30-40	7	22.6
80-90			80-90	4	14.3	40-50	8	25.8
90-100	1	3.2	90-100	1	3.6	50-60	5	16.1
						60-70		
						70-80		
						80-90		
						90-100		
						100-110		
						110-120	1	3.2
Total	31			28			31	

resident foraging ranges in the Bahamas, Greater Antilles, Florida Keys, and Gulf of Mexico. It may be there that they put on the last 10 cm or so of growth before maturing and then, in a year or so, join the older remigrants for the trek to the nesting beaches. L. Ogren (Panama City Lab., Natl. Mar. Fish. Serv., NOAA, Panama City, FL 32407, pers. commun. 1984) has recently reiterated the fact that the morphometrics of these coastal loggerhead populations are always seen to be subequally bimodal. The subequal peaks in that distribution are easily explained by considering the resident subadults and the adult migrants and remigrants. The hypothesis I have offered is one that may explain the depression between those two peaks, in approximately the 80-90 cm range.

The predominance of adults in our records for June and July is clear evidence that the habitat attributes of Port Canaveral that are apparently so attractive to subadults throughout the year are equally attractive to the adults who arrive in the area each spring to mate and nest on the beaches to the north and south. It appears that many of them spend time at Port Canaveral before and after nesting and during the interim between nesting and emergences. That fact should be a prominent component in the planning and management of activities at the Port.

The resident green turtle population of the Florida coast in the vicinity of Port Canaveral appears to be the demographic antithesis of the loggerhead population. Whereas loggerheads smaller than 45 cm are unknown here, green turtles larger than about 60 cm, which is not nearly adult size, are equally nonexistent. All of our green turtle records are compiled in Appendix Table 9, together with summary statistics for the various morphometrics. The size- and weight-class distributions of ocean/port and lagoon green turtle carcasses are given in Tables 6 and 7 and the age-class distribution in Table 4. Those distributions are in basic alignment with those given by Mendonca and Ehrhart (1982) for the green turtle population of the northern part of the Indian River Lagoon system.

Table 6—Size and weight class distributions for all ocean/port green turtle carcass stranding records in Brevard, Volusia, and Indian River Counties, Florida, 10 November 1977 to 31 December 1984. CLSL = straight carapace length; CLOC = overcurvature carapace length.

CLSL (cm)	*N*	CLOC (cm)	*N*	Wt. (kg)	*N*
10-20	1	10-20	1		
20-30	3	20-30	2		
30-40	5	30-40	6		
40-50		40-50		0-10	5
50-60	1	50-60		10-20	
60-70	1	60-70	2	20-30	2
70-80		70-80		30-40	
80-90	1	80-90	1	40-50	
90-100		90-100		50-60	
100-110	1	100-110	1	60-70	
				70-80	
				80-90	
				90-100	
				100-110	
				110-120	
				120-130	
				130-140	
				140-150	1
Total	13		13		8

Table 7—Size and weight class distributions for all lagoon green turtle carcass stranding records in Brevard, Volusia, and Indian River Counties, Florida, 10 November 1977 to 31 December 1984. CLSL = straight carapace length; CLOC = overcurvature carapace length.

CLSL (cm)	*N*	CLOC (cm)	*N*	Wt. (kg)	*N*
20-30	1				
30-40	2	30-40	2		
40-50	3	40-50	2	0-10	2
50-60	2	50-60	1	10-20	2
60-70	1	60-70	2	20-30	
		70-80	1	30-40	1
Total	9		8		5

The records for leatherbacks, Kemp's ridleys, and a single hawksbill are compiled in Appendix Table 10. The data are too scant for calculation of summary statistics, but there are at least two interesting features. Three of the four leatherbacks and all four of the Kemp's ridley carcasses are from Volusia County. Assuming, for the sake of argument, that most of these strandings resulted from accidental drowning, it is safe to say that they are related to the fisheries and other activities at Ponce Inlet. Just why these two rare species should be affected in the waters off Ponce Inlet, but not at Port Canaveral, remains an open question.

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Appendix Tables

Appendix Table 1—Summary of loggerhead turtle mortality records, Indian River, Brevard, and Volusia Counties, Florida, 10 November to 31 December 1977. CLSL = straight carapace length; CLOC = overcurvature carapace length. See text for explanation of class.

No.	Class	Date reported	Location	CLSL (cm)	CLOC (cm)	Computed weight (kg)	Age
1	1	10 November	Brevard Co., Cape Can. AFS	59.5	—	27.2	Juvenile
2	1	10 November	Brevard Co., Cape Can. AFS	68.7	73.2	43.7	Juvenile
3	3	10 November	Brevard Co., Cape Can. AFS	—	—	—	—
4	3	10 November	Brevard Co., Cape Can. AFS	—	—	—	—
5	3	10 November	Brevard Co., Cape Can. AFS	—	—	—	—
6	4	11 November	Volusia Co., New Smyrna Beach	—	—	—	—
7	4	11 November	Volusia Co., New Smyrna Beach	—	—	—	—
8	2	13 November	Brevard Co., Satellite Beach	—	—	—	—
9	2	14 November	Brevard Co., Satellite Beach	—	—	—	—
10	2	15 November	Brevard Co., Patrick AFB	—	—	—	—
11	2	15 November	Brevard Co., Patrick AFB	—	—	—	—
12	3	15 November	Brevard Co., Patrick AFB	—	—	—	—
13	1	19 November	Brevard Co., Playalinda Beach	67.0	71.5	40.7	Juvenile
14	1	19 November	Brevard Co., Indialantic	91.9	98.0	112.1	Adult
15	4	19 November	Brevard Co., Satellite Beach	—	—	—	—
16	4	19 November	Brevard Co., Melbourne Beach	—	—	—	—
17	1	21 November	Brevard Co., Satellite Beach	63.0	68.5	33.5	Juvenile
18	2	21 November	Brevard Co., Patrick AFB	—	—	—	—
19	1	21 November	Brevard Co., Patrick AFB	61.8	66.7	31.3	Juvenile
20	1	21 November	Brevard Co., Patrick AFB	66.7	69.6	40.1	Juvenile
21	1	21 November	Brevard Co., Patrick AFB	76.7	81.0	61.0	Juvenile-Young adult
22	1	21 November	Brevard Co., Satellite Beach	—	99.5	116.1	Adult
23	3	23 November	Brevard Co., Patrick AFB	—	—	—	—
24	1	25 November	Volusia Co., New Smyrna Beach	64.1	67.0	35.4	Juvenile
25	1	2 December	Volusia Co., Turtle Mound	71.5	76.9	48.8	Juvenile
26	1	3 December	Brevard Co., Patrick AFB	63.2	67.8	33.8	Juvenile
27	1	9 December	Brevard Co., Patrick AFB	—	—	—	Juvenile
28	2	9 December	Central Brevard Co.	—	—	—	—
29	2	9 December	Central Brevard Co.	—	—	—	—
30	2	9 December	Central Brevard Co.	—	—	—	—
31	2	11 December	Brevard Co., Satellite Beach	—	—	—	—
32	2	11 December	Central Brevard Co.	—	—	—	—
33	3	12 December	Brevard Co., Patrick AFB	—	—	—	—
34	4	12 December	Brevard Co., Indian Harbor Beach	—	—	—	—
			$\bar{X}$ =	68.6	76.3	52.0	
			SD =	9.1	11.9	30.4	
			Range =	59.5-91.9	66.7-99.5	27.2-116.1	
			N =	11	11	12	

Appendix Table 2—Summary of loggerhead turtle mortality records, Indian River, Brevard, and Volusia Counties, Florida, 1978. CLSL = straight carapace length; CLOC = overcurvature carapace length. See text for explanation of class.

No.	Class	Date reported	Location	CLSL (cm)	CLOC (cm)	Computed weight (kg)	Age
1	1	5 January	Volusia Co., New Smyrna Beach	72.3	78.3	50.2	Juvenile
2	1	4 April	Brevard Co., Kennedy SC	89.4	96.4	103.7	Juvenile-Young adult
3	1	6 April	Brevard Co., Patrick AFB	87.2	92.2	96.3	Juvenile-Young adult
4	3	7 April	Brevard Co., Melbourne Beach	—	—	—	—
5	4	15 April	Indian River Co., Vero Beach	—	—	—	—
6	4	15 April	Brevard Co., Cocoa Beach	—	—	—	—
7	2	15 April	Volusia Co., New Smyrna Beach	—	—	—	—
8	4	18 April	Volusia Co., Daytona Beach	—	—	—	—
9	4	18 April	Indian River Co., Vero Beach	—	—	—	—
10	1	18 April	Brevard Co., Indialantic	86.5	78.7	93.9	Juvenile-Young adult
11	1	28 April	Brevard Co., Holland St. Park	—	98.0	111.0	Adult
12	1	1 May	Brevard Co., Cape Can. AFS	—	98.0	111.0	Adult
13	1	1 May	Brevard Co., Cape Can. AFS	—	94.6	99.4	Juvenile-Young adult
14	1	7 May	Brevard Co., Patrick AFB	87.4	90.3	97.0	Juvenile-Young adult
15	1	8 May	Volusia Co., Rose Bay	66.1	70.3	39.0	Juvenile
16	1	16 May	Brevard Co., Cape Can. AFS	—	—	—	—
17	1	16 May	Volusia Co., Rose Bay	74.4	76.6	54.0	Juvenile
18	1	27 May	Volusia Co., Mosquito Lagoon (lagoon)	—	—	—	—
19	3	29 May	Volusia Co., Ponce Inlet	—	—	—	—
20	1	13 June	Volusia Co., New Smyrna Beach	100.1	105.4	139.6	Adult
21	1	26 June	Brevard Co., Patrick AFB	62.2	65.7	32.0	Juvenile
22	1	2 July	Brevard Co., Mosquito Lagoon (lagoon)	—	—	—	—
23	1	4 July	Volusia Co., New Smyrna Beach	91.5	99.9	110.7	Adult
24	1	7 July	Indian River Co., Vero Beach	65.3	68.6	37.6	Juvenile
25	1	17 July	Brevard Co., Playalinda Beach	62.5	68.0	32.6	Juvenile
26	1	17 July	Volusia Co., Ponce Inlet	—	—	—	—
27	1	21 July	Volusia Co., Mosquito Lagoon (lagoon)	—	—	—	—
28	1	21 July	Volusia Co., Daytona Beach	94.9	98.5	122.2	Adult
29	2	23 July	Volusia Co., Daytona Beach	—	—	—	—
30	1	11 August	Brevard Co., Kennedy SC	57.5	62.3	23.6	Juvenile
31	1	24 August	Volusia Co., New Smyrna Beach	51.9	56.9	13.5	Juvenile
32	1	25 August	Volusia Co., New Smyrna Beach	61.2	67.4	30.2	Juvenile
33	1	10 September	Brevard Co., Holland State Park	72.3	77.3	50.2	Juvenile
34	1	11 September	Volusia Co., New Smyrna Beach	—	—	—	—
35	1	22 September	Brevard Co., Playalinda Beach	95.3	99.5	123.5	Adult
36	3	27 September	Brevard Co., Cocoa Beach	—	—	—	—
37	3	27 September	Brevard Co., Cocoa Beach	—	—	—	—
38	1	27 September	Brevard Co., Cape Canaveral	62.1	66.1	31.8	Juvenile
39	1	27 September	Brevard Co., Indian River	113.2	124.3	183.6	Adult
40	1	28 September	Brevard Co., Cocoa Beach	67.0	—	40.7	Juvenile
41	1	28 September	Brevard Co., Cocoa Beach	75.4	—	56.6	Juvenile-Young adult
42	1	30 September	Brevard Co., Cocoa Beach	54.8	—	18.7	Juvenile
43	1	30 September	Brevard Co., Cocoa Beach	95.0	99.8	122.5	Adult
44	1	30 September	Brevard Co., Cocoa Beach	61.2	65.7	30.2	Juvenile
45	2	30 September	Brevard Co., Cocoa Beach	—	—	—	—
46	2	30 September	Brevard Co., Cocoa Beach	—	—	—	—
47	2	30 September	Brevard Co., Cocoa Beach	—	—	—	—
48	2	30 September	Brevard Co., Cocoa Beach	—	—	—	—
49	2	30 September	Brevard Co., Cocoa Beach	—	—	—	—
50	1	1 October	Brevard Co., Cocoa Beach	78.7	85.1	67.7	Juvenile-Young adult
51	1	1 October	Brevard Co., Cocoa Beach	72.0	78.6	49.7	Juvenile
52	1	1 October	Brevard Co., Cocoa Beach	100.0	105.2	139.3	Adult
53	1	1 October	Brevard Co., Cocoa Beach	73.0	79.1	51.5	Juvenile
54	1	1 October	Brevard Co., Cocoa Beach	—	—	—	—
55	1	1 October	Brevard Co., Cocoa Beach	79.5	84.9	70.4	Juvenile-Young adult
56	1	1 October	Brevard Co., Cocoa Beach	—	—	—	—
57	1	1 October	Brevard Co., Cocoa Beach	63.0	68.8	33.5	Juvenile
58	1	1 October	Brevard Co., Cocoa Beach	76.4	83.1	60.0	Juvenile-Young adult
59	1	1 October	Brevard Co., Cocoa Beach	64.7	71.0	36.5	Juvenile
60	1	1 October	Brevard Co., Cocoa Beach	67.2	72.5	41.0	Juvenile
61	1	1 October	Brevard Co., Cape Can. AFS	84.2	92.0	86.2	Juvenile-Young adult
62	1	2 October	Brevard Co., Cocoa Beach	78.0	82.0	65.4	Juvenile-Young adult
63	1	2 October	Brevard Co., Cocoa Beach	67.1	73.4	40.8	Juvenile
64	1	2 October	Brevard Co., Cocoa Beach	67.0	73.2	40.7	Juvenile
65	1	2 October	Brevard Co., Cocoa Beach	62.9	67.5	33.3	Juvenile
66	1	2 October	Brevard Co., Cocoa Beach	73.8	78.0	52.9	Juvenile
67	2	3 October	Brevard Co., Cocoa Beach	—	—	—	—
68	2	3 October	Brevard Co., Cocoa Beach	—	—	—	—
69	2	3 October	Brevard Co., Cocoa Beach	—	—	—	—

Appendix Table 2—(Continued).

No.	Class	Date reported	Location	CLSL (cm)	CLOC (cm)	Computed weight (kg)	Age
70	2	3 October	Brevard Co., Cocoa Beach	—	—	—	—
71	2	3 October	Brevard Co., Cocoa Beach	—	—	—	—
72	1	3 October	Brevard Co., Patrick AFB	70.2	76.2	46.4	Juvenile
73	1	3 October	Brevard Co., Patrick AFB	68.8	74.4	43.9	Juvenile
74	1	3 October	Brevard Co., Cocoa Beach	62.4	67.3	32.4	Juvenile
75	1	3 October	Brevard Co., Cocoa Beach	73.0	78.5	51.5	Juvenile
76	1	3 October	Brevard Co., Satellite Beach	63.4	67.4	34.2	Juvenile
77	1	4 October	Volusia Co., New Smyrna Beach	92.3	100.5	113.4	Adult
78	1	4 October	Brevard Co., Cocoa Beach	68.6	71.1	43.5	Juvenile
79	1	4 October	Brevard Co., Cocoa Beach	—	—	—	Juvenile
80	1	4 October	Brevard Co., Cocoa Beach	92.2	100.5	113.1	Adult
81	1	4 October	Brevard Co., Cocoa Beach	79.0	84.0	68.7	Juvenile-Young adult
82	1	4 October	Brevard Co., Cocoa Beach	92.1	97.0	112.4	Adult
83	4	4 October	Brevard Co., Cocoa Beach	—	—	—	—
84	4	4 October	Brevard Co., Cocoa Beach	—	—	—	—
85	4	4 October	Brevard Co., Cocoa Beach	—	—	—	—
86	4	4 October	Brevard Co., Cocoa Beach	—	—	—	—
87	4	4 October	Brevard Co., Cocoa Beach	—	—	—	—
88	4	4 October	Brevard Co., Cocoa Beach	—	—	—	—
89	2	5 October	Brevard Co., Cocoa Beach	—	—	—	—
90	2	5 October	Brevard Co., Cocoa Beach	—	—	—	—
91	2	5 October	Brevard Co., Cocoa Beach	—	—	—	—
92	2	5 October	Brevard Co., Cocoa Beach	—	—	—	—
93	2	5 October	Brevard Co., Cocoa Beach	—	—	—	—
94	1	6 October	Brevard Co., Cocoa Beach	76.2	79.0	59.3	Juvenile-Young adult
95	1	6 October	Brevard Co., Cocoa Beach	74.4	78.0	54.0	Juvenile
96	1	7 October	Brevard Co., Cocoa Beach	—	—	—	Juvenile
97	1	7 October	Brevard Co., Cocoa Beach	90.9	95.8	108.7	Adult
98	1	7 October	Brevard Co., Cape Canaveral	—	76.0	53.1	Juvenile
99	4	8 October	Brevard Co., Cocoa Beach	—	—	—	—
100	1	9 October	Brevard Co., Patrick AFB	65.0	71.0	37.1	Juvenile
101	1	15 October	Volusia Co., New Smyrna Beach	90.0	97.2	105.7	Adult
102	1	17 October	Brevard Co., Cocoa Beach	62.9	69.5	33.3	Juvenile
103	1	18 October	Volusia Co., New Smyrna Beach	65.4	71.3	37.8	Juvenile
104	1	5 November	Volusia Co., Daytona Beach	58.7	62.6	25.7	Juvenile
105	1	14 November	Brevard Co., Cocoa Beach	80.4	86.3	73.4	Juvenile-Young adult
106	1	14 November	Brevard Co., Cocoa Beach	74.7	81.2	54.3	Juvenile-Young adult
107	1	14 November	Brevard Co., Cocoa Beach	63.9	68.5	35.1	Juvenile
108	1	19 November	Brevard Co., Cocoa Beach	85.0	92.3	88.9	Juvenile-Young adult
109	1	24 November	Volusia Co., Can. Natl. Seashore	72.0	78.3	49.7	Juvenile
110	1	24 November	Volusia Co., Can. Natl. Seashore	60.4	64.0	28.8	Juvenile
111	1	24 November	Volusia Co., Can. Natl. Seashore	71.5	76.3	48.8	Juvenile
112	1	24 November	Volusia Co., Can. Natl. Seashore	74.0	80.0	53.3	Juvenile
113	1	26 November	Brevard Co., Cocoa Beach	73.3	79.1	52.0	Juvenile
114	1	27 November	Brevard Co., Cape Can. AFS	79.0	86.5	68.7	Juvenile-Young adult
115	1	27 November	Brevard Co., Cape Can. AFS	75.3	80.2	56.3	Juvenile-Young adult
116	1	27 November	Brevard Co., Cape Can. AFS	94.0	102.0	119.1	Adult
117	1	27 November	Brevard Co., Cape Can. AFS	73.7	80.6	52.7	Juvenile
118	1	3 December	Brevard Co., Indialantic	57.5	62.8	23.6	Juvenile
119	1	29 December	Brevard Co., Cocoa Beach	72.9	77.2	51.3	Juvenile
			$\bar{X}$ =	74.6	80.5	63.0	
			SD =	12.6	13.3	35.0	
			Range =	51.9-113.2	61.0-124.3	13.5-183.6	
			N =	75	75	78	

Appendix Table 3—Summary of loggerhead turtle mortality records, Indian River, Brevard, and Volusia Counties, Florida, 1979. CLSL = straight carapace length; CLOC = overcurvature carapace length. See text for explanation of class.

No.	Class	Date reported	Location	CLSL (cm)	CLOC (cm)	Computed weight (kg)	Age
1	1	2 March	Brevard Co., Cocoa Beach	67.5	72.7	41.6	Juvenile
2	1	17 March	Volusia Co., New Smyrna Beach	—	—	—	—
3	1	19 March	Brevard Co., Kennedy SC	75.8	81.0	58.0	Juvenile-Young adult
4	1	20 March	Brevard Co., Kennedy SC	73.2	79.5	51.8	Juvenile
5	1	20 March	Brevard Co., Cape Can. AFS	79.2	86.5	69.4	Juvenile-Young adult
6	1	28 March	Brevard Co., Cocoa Beach	61.0	66.0	29.9	Juvenile
7	3	28 March	Indian River Co., S. of Sebastian Inlet	—	—	—	—
8	1	28 March	Brevard Co., Cocoa Beach	79.1	85.4	69.1	Juvenile-Young adult
9	1	31 March	Brevard Co., Kennedy SC	92.5	98.6	114.1	Adult
10	1	21 April	Volusia Co., Ormond Beach	75.5	81.7	57.0	Juvenile-Young adult
11	1	30 April	Brevard Co., Playalinda Beach	71.0	78.9	47.9	Juvenile
12	1	1 June	Brevard Co., Kennedy SC	76.0	81.6	58.7	Juvenile-Young adult
13	1	19 June	Brevard Co., Melbourne (lagoon)	66.9	77.7	40.5	Juvenile
14	1	20 June	Brevard Co., Port Canaveral	90.8	96.6	108.4	Adult
15	1	21 June	Brevard Co., Kennedy SC	56.7	60.7	22.1	Juvenile
16	4	25 June	Brevard Co., Port Canaveral	—	—	—	—
17	4	25 June	Brevard Co., Port Canaveral	—	—	—	—
18	1	25 June	Brevard Co., Cocoa Beach	—	—	—	—
19	1	25 June	Brevard Co., Kennedy SC	94.4	101.0	120.5	Adult
20	1	27 June	Brevard-Volusia Co. Line	75.1	81.5	55.6	Juvenile-Young adult
21	1	2 July	Brevard Co., Cape Canaveral	80.0	85.6	72.1	Juvenile-Young adult
22	12	4 July	Brevard Co., Cape Can. AFS	—	—	—	Adult
23	1	9 July	Brevard Co., Cape Can. AFS	92.0	98.7	112.4	Adult
24	1	11 July	Brevard Co., Playalinda Beach	73.6	78.1	52.5	Juvenile
25	2	14 July	Brevard Co., Jetty Park	102.9	—	149.0	Adult
26	1	18 July	Brevard Co., Cape Can. AFS	93.9	99.7	118.8	Adult
27	1	18 July	Brevard Co., Cape Can. AFS	91.0	97.6	109.1	Adult
28	1	18 July	Brevard Co., Cape Can. AFS	84.9	91.3	88.6	Juvenile-Young adult
29	1	19 July	Brevard Co., Kennedy SC	71.4	77.9	48.6	Juvenile
30	1	19 July	Brevard Co., Kennedy SC	87.8	93.4	98.3	Juvenile-Young adult
31	1	20 July	Brevard Co., Kennedy SC	65.1	69.2	37.2	Juvenile
32	1	20 July	Brevard Co., Cape Can. AFS	46.6	50.0	15.0	Juvenile
33	1	20 July	Brevard Co., Kennedy SC	62.2	68.3	32.0	Juvenile
34	1	23 July	Brevard Co., Cape Can. AFS	—	—	—	Adult
35	1	23 July	Brevard Co., Cape Can. AFS	—	—	—	Adult
36	1	23 July	Brevard Co., Cape Can. AFS	95.5	102.5	124.2	Adult
37	1	23 July	Brevard Co., Cape Can. AFS	—	—	—	Adult
38	1	23 July	Brevard Co., Cape Can. AFS	—	—	—	Adult
39	1	23 July	Brevard Co., Cape Can. AFS	—	—	—	Adult
40	1	23 July	Brevard Co., Cape Can. AFS	70.0	75.7	46.1	Juvenile
41	1	23 July	Brevard Co., Cape Can. AFS	88.2	95.2	99.6	Juvenile-Young adult
42	1	23 July	Brevard Co., Cape Can. AFS	66.7	72.0	40.1	Juvenile
43	1	24 July	Brevard Co., Cape Can. AFS	68.0	75.0	42.5	Juvenile
44	1	24 July	Brevard Co., Cape Can. AFS	88.0	92.3	99.0	Juvenile-Young adult
45	3	30 August	Volusia Co., Ormond Beach	—	—	—	—
46	1	30 August	Brevard Co., Melbourne Beach	67.4	70.4	41.4	Juvenile
47	2	11 September	Volusia Co., New Smyrna Beach	—	—	—	—
48	2	28 September	Volusia Co., New Smyrna Beach	—	—	—	—
49	2	28 September	Volusia Co., Daytona Beach	—	—	—	—
50	1	8 October	Volusia Co., Daytona Beach	86.5	94.5	93.9	Juvenile-Young adult
51	1	10 October	Volusia Co., Daytona Beach	67.4	72.9	41.4	Juvenile
52	1	15 October	Brevard Co., Cocoa Beach	56.6	61.9	21.9	Juvenile
53	1	15 October	Brevard Co., Cocoa Beach	75.8	—	58.0	Juvenile-Young adult
54	1	7 November	Volusia Co., Ormond-by-the-Sea	78.5	85.0	67.1	Juvenile-Young adult
55	1	9 November	Brevard Co., Cape Canaveral	65.6	70.0	38.1	Juvenile
56	1	16 November	Volusia Co., Daytona Beach	65.6	70.8	38.1	Juvenile
57	1	17 November	Brevard Co., Patrick AFB	58.1	64.3	24.6	Juvenile
58	1	18 November	Brevard Co., Cocoa Beach	72.5	77.5	50.6	Juvenile
59	4	20 November	Volusia Co., Daytona Beach	—	—	—	—
60	1	20 November	Brevard Co., Indialantic	78.9	84.6	68.4	Juvenile-Young adult
61	2	20 November	Volusia Co., Daytona Beach Shores	—	—	—	—
62	1	22 November	Volusia Co., New Smyrna Beach	74.2	79.8	53.6	Juvenile
63	3	28 November	Brevard Co., Cocoa Beach	—	—	—	—
64	4	30 November	Brevard Co., Cape Canaveral	—	—	—	—
65	1	2 December	Volusia Co., New Smyrna Beach	73.6	78.0	52.5	Juvenile
66	1	3 December	Brevard Co., Cocoa Beach	63.0	69.2	33.5	Juvenile
67	2	4 December	Volusia Co., Ormond Beach	—	—	—	—
68	2	4 December	Brevard Co., Cocoa Beach	—	—	—	—
69	2	6 December	Volusia Co., Ormond-by-the-Sea	—	—	—	—

Appendix Table 3—(Continued).

No.	Class	Date reported	Location	CLSL (cm)	CLOC (cm)	Computed weight (kg)	Age
70	3	7 December	Brevard Co., Cape Canaveral	—	—	—	—
71	3	9 December	Brevard Co., Indialantic	—	—	—	—
72	2	9 December	Volusia Co., Port Orange	—	—	—	—
73	2	10 December	Volusia Co., Ormond-by-the-Sea	—	—	—	—
74	3	11 December	Brevard Co., Satellite Beach	—	—	—	—
75	2	12 December	Brevard Co., Cocoa Beach	—	—	—	—
76	2	12 December	Brevard Co., Satellite Beach	—	—	—	—
77	3	15 December	Brevard Co., Playalinda Beach	—	—	—	—
78	1	16 December	Brevard Co., Playalinda Beach	74.1	78.7	53.4	Juvenile
79	1	17 December	Brevard Co., Cocoa Beach	95.8	—	125.2	Adult
80	1	17 December	Volusia Co., Daytona Beach	59.4	65.1	27.0	Juvenile
81	4	17 December	Volusia Co., Can. Natl. Seashore	—	—	—	—
82	1	20 December	Brevard Co., Playalinda Beach	90.4	98.5	107.0	Adult
83	2	21 December	Brevard Co., Cocoa Beach	—	—	—	—
84	2	22 December	Volusia Co., Ormond-by-the-Sea	—	—	—	—
85	3	23 December	Brevard Co., Cocoa Beach	—	—	—	—
86	1	23 December	Brevard Co., Patrick AFB	65.4	69.5	37.8	Juvenile
87	1	24 December	Brevard Co., Sebastian Inlet	—	—	—	—
88	1	24 December	Brevard Co., Cocoa Beach	75.2	80.7	56.0	Juvenile-Young adult
89	1	27 December	Brevard Co., Cape Canaveral	56.6	60.9	21.8	Juvenile
			$\bar{X}$ =	75.2	80.1	63.7	
			SD =	12.4	12.4	33.2	
			Range =	46.6-102.9	50.0-102.5	15.0-149.0	
			N =	54	51	54	

Appendix Table 4—Summary of loggerhead turtle mortality records, Indian River, Brevard, and Volusia Counties, Florida, 1980. CLSL = straight carapace length; CLOC = overcurvature carapace length. See text for explanation of class. Asterisk = actual weight; others computed from regression equation.

No.	Class	Date reported	Location	CLSL (cm)	CLOC (cm)	Computed weight (kg)	Age
1	1	15 January	Brevard Co., Satellite Beach	60.3	64.9	28.6	Juvenile
2	1	15 January	Brevard Co., Satellite Beach	66.9	72.2	40.5	Juvenile
3	1	17 January	Brevard Co., Melbourne Beach	—	—	—	Juvenile
4	1	20 January	Brevard Co., Cocoa Beach	73.8	79.5	52.9	Juvenile
5	1	30 January	Brevard Co., Melbourne Beach	—	—	—	Juvenile
6	1	30 January	Brevard Co., Melbourne Beach	53.4	59.5	16.2	Juvenile
7	1	9 February	Volusia Co., New Smyrna Beach	—	—	—	Juvenile
8	3	18 March	Brevard Co., Melbourne Beach	—	—	—	—
9	4	18 March	Brevard Co., Cocoa Beach	—	—	—	—
10	1	19 March	Brevard Co., Sunniland Beach	60.2	64.3	23.6*	Juvenile
11	2	19 March	Brevard Co., Cocoa Beach	—	—	—	—
12	2	20 March	Brevard Co., Cocoa Beach	—	—	—	—
13	2	20 March	Brevard Co., Cocoa Beach	—	—	—	—
14	2	21 March	Brevard Co., Cocoa Beach	—	—	—	—
15	2	21 March	Brevard Co., Cocoa Beach	—	—	—	—
16	2	23 March	Volusia Co., Daytona Beach Shores	—	—	—	—
17	1	23 March	Brevard Co., Cocoa Beach	—	—	—	Adult (F)
18	2	24 March	Brevard Co., Cocoa Beach	—	—	—	—
19	2	24 March	Brevard Co., Cape Canaveral	—	—	—	—
20	1	25 March	Brevard Co., Cocoa Beach	57.0	61.6	22.7	Juvenile
21	1	27 March	Brevard Co., Cape Canaveral	64.3	68.9	35.88	Juvenile
22	1	27 March	Volusia Co., ICW at Edgewater (lagoon)	55.4	60.8	19.8	Juvenile (M)
23	1	27 March	Brevard Co., Satellite Beach	62.0	65.5	31.7	Juvenile (M)
24	1	27 March	Brevard Co., Cape Canaveral	69.2	75.7	44.6	Juvenile
25	1	28 March	Volusia Co., Edgewater	63.3	66.0	34.0	Juvenile (M)
26	1	28 March	Brevard Co., Patrick AFB	92.7	—	114.8	Adult (F)
27	1	3 April	Brevard Co., Cocoa Beach	57.5	63.2	23.8*	Juvenile
28	2	3 April	Brevard Co., Cocoa Beach	—	—	—	—
29	2	3 April	Brevard Co., Cocoa Beach	—	—	—	—
30	1	10 April	Volusia Co., New Smyrna Beach	71.0	76.8	47.9	Juvenile

Appendix Table 4—(Continued).

No.	Class	Date reported	Location	CLSL (cm)	CLOC (cm)	Computed weight (kg)	Age
31	1	10 April	Brevard Co., Port Canaveral	104.6	110.5	154.8	Adult (M)
32	1	15 April	Brevard Co., Cape Can. AFS	62.9	69.1	33.3	Juvenile
33	1	15 April	Volusia Co., New Smyrna Beach	92.9	99.5	115.4	Adult (M)
34	1	18 April	Brevard Co., Playalinda Beach	68.6	72.5	33.6*	Juvenile
35	1	18 April	Volusia Co., Daytona Beach Shores	61.7	66.0	21.8*	Juvenile
36	1	19 April	Brevard Co., Cocoa Beach	72.2	78.5	50.0	Juvenile
37	1	19 April	Volusia Co., New Smyrna Beach	71.4	76.9	48.6	Juvenile
38	1	20 April	Volusia Co., Ormond-by-the-Sea	101.3	106.5	143.7	Adult (M)
39	1	22 April	Volusia Co., Ormond Beach	58.4	64.0	21.9*	Juvenile
40	1	22 April	Volusia Co., Oakhill-Edgewater (lagoon)	67.6	74.5	41.7	Juvenile
41	1	3 May	Brevard Co., Sebastian Inlet	69.4	74.1	45.0	Juvenile
42	2	3 May	Brevard Co., Sebastian Inlet (lagoon)	—	—	—	Juvenile
43	1	3 May	Brevard Co., Cocoa Beach	66.3	72.0	34.1*	Juvenile
44	1	3 May	Brevard Co., Cocoa Beach	81.9	91.2	78.5	Juvenile-Young adult (M)
45	1	4 May	Volusia Co., New Smyrna Beach	58.8	63.0	25.9	Juvenile
46	2	4 May	Indian River Co., Vero Beach	—	—	—	—
47	1	5 May	Brevard Co., Jetty Park	73.7	79.4	52.7	Juvenile
48	2	7 May	Brevard Co., Sebastian Inlet	—	—	—	—
49	1	8 May	Brevard Co., Cape Can. AFS	—	—	—	—
50	1	8 May	Brevard Co., Kennedy SC	—	—	—	—
51	1	8 May	Brevard Co., Cape Can. AFS	—	—	—	—
52	1	8 May	Brevard Co., Cape Can. AFS	—	70.0	42.3	Juvenile
53	2	12 May	Volusia Co., New Smyrna Beach	—	—	—	—
54	1	13 May	Brevard Co., Cape Can. AFS	92.3	100.0	113.4	Adult (F)
55	1	16 May	Brevard Co., Sebastian Inlet	72.0	78.5	31.8*	Juvenile
56	1	18 May	Brevard Co., Cocoa Beach	69.2	74.0	31.4*	Juvenile
57	2	19 May	Brevard Co., Cocoa Beach	—	—	—	—
58	1	20 May	Brevard Co., Kennedy SC	—	—	—	—
59	3	23 May	Volusia Co., Ponce Inlet	—	—	—	—
60	1	1 June	Brevard Co., Jetty Park	73.0	79.4	45.5*	Juvenile
61	1	3 June	Brevard Co., Cocoa Beach	68.4	71.2	43.2	Juvenile
62	3	4 June	Brevard Co., Cocoa Beach	—	—	—	—
63	1	6 June	Brevard Co.	74.4	79.2	39.1*	Juvenile
64	1	11 June	Brevard Co., Cape Can. AFS	—	—	—	—
65	2	23 June	Volusia Co., New Smyrna Beach	—	—	—	—
66	2	23 June	Volusia Co., Daytona Beach	—	—	—	—
67	1	24 June	Volusia Co., Can. Natl. Seashore	75.3	—	56.3	Juvenile-Young adult
68	2	27 June	Volusia Co., New Smyrna Beach	—	—	—	—
69	2	27 June	Indian River Co., Wabasso Beach	—	—	—	— (F)
70	1	27 June	Volusia Co., Daytona Beach Shores	90.7	94.7	108.0	Adult
71	1	30 June	Brevard Co., Cape Can. AFS	—	—	—	—
72	1	4 July	Volusia Co., Ponce Inlet	98.8	100.6	135.3	Adult (M)
73	1	5 July	Volusia Co., Daytona Beach Shores	93.2	95.0	96.4*	Adult (M)
74	3	5 July	Volusia Co., Ponce Inlet	—	—	—	—
75	3	5 July	Volusia Co., Daytona Beach Shores	—	—	—	—
76	2	5 July	Volusia Co., Ponce Inlet	—	—	—	—
77	3	15 July	Brevard Co., Cape Canaveral	—	—	—	—
78	2	16 July	Brevard Co., Port Canaveral	—	—	—	—
79	4	17 July	Volusia Co., Daytona Beach	—	—	—	—
80	4	17 July	Brevard Co., Cocoa Beach	—	—	—	—
81	1	19 July	Brevard Co., Cape Can. AFS	—	—	—	—
82	1	20 July	Brevard Co., Cape Can. AFS	—	—	—	Adult (F)
83	1	20 July	Brevard Co., Cape Can. AFS	—	—	—	—
84	1	20 July	Brevard Co., Cape Can. AFS	—	—	—	—
85	1	20 July	Brevard Co., Cape Can. AFS	—	—	—	—
86	1	20 July	Brevard Co., Cape Can. AFS	—	—	—	—
87	1	20 July	Brevard Co., Cape Can. AFS	72.2	—	50.0	Juvenile
88	1	20 July	Brevard Co., Cape Can. AFS	—	—	—	—
89	1	20 July	Brevard Co., Cape Can. AFS	—	—	—	—
90	1	20 July	Brevard Co., Cape Can. AFS	—	—	—	—
91	1	20 July	Brevard Co., Cape Can. AFS	—	—	—	—
92	1	20 July	Brevard Co., Cape Can. AFS	—	—	—	—
93	1	23 July	Brevard Co., Cape Can. AFS	—	—	—	—
94	1	1 August	Brevard Co., Cape Can. AFS	—	—	—	—
95	1	1 August	Brevard Co., Cape Can. AFS	68.5	73.2	43.4	Juvenile
96	1	4 August	Brevard Co., Cape Can. AFS	—	—	—	—
97	1	4 August	Volusia Co., New Smyrna Beach	64.3	70.1	35.8	Juvenile
98	1	11 August	Brevard Co., Cape Can. AFS	73.0	78.5	51.5	Juvenile
99	1	22 August	Brevard Co., Kennedy SC	—	—	—	—
100	1	14 September	Brevard Co., Port Canaveral	—	—	—	—

Appendix Table 4—(Continued).

No.	Class	Date reported	Location	CLSL (cm)	CLOC (cm)	Computed weight (kg)	Age
101	1	19 September	Brevard Co., Port Canaveral	—	—	—	—
102	1	28 September	Brevard Co., Port Canaveral	76.1	81.4	59.0	Juvenile-Young adult
103	1	6 October	Volusia Co., New Smyrna Beach	70.8	75.4	47.5	Juvenile
104	1	18 October	Brevard Co., Port Canaveral	—	—	—	Juvenile-Young adult
105	1	28 October	Brevard Co., Port Canaveral	—	—	—	Juvenile-Young adult
106	1	30 October	Brevard Co., Patrick AFB	89.9	97.0	105.4	Adult (F)
107	3	30 October	Brevard Co., Cocoa Beach	—	—	—	—
108	1	2 November	Brevard Co., Kennedy SC	63.3	67.2	34.0	Juvenile
109	1	3 November	Brevard Co., Port Canaveral	—	—	—	—
110	1	3 November	Brevard Co., Port Canaveral	—	—	—	—
111	1	3 November	Brevard Co., Port Canaveral	—	—	—	—
112	1	4 November	Brevard Co., Port Canaveral	—	—	—	—
113	1	4 November	Brevard Co., Port Canaveral	—	—	—	Juvenile (F)
114	1	4 November	Brevard Co., Port Canaveral	—	—	—	—
115	1	5 November	Brevard Co., Port Canaveral	—	—	—	—
116	1	5 November	Brevard Co., Port Canaveral	—	—	—	—
117	1	5 November	Brevard Co., Port Canaveral	—	—	—	—
118	1	6 November	Brevard Co., Port Canaveral	—	—	—	—
119	1	9 November	Brevard Co., Port Canaveral	—	—	—	—
120	1	10 November	Brevard Co., Port Canaveral	—	—	—	—
121	1	10 November	Brevard Co., Port Canaveral	—	—	—	— (F)
122	1	11 November	Brevard Co., Port Canaveral	—	—	—	—
123	1	12 November	Brevard Co., Port Canaveral	—	—	—	Adult (F)
124	1	12 November	Brevard Co., Port Canaveral	—	—	—	— (F)
125	1	14 November	Volusia Co., Daytona Beach	72.6	79.2	50.7	Juvenile
126	1	16 November	Brevard Co., Port Canaveral	—	—	—	—
127	1	19 November	Brevard Co., Port Canaveral	—	—	—	—
128	1	27 November	Brevard Co., Satellite Beach	62.2	67.2	33.4*	Juvenile
129	1	27 November	Brevard Co., Cape Can. AFS	62.2	68.6	32.0	Juvenile
130	1	4 December	Brevard Co., Indialantic	68.2	72.5	42.8	Juvenile
131	1	4 December	Brevard Co., Indialantic	59.4	65.0	27.0	Juvenile
132	1	4 December	Brevard Co., Indialantic	63.9	71.1	35.1	Juvenile
133	1	7 December	Brevard Co., Patrick AFB	59.3	64.0	26.8	Juvenile
134	1	7 December	Brevard Co., Cocoa Beach	58.2	62.6	24.8	Juvenile
135	1	7 December	Volusia Co., New Smyrna Beach	67.5	75.2	32.6*	Juvenile
136	1	8 December	Volusia Co., New Smyrna Beach	69.3	76.2	44.8	Juvenile
137	3	13 December	Brevard Co., Patrick AFB	—	—	—	—
138	1	13 December	Brevard Co., Melbourne Shores	—	—	—	—
139	3	14 December	Volusia Co., New Smyrna Beach	—	—	—	—
140	1	19 December	Brevard Co., Melbourne Beach	60.1	66.5	28.2	Juvenile
141	1	20 December	Brevard Co., Cocoa Beach	62.0	69.0	31.7	Juvenile
142	1	22 December	Brevard Co., Cocoa Beach	70.7	78.0	54.0*	Juvenile
143	3	23 December	Brevard Co., Patrick AFB	—	—	—	—
144	1	23 December	Brevard Co., Cocoa Beach	58.3	64.6	25.0	Juvenile
			$\bar{X}$ =	70.4	75.3	49.9	
			SD =	12.0	12.0	32.2	
			Range =	53.4-104.6	59.5-110.5	16.2-154.8	
			N =	61	59	62	

Appendix Table 5—Summary of loggerhead turtle mortality records, Indian River, Brevard, and Volusia Counties, Florida, 1981. CLSL = straight carapace length; CLOC = overcurvature carapace length. See text for explanation of class. Asterisk = actual weight; others computed from regression equation.

No.	Class	Date reported	Location	CLSL (cm)	CLOC (cm)	Computed weight (kg)	Age
1	1	4 January	Brevard Co., Parrish Park (lagoon)	67.3	73.5	40.5*	Juvenile
2	1	4 January	Brevard Co., Melbourne Beach	64.8	71.0	27.2*	Juvenile
3	1	20 January	Volusia Co., New Smyrna Beach	61.1	68.0	30.0	Juvenile
4	1	26 January	Brevard Co., Melbourne-Paradise Beach	78.2	88.1	66.0	Juvenile-Young adult
5	3	29 January	Volusia Co., Edgewater (lagoon)	—	—	—	—
6	1	9 February	Brevard Co., Satellite Beach	60.8	67.6	29.5	Juvenile
7	1	16 February	Brevard Co., Indialantic	72.0	81.0	50.0	Juvenile
8	1	19 February	Brevard Co., Cocoa Beach	69.4	75.1	45.0	Juvenile
9	1	23 February	Volusia Co., New Smyrna Beach	65.5	72.3	38.0	Juvenile
10	1	2 March	Brevard Co., Kennedy SC	93.5	101.3	117.5	Adult
11	1	2 March	Brevard Co., Cape Can. AFS	58.3	62.3	25.0	Juvenile
12	1	2 March	Brevard Co., Cape Can. AFS	71.7	77.6	49.1	Juvenile
13	1	2 March	Brevard Co., Cape Can. AFS	53.0	57.6	15.5	Juvenile
14	1	3 March	Brevard Co., Cape Canaveral	73.2	80.7	51.8	Juvenile
15	1	8 March	Brevard Co., Indialantic	91.3	100.1	110.1	Adult (F)
16	1	9 March	Brevard Co., Satellite Beach	66.2	74.6	39.2	Juvenile
17	1	12 March	Brevard Co., Melbourne Beach	72.7	79.1	50.9	Juvenile
18	1	12 March	Brevard Co., Patrick AFB	67.0	—	40.7	Juvenile
19	1	13 March	Brevard Co., Cocoa Beach	—	63.0	29.7	Juvenile (F)
20	1	14 March	Brevard Co., Patrick AFB	81.0	—	75.5	Juvenile-Young adult (F)
21	1	22 March	Brevard Co., Long Point Park (lagoon)	62.2	68.4	25.2*	Juvenile
22	2	23 March	Volusia Co., Ormond Beach	76.2	—	59.3	Juvenile-Young adult
23	2	29 March	Volusia Co., Ormond Beach	—	—	—	—
24	1	8 April	Indian River Co., Wabasso Beach (lagoon)	74.0	80.3	53.3	Juvenile
25	1	8 April	Indian River Co., Wabasso Beach (lagoon)	67.9	74.4	33.2*	Juvenile
26	1	24 April	Brevard Co., Patrick AFB	59.0	63.7	23.4*	Juvenile
27	1	4 May	Brevard Co., Cape Can. AFS	—	—	—	—
28	1	4 May	Brevard Co., Cape Can. AFS	65.5	72.0	38.0	Juvenile
29	1	4 May	Brevard Co., Cape Can. AFS	68.5	76.0	43.4	Juvenile
30	1	6 May	Brevard Co., Cocoa Beach	66.8	72.4	40.3	Juvenile
31	1	31 May	Brevard Co., Cape Can. AFS	59.0	62.0	26.3	Juvenile
32	1	31 May	Brevard Co., Cape Can. AFS	61.5	64.4	20.6*	Juvenile
33	1	21 June	Brevard Co., Cocoa Beach	101.0	104.3	142.7	Adult (F)
34	2	7 July	Brevard Co., Cocoa Beach	—	—	—	—
35	1	27 July	Volusia Co., Daytona Beach	—	—	—	—
36	1	6 August	Brevard Co., Cape Canaveral	65.8	71.4	38.5	Juvenile
37	2	6 August	Volusia Co., New Smyrna Beach	—	—	—	—
38	1	10 August	Brevard Co., Cape Can. AFS	—	75.7	52.5	Juvenile
39	1	10 August	Brevard Co., Cape Can. AFS	—	104.4	132.8	Adult
40	1	10 August	Brevard Co., Cape Can. AFS	—	67.0	36.9	Juvenile
41	1	20 August	Brevard Co., Cape Can. AFS	—	—	—	—
42	1	20 August	Brevard Co., Cape Can. AFS	—	—	—	—
43	1	6 September	Brevard Co., Cocoa Beach	—	—	—	—
44	2	14 September	Volusia Co., New Smyrna Beach	—	—	—	—
45	1	14 September	Volusia Co., New Smyrna Beach	50.6	55.9	11.1	Juvenile
46	1	15 September	Volusia Co., Bethune Beach	—	73.7	48.9	Juvenile
47	3	18 September	Volusia Co., New Smyrna Beach	—	—	—	—
48	2	18 September	Volusia Co., New Smyrna Beach	—	—	—	—
49	1	22 September	Brevard Co., Satellite Beach	—	—	—	—
50	1	25 September	Volusia Co., New Smyrna Beach	91.6	97.8	106.8*	Adult
51	1	29 September	Volusia Co., New Smyrna Beach	54.9	59.8	26.5*	Juvenile
52	1	3 October	Brevard Co., Can. Natl. Seashore	82.0	89.0	78.8	Juvenile-Young adult
53	1	3 October	Brevard Co., Can. Natl. Seashore	79.2	87.3	69.4	Juvenile-Young adult
54	2	3 October	Brevard Co., Sebastian Inlet	—	—	—	—
55	2	4 October	Volusia Co., Daytona Beach Shores	—	—	—	—
56	1	7 October	Volusia Co., Daytona Beach	73.2	—	51.8	Juvenile
57	1	7 October	Brevard Co., Can. Natl. Seashore	63.9	70.0	41.6*	Juvenile (M)
58	2	24 October	Volusia Co., New Smyrna Beach	—	—	—	—
59	4	27 October	Volusia Co., Daytona Beach	—	—	—	—
60	3	27 October	Volusia Co., Daytona Beach	—	—	—	—
61	2	24 November	Volusia Co., Edgewater (lagoon)	—	—	—	—
62	3	30 November	Brevard Co., Port Canaveral	—	—	—	—
63	1	1 December	Brevard Co., Cape Canaversl	69.9	76.0	45.9	Juvenile
64	1	1 December	Brevard Co., Melbourne Beach (lagoon)	71.6	—	48.9	Juvenile
65	2	2 December	Brevard Co., Cape Canaveral	—	—	—	—
66	1	7 December	Brevard Co., Satellite Beach	68.6	76.7	43.5	Juvenile
67	3	10 December	Volusia Co., Daytona Beach	—	—	—	—
68	1	24 December	Brevard Co., S. of Titusville (lagoon)	71.8	78.2	49.3	Juvenile

Appendix Table 5—(Continued).

No.	Class	Date reported	Location	CLSL (cm)	CLOC (cm)	Computed weight (kg)	Age
69	2	31 December	Brevard Co., Paradise Beach Park	—	—	—	—
			$\bar{X}$ =	70.0	75.9	50.4	
			SD =	10.8	12.3	29.4	
			Range =	50.6-101.0	55.9-104.4	11.1-142.7	
			N =	41	41	46	

Appendix Table 6—Summary of loggerhead turtle mortality records, Indian River, Brevard, and Volusia Counties, Florida, 1982. CLSL = straight carapace length; CLOC = overcurvature carapace length. See text for explanation of class. Asterisk = actual weight; others computed from regression equation.

No.	Class	Date reported	Location	CLSL (cm)	CLOC (cm)	Computed weight (kg)	Age
1	1	1 January	Brevard Co., Cocoa Beach	59.1	65.7	26.4	Juvenile
2	1	2 January	Brevard Co., Cocoa Beach	62.5	67.7	32.6	Juvenile
3	1	3 January	Brevard Co., Cocoa Beach	61.1	66.8	30.0	Juvenile
4	1	17 January	Brevard Co., Cocoa Beach	64.8	70.4	36.7	Juvenile
5	1	21 January	Brevard Co., Port Canaveral	83.6	91.0	84.2	Juvenile-Young adult
6	1	22 January	Brevard Co., Cape Can. AFS	—	—	—	—
7	1	24 January	Brevard Co., Cocoa Beach	61.0	66.0	29.9	Juvenile
8	1	16 February	Volusia Co., Can. Natl. Seashore	—	63.5	30.6	Juvenile
9	1	27 February	Brevard Co., Cocoa Beach	59.3	64.7	26.8	Juvenile
10	1	3 March	Brevard Co., Kennedy SC	—	105-7	137.2	Adult
11	1	4 March	Brevard Co., Cocoa Beach	75.7	82.7	57.7	Juvenile-Young adult
12	1	6 March	Brevard Co., Port Canaveral	70.5	—	47.0	Juvenile
13	1	13 March	Brevard Co., Cocoa Beach	81.5	87.3	77.1	Juvenile-Young adult
14	1	14 March	Brevard Co., Cocoa Beach	66.5	73.1	39.8	Juvenile
15	1	28 March	Brevard Co., Cocoa Beach	69.0	—	44.3	Juvenile
16	1	31 March	Brevard Co., Port Canaveral Ship Channel	—	—	—	Juvenile
17	2	2 April	Volusia Co., Port Orange (lagoon)	—	—	—	—
18	4	2 April	Brevard Co., Cape Canaveral	—	—	—	—
19	1	3 April	Brevard Co., Titusville (lagoon)	72.3	79.8	31.5*	Juvenile
20	4	3 April	Volusia Co., Can. Natl. Seashore	—	—	—	—
21	4	3 April	Brevard Co., Canova Beach	—	—	—	—
22	1	13 April	Brevard Co., Cape Canaveral	62.9	68.0	33.3	Juvenile
23	1	14 April	Brevard Co., Cocoa Beach	55.3	—	19.6	Juvenile
24	1	15 April	Brevard Co., Indialantic	72.2	78.8	50.0	Juvenile
25	1	5 May	Volusia Co., Daytona Beach	79.4	85.8	70.0	Juvenile-Young adult
26	1	10 May	Brevard Co., Melbourne Beach (lagoon)	70.9	—	47.7	Juvenile
27	1	17 May	Brevard Co., Sebastian Inlet (lagoon)	72.8	80.2	51.1	Juvenile
28	1	22 May	Volusia Co., Can. Natl. Seashore	—	86.4	71.4	Adult
29	1	23 May	Volusia Co., New Smyrna Beach (lagoon)	64.7	71.0	30.5*	Juvenile
30	1	6 June	Brevard Co., Port Canaveral	74.8	81.0	54.7	Juvenile
31	1	6 June	Brevard Co., Sebastian Inlet State Park (lagoon)	75.9	81.3	58.3	Juvenile-Young adult
32	1	8 June	Brevard Co., Patrick AFB	70.3	77.9	46.6	Juvenile
33	2	8 June	Brevard Co., Cocoa Beach	—	—	—	—
34	2	8 June	Brevard Co., Cocoa Beach	—	—	—	—
35	1	9 June	Brevard Co., Cocoa Beach	94.8	103.5	121.8	Adult
36	1	13 June	Brevard Co., Sebastian Inlet State Park (lagoon)	53.8	56.4	16.9	Juvenile
37	1	13 June	Brevard Co., Cocoa Beach	63.5	68.8	34.4	Juvenile
38	1	25 June	Brevard Co., Cape Canaveral	97.5	107.0	130.9	Adult
39	1	27 June	Brevard Co., Cape Canaveral	97.6	100.0	131.2	Adult
40	1	27 June	Brevard Co., Cape Canaveral	82.0	—	78.8	Juvenile-Young adult
41	1	28 June	Brevard Co., Cape Canaveral	83.5	88.3	83.9	Juvenile-Young adult
42	1	29 June	Brevard Co., Cape Can. AFS	97.4	106.6	130.6	Adult
43	1	29 June	Brevard Co., Cape Can. AFS	95.3	99.4	123.5	Adult
44	1	29 June	Brevard Co., Cape Can. AFS	86.6	94.0	94.3	Adult
45	1	29 June	Brevard Co., Port Canaveral	95.2	103.0	123.2	Adult
46	1	29 June	Brevard Co., Port Canaveral	92.9	100.0	115.4	Adult
47	1	29 June	Brevard Co., Cape Can. AFS	92.8	99.8	115.1	Adult
48	1	29 June	Brevard Co., Cape Can. AFS	92.5	101.4	114.1	Adult
49	1	29 June	Brevard Co., Cape Can. AFS	—	—	—	Juvenile

Appendix Table 6—(Continued).

No.	Class	Date reported	Location	CLSL (cm)	CLOC (cm)	Computed weight (kg)	Age
50	1	29 June	Brevard Co., Cape Can. AFS	—	—	—	Juvenile
51	1	29 June	Brevard Co., Cape Can. AFS	96.0	101.0	125.9	Adult
52	1	29 June	Brevard Co., Cape Canaveral	69.6	79.2	47.4	Juvenile
53	1	29 June	Brevard Co., Cape Canaveral	81.2	87.3	76.1	Juvenile-Young adult
54	1	29 June	Brevard Co., Cape Canaveral	70.7	78.3	47.3	Juvenile
55	1	9 July	Brevard Co., Indialantic	64.5	70.9	36.2	Juvenile
56	1	15 July	Brevard Co., Indialantic	53.0	60.0	15.5	Juvenile
57	1	21 July	Brevard Co., Melbourne (lagoon)	74.3	—	53.8	Juvenile
58	1	2 August	Brevard Co., Port Canaveral	56.6	61.7	25.7*	Juvenile
59	1	3 August	Brevard Co., Sebastian Inlet (lagoon)	61.7	68.4	29.5*	Juvenile
60	1	10 August	Brevard Co., Sebastian Inlet (lagoon)	56.2	62.0	25.1*	Juvenile
61	1	21 August	Brevard Co., Port Canaveral	54.6	59.3	27.3*	Juvenile
62	1	21 August	Brevard Co., Port Canaveral	73.1	79.9	55.4*	Juvenile
63	2	7 September	Brevard Co., Patrick AFB	—	—	—	—
64	1	14 September	Brevard Co., Indian River (lagoon)	73.7	81.3	52.7	Juvenile
65	1	24 September	Volusia Co., New Smyrna Beach	61.7	68.2	34.0*	Juvenile
66	1	30 September	Volusia Co., Can. Natl. Seashore	—	77.0	54.9	Juvenile
67	2	30 September	Volusia Co., Daytona Beach	—	—	—	—
68	2	22 October	Volusia Co., Daytona Beach	—	—	—	—
69	1	24 October	Brevard Co., Sunnyland Beach	68.6	74.2	43.5	Juvenile
70	2	18 November	Volusia Co., Daytona Beach Shores	—	—	—	—
71	1	22 November	Brevard Co., Indialantic	65.1	72.4	37.2	Juvenile
72	1	26 November	Brevard Co., Cocoa Beach	57.3	61.0	23.2	Juvenile
73	2	27 November	Volusia Co., Klondike Beach	—	69.8	41.9	Juvenile
74	2	29 November	Brevard Co., Cape Canaveral	—	—	—	—
75	2	4 December	Brevard Co., Port Canaveral	—	100.0	117.8	Adult (M)
76	1	8 December	Brevard Co., Patrick AFB	89.4	97.0	95.4*	Adult (M)
77	3	9 December	Brevard Co., Cape Can. AFS	—	—	—	—
78	1	9 December	Brevard Co., Cape Can. AFS	69.0	76.2	44.3	Juvenile
79	3	9 December	Brevard Co., Cocoa Beach	—	—	—	—
80	3	16 December	Brevard Co., Cocoa BEach	—	—	—	—
81	1	27 December	Volusia Co., New Smyrna Beach	78.0	84.0	47.7*	Juvenile-Young adult
			$\bar{X}$ =	73.4	80.6	60.9	
			SD =	13.2	14.4	35.8	
			Range =	53.0-97.6	56.4-107.0	15.5-137.2	
			N =	57	57	63	

Appendix Table 7—Summary of loggerhead turtle mortality records, Indian River, Brevard, and Volusia Counties, Florida, 1983. CLSL = straight carapace length; CLOC = overcurvature carapace length. See text for explanation of class. Asterisk = actual weight; others computed from regression equation.

No.	Class	Date reported	Location	CLSL (cm)	CLOC (cm)	Computed weight (kg)	Age
1	3	2 January	Volusia Co., New Smyrna Beach	—	—	—	—
2	1	20 January	Volusia Co., Daytona Beach	47.2	50.9	15.6*	Juvenile
3	1	20 March	Brevard Co., Indian River (lagoon)	62.4	67.6	34.4*	Juvenile (F)
4	1	5 April	Volusia Co., Apollo Beach	—	63.0	29.7	Juvenile
5	1	17 April	Brevard Co., Cape Can. AFS	—	60.5	25.2	Juvenile
6	1	17 April	Brevard Co., Cape Can. AFS	—	56.3	17.6	Juvenile
7	1	28 April	Brevard Co., Melbourne Beach (lagoon)	70.2	77.0	46.4	Juvenile
8	1	2 May	Volusia Co., Daytona BEach	57.3	61.0	23.2	Juvenile
9	1	19 May	Brevard Co., Cape Can. AFS	—	—	—	Adult
10	1	20 May	Brevard Co., Cape Can. AFS	—	59.0	22.5	Juvenile
11	1	20 May	Brevard Co., Cape Can. AFS	—	—	—	—
12	1	28 May	Brevard Co., Indian River (lagoon)	69.5	77.8	45.2	Juvenile (M)
13	1	30 May	Brevard Co., Indian River (lagoon)	91.5	97.0	110.7	Adult
14	1	7 June	Brevard Co., Sebastian Inlet (lagoon)	64.9	70.7	36.9	Juvenile
15	1	17 June	Indian River Co., Vero Beach (lagoon)	53.4	60.2	21.7*	Juvenile
16	1	28 June	Brevard Co., Cape Canaveral	97.9	107.0	132.2	Adult (M)
17	1	27 August	Brevard Co., Jetty Park	67.3	74.1	41.2	Juvenile
18	1	11 September	Volusia Co., New Smyrna Beach	70.1	74.5	46.2	Juvenile
19	1	1 October	Brevard Co., Cocoa Beach	89.1	96.5	102.7	Adult
20	1	29 October	Brevard Co., Patrick AFB	48.0	50.5	13.6*	Juvenile
21	1	21 December	Brevard Co., Melbourne Beach	—	—	—	Juvenile
			$\bar{X}$ =	68.4	70.8	45.0	
			SD =	16.1	16.4	35.5	
			Range =	47.2-97.9	50.5-107.0	13.6-132.2	
			N =	13	17	17	

Appendix Table 8—Summary of loggerhead turtle mortality records, Indian River, Brevard, and Volusia Counties, Florida, 1984. CLSL = straight carapace length; CLOC = overcurvature carapace length. See text for explanation of class. Asterisk = actual weight; others computed from regression equation.

No.	Class	Date reported	Location	CLSL (cm)	CLOC (cm)	Computed weight (kg)	Age
1	1	10 January	Brevard Co., Patrick AFB	69.9	76.0	45.9	Juvenile
2	1	23 January	Brevard Co., Cocoa Beach	—	—	—	—
3	1	11 February	Brevard Co., Port Canaveral	90.8	96.7	108.4	Adult (M)
4	1	23 February	Volusia Co., Daytona Beach	—	—	21.6*	Juvenile
5	1	4 March	Brevard Co., Cocoa Beach	48.6	52.7	16.9*	Juvenile
6	1	15 March	Brevard Co., Grant (lagoon)	54.0	60.2	21.4*	Juvenile
7	1	27 March	Volusia Co., Ormond Beach	45.8	50.2	16.0*	Juvenile
8	1	14 April	Brevard Co., Cape Can. AFS	67.5	—	41.6	Juvenile
9	1	14 April	Brevard Co., Cape Can. AFS	91.8	—	111.7	Adult (M)
10	1	14 April	Brevard Co., Cape Can. AFS	—	71.0	44.1	Juvenile
11	1	14 April	Brevard Co., Cape Can. AFS	—	—	—	—
12	1	14 April	Brevard Co., Cape Can. AFS	—	81.0	62.1	Juvenile-Young adult
13	1	13 May	Brevard Co., Cape Canaveral	96.2	105.1	126.5	Adult (F)
14	1	13 May	Brevard Co., Cape Can. AFS	—	—	—	Juvenile
15	1	13 May	Brevard Co., Cape Can. AFS	—	78.0	56.7	Juvenile
16	1	28 May	Brevard Co., Cape Can. AFS	—	95.5	102.5	Adult
17	1	30 May	Brevard Co., Satellite Beach	75.7	82.5	57.6	Juvenile
18	2	8 June	Brevard Co., Cocoa Beach	—	—	—	—
19	2	11 June	Volusia Co., Daytona Beach	—	—	—	—
20	1	11 June	Brevard Co., Cape Canaveral	87.7	94.1	98.0	Juvenile-Young adult
21	1	17 June	Brevard Co., Port Canaveral	65.0	—	37.1	Juvenile
22	1	25 June	Indian River Co., Sebastian Inlet (lagoon)	56.2	61.9	21.2	Juvenile
23	1	1 July	Brevard Co., Cape Can. AFS	—	85.4	70.0	Juvenile-Young adult
24	1	9 July	Brevard Co., Cape Canaveral	92.2	98.7	113.1	Adult (F)
25	1	9 July	Brevard Co., Cape Canaveral	86.1	92.0	92.6	Juvenile-Young adult
26	1	9 July	Brevard Co., Cape Canaveral	91.6	101.5	111.1	Adult
27	1	9 July	Brevard Co., Cape Canaveral	71.2	77.0	48.2	Juvenile
28	2	10 July	Volusia Co., Daytona Beach	—	—	—	—
29	2	10 July	Volusia Co., Daytona Beach	—	—	—	—
30	1	11 July	Brevard Co., Cape Can. AFS	—	94.4	98.7	Adult
31	3	25 July	Volusia Co., Daytona Beach	—	—	—	—
32	3	25 July	Volusia Co., Daytona Beach	—	—	—	—
33	1	18 August	Brevard Co., Melbourne Beach (lagoon)	51.4	58.0	12.6	Juvenile
34	2	31 August	Volusia Co., New Smyrna Beach	—	—	—	—
35	2	21 September	Brevard Co., Cocoa Beach	—	—	45.5	Juvenile
36	1	26 September	Brevard Co., Grant (lagoon)	63.2	70.0	37.1	Juvenile
37	1	3 October	Brevard Co., Indialantic	75.2	82.0	55.4	Juvenile
38	2	16 October	Brevard Co., Port Canaveral	—	—	—	—
39	1	20 October	Brevard Co., Cape Canaveral	59.7	64.0	30.1*	Juvenile (F)
40	1	28 November	Brevard Co., Sebastian Inlet (lagoon)	63.5	68.5	33.0*	Juvenile
41	3	14 December	Brevard Co., Melbourne Beach (lagoon)	—	—	—	—
42	1	18 December	Volusia Co., Apollo Beach	—	—	—	—
43	1	18 December	Brevard Co., Playalinda Beach	—	—	—	—
44	1	18 December	Brevard Co., Playalinda Beach	—	—	—	—
45	2	26 December	Volusia Co., New Smyrna Beach	—	—	—	—
			$\bar{X}$ =	71.6	79.0	59.9	
			SD =	16.1	16.1	35.4	
			Range =	45.8-96.2	50.2-105.1	12.6-126.5	
			N =	21	24	29	

Appendix Table 9—Summary of green turtle mortality records, Indian River, Brevard, and Volusia Counties, Florida, 10 November 1977 through 31 December 1984. CLSL = straight carapace length; CLOC = overcurvature carapace length. See text for explanation of class. Asterisk = actual weight; others computed from regression equation.

No.	Class	Date reported	Location	CLSL (cm)	CLOC (cm)	Computed weight (kg)	Age
1	1	20 March 1978	Brevard Co. (lagoon)	59.6	64.8	31.0	Juvenile
2	1	12 June 1978	Indian River Co., Sebastian Inlet	101.5	109.6	143.0	Adult
3	1	3 April 1979	Indian River Co., Vero Beach	33.0	35.3	4.7	Juvenile
4	1	13 June 1979	Brevard Co., Mosquito Lagoon (lagoon)	29.0	—	3.5*	Juvenile
5	1	16 March	Brevard Co., Cocoa Beach	60.7	65.0	25.1	Juvenile
6	1	4 June 1980	Brevard Co., Cape Can. AFS	85.2	89.4	—	Juvenile-Young adult
7	1	5 December 1980	Brevard Co., Playalinda Beach	30.2	31.5	—	Juvenile
8	1	18 February 1981	Brevard Co., Indian Harbor Beach	13.2	13.5	0.28	Juvenile
9	1	12 January 1982	Brevard Co., Melbourne (lagoon)	31.0	32.5	—	Juvenile
10	1	4 April 1982	Brevard Co., Port Canaveral	31.2	33.4	—	Juvenile
11	1	12 April 1982	Brevard Co., Cape Canaveral	33.1	34.4	—	Juvenile
12	1	17 July 1982	Brevard Co., Satellite Beach	59.4	62.1	29.5	Juvenile
13	1	21 July 1982	Volusia Co., Mosquito Lagoon (lagoon)	42.7	45.5	—	Juvenile
14	1	20 January 1983	Volusia Co., Ponce Inlet	25.1	27.0	1.9	Juvenile
15	1	30 May 1983	Brevard Co., Indian River (lagoon)	67.0	70.5	—	Juvenile
16	1	12 January 1984	Brevard Co., Banana River (lagoon)	49.4	53.9	—	Juvenile
17	1	28 February, 1984	Volusia Co.	31.5	32.0	—	Juvenile
18	1	20 March 1984	Brevard Co., Indian River (lagoon)	56.1	60.2	—	Juvenile
19	1	2 June 1984	Indian River Co., Indian River (lagoon)	33.4	35.4	4.4	Juvenile
20	1	30 June 1984	Volusia Co., Ponce Inlet	27.6	28.9	2.7	Juvenile
21	2	18 September 1984	Indian River Co., Sebastian (lagoon)	—	—	11.0	Juvenile
22	1	9 October 1984	Indian River Co., Vero Beach	29.6	31.2	3.2	Juvenile
23	1	13 Octiber 1984	Brevard Co., Haulover Canal (lagoon)	47.3	49.9	11.7	Juvenile
			$\bar{X}$ =	44.4	47.9	20.9	
			SD =	21.3	23.2	38.2	
			Range =	13.2-101.5	13.5-109.6	0.3-143.0	
			N =	22	21	13	

Appendix Table 10—Summary of leatherback, Kemp's ridley, and hawksbill turtle mortality records from Indian River, Brevard, and Volusia Counties, Florida, 10 November 1977 through 31 December 1984. CLSL = straight carapace length; CLOC = overcurvature carapace length. See text for explanation of class.

No.	Class	Date reported	Location	CLSL (cm)	CLOC (cm)	Computed weight (kg)	Age
Leatherback							
1	1	7 January 1980	Volusia Co., New Smyrna Beach	120.4	125.4	—	Juvenile
2	2	18 November 1980	Volusia Co., Daytona Beach	—	—	—	—
3	2	20 November 1982	Volusia Co., Ormond Beach	—	—	—	—
4	1	8 March 1983	Brevard Co., Melbourne Beach	126.5	131.0	161.4	Juvenile
Kemp's Ridley							
1	1	3 March 1981	Volusia Co., Daytona Beach Shores	31.3	33.1	4.2	Juvenile
2	1	3 January 1982	Volusia Co., New Smyrna Beach	42.9	45.0	—	Juvenile
3	1	20 January 1983	Volusia Co., Daytona Beach	47.0	50.0	15.4	Juvenile
4	1	14 February 1983	Volusia Co., Can. Natl. Seashores	40.2	42.2	—	Juvenile
Hawksbill							
1	1	14 July 1983	Brevard Co., Melbourne Beach	19.5	—	0.9	Juvenile

Loggerhead Turtle, *Caretta caretta*, and Green Turtle, *Chelonia mydas*, Nesting Densities in South Brevard County, Florida, 1981-84

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ABSTRACT

Several authors have alluded to the importance of the south Brevard County, Florida, shoreline as a loggerhead and green turtle nesting beach. Those inferences stemmed mainly from the results of a limited number of aerial surveys and, until 1981, no systematic season-long survey of marine turtle nesting density had been carried out in the vicinity of the village of Melbourne Beach. In 1981 we documented 1,304 loggerhead nests (140/km) in a 9.3 km survey area at Indialantic and Melbourne Beach. In 1982 a survey of a larger area (29 km, from Indialantic to Sebastian Inlet State Recreation Area) produced an overall estimate of 9,674 nests (334/km), with more concentrated nesting (440/km) in the more southerly 21 km. In 1983 and 1984 the survey was limited to that 21-km stretch and produced estimates of 9,423 (449/km) and 7,753 (369/km) loggerhead nests. There is reason to believe that the loggerhead densities observed here exceed those seen anywhere else in the western Atlantic basin. No green turtle nests were observed in the small survey area of 1981. In 1982, 1983 and 1984, respective totals of 47, 43 and 32 *Chelonia* nests were documented. Some green turtle nesting was missed in late August each year, but the total was likely to be somewhat less than 100 nests in any of the three years. Although the 1.5 green turtle nests/km · year seem paltry in the comparison, there is probably no area in this country that support substantially more nesting by this nearly extirpated species.

INTRODUCTION

Ross (1982) recently assessed the worldwide status of stocks of the loggerhead turtle, *Caretta caretta*. He concluded that the aggregation of adult females nesting on the beaches of the southeastern United States is second in size only to that at Masirah, an island on the Oman coast, in the northwest Indian Ocean. The difference between these two is apparently not great, with the Oman group numbering about 30,000 adult females and the southeastern U.S. group having perhaps as many as 25,000 (Ross 1982). They constitute the two largest groups of loggerheads on earth.

The green turtle, *Chelonia mydas*, is regarded as endangered in the United States, and rightly so. The fact that green turtles nest at all on the Florida coast was not even reported in the scientific literature until 1959, and Dodd (1981) and others have questioned the idea that there ever have been substantially more green turtles nesting in Florida than at present. Less than 1% of the marine turtles nesting in Florida are green turtles. It seems probable that there once were many more greens nesting on the Florida coast, judging by old landings statistics which show that thousands of juvenile green turtles were taken for commerce there in the late 19th century. At any rate, green turtles are somewhat better off than loggerheads on a worldwide basis, there being about 36 major nesting aggregations distributed throughout the Tropics (Sternberg 1981).

Bjorndal et al. (1983) implied that a stretch of shoreline near the towns of Indialantic and Melbourne Beach in south Brevard County, Florida, may well be the best (i.e., most densely nested) loggerhead beach in the United States. Groombridge (1982) published a similar statement. The south Brevard beach had, however, been largely ignored insofar as estimating nesting densities is concerned, and the assessment of Bjorndal et al. (1983) was based largely on a few aerial surveys in the late 1970's. So, although there were indications that it is a very important nesting beach, no systematic season-long survey of nesting activity had ever been done in south Brevard.

In the summer of 1981 we carried out a survey of marine turtle nesting on a relatively short section (9.3 km long) of the beach in the Indialantic-Melbourne Beach area (Fig. 1, 2). We were surprised by the relatively large number of loggerhead turtles found nesting there and by the large number of nesting emergences we counted during a few late-season reconnaissance surveys on the beach south of there. It appeared that the Indialantic-Melbourne Beach area might be a transition zone between an area (on the north) which supported moderately dense nesting, and one on the south where loggerhead nesting density was truly extraordinary. In 1982 we expanded our survey area by 19.7 km, to include all of the beach from a point just north of Indialantic to Sebastian Inlet State Recreation Area, a distance of 29 km.

We were aware from the outset that some number of females from the remnant Florida population of green turtles also nested in south Brevard, but had no clue as to their number. It was our objective, therefore, to begin to document and quantify patterns of loggerhead and green turtle nesting on this important stretch of beach.

METHODS

In 1981 the 9.3 km study area (Fig. 2) was traversed nightly (seven nights per week), from 14 May to 19 August. Virtually every marine turtle emergence was logged and many of the turtles were tagged. A final traversal was made at dawn (by which time nesting is finished

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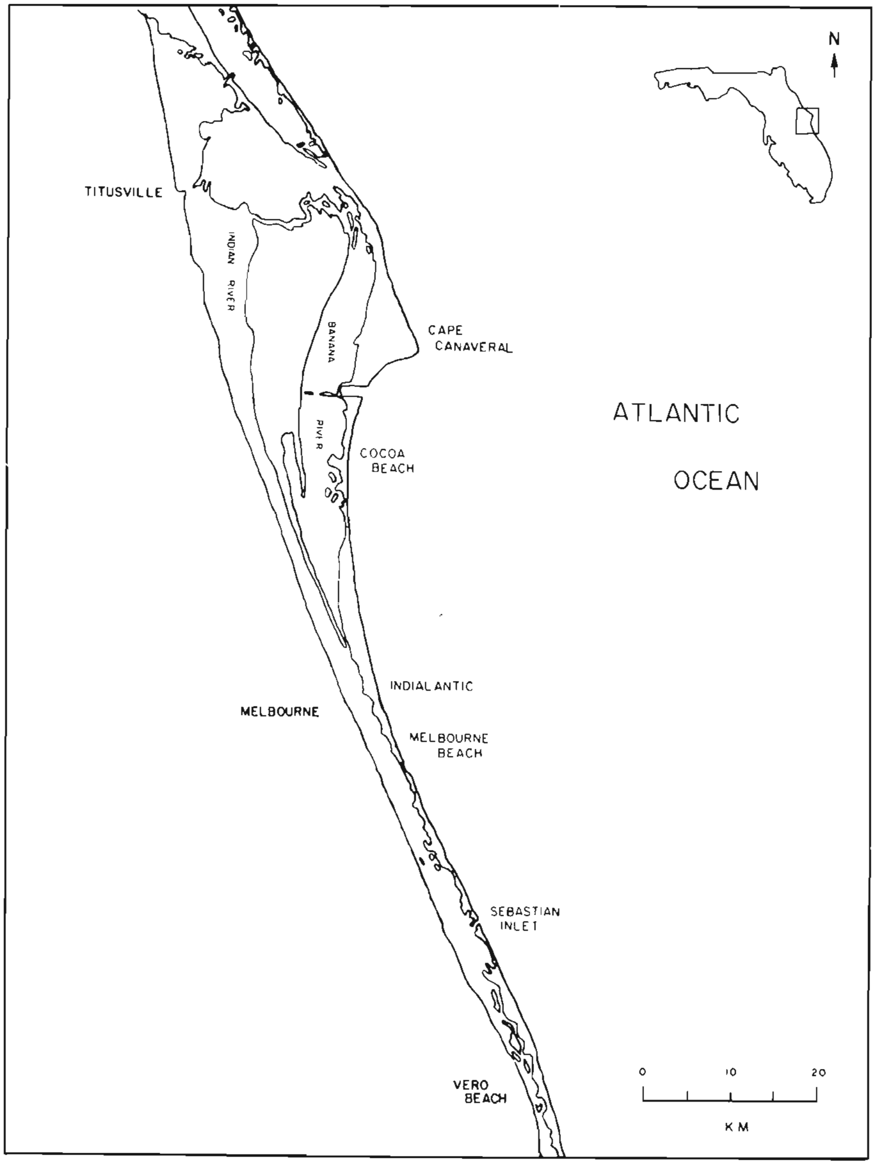

Figure 1—General geographic aspect of south Brevard County, Florida. This study concerns the shoreline from Indialantic to Sebastian Inlet, extending from approximately 44 to 64 km south of Port Canaveral (the conspicuous inlet between Cape Canaveral and Cocoa Beach).

for the date). All nesting and non-nesting emergences made by turtles unseen during the night were added to the total by reading characteristics of the tracks and nest sites. A total census of turtle nesting emergences was thus accomplished. In 1982, because the study area was expanded by 200% (Fig. 2), a total census was not possible. Total nest counts were made on 56 days of the 100-day season. These sample census days were distributed uniformly throughout the season, and simple ratio estimates of total loggerhead nesting, by kilometer, were made as follows:

$$\text{Total nests} = \frac{\text{counted nests} \times \text{total season length (days)}}{\text{No. of census days}}.$$

In 1983 the study area was shortened by 8 km on the north, leaving a survey area of 21 km, stretching from the village of Melbourne Beach to Sebastian Inlet State Recreation Area. This same 21 km stretch was surveyed again in 1984. Most of the counts in 1982 through 1984 were made during survey runs that lasted from about one hour before dawn until about two hours after dawn. As in the early morning counts of 1981, each new emergence was evaluated according to characteristics of the track and nest site, and a determination of species and result (nesting vs. non-nesting emergence) was made.

RESULTS

In 1981 a total census of nesting emergences was accomplished and the results are given in Table 1 and Figure 3. There were no green turtle nests in the 9.3 km survey area (only two green turtle "false crawls"), so Figure 3 shows the distribution of loggerhead nesting emergences by kilometer. Loggerhead "false crawls" are included in Table 1 but not in Figure 3. The total number of nests represented by the histogram in Figure 3 is 1,304. That translates to a mean of 140 nests/km, a density exceeded by only a few other loggerhead nesting beaches in this hemisphere.

The distribution of these nesting emergences was, however, not uniform. In the northern half of the area the mean was 88 nests/km, while in the more southerly half it rose to 193/km. This pattern suggested that even greater densities might be observed on the beach

Table 1—Summary of loggerhead turtle nesting survey results, south Brevard County, Florida, 1981-84.

Year	Area	Season length (days)	Survey distance (km)	Nesting emergences Count	Nesting emergences Estimate	Nesting emergences Total	Non-nesting emergences Count	Non-nesting emergences Estimate	Non-nesting emergences Total	Total emergences
1981	Indialantic-Melbourne Beach	100	9.3	1,304	0	1,304	1,619	0	1,619	2,923
1982	Indialantic-Sebastian Inlet State Rec. Area	100	29.0	5,416	4,258	9,674	3,159	2,484	5,643	15,317
1983	Melbourne Beach-Sebastian Inlet State Rec. Area	95	21.0	3,836	5,587	9,423	4,370	6,363	10,733	20,156
1984	Melbourne Beach-Sebastian Inlet State Rec. Area	111	21.0	4,820	2,933	7,753	4,783	2,911	7,694	15,447

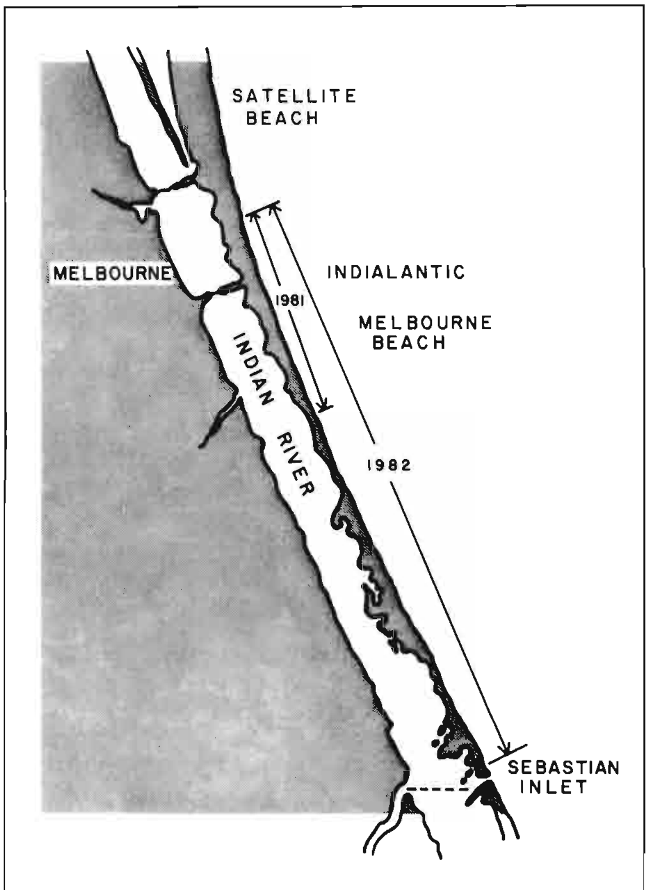

Figure 2—Specific locations of the 1981 (9.3 km) and 1982 (29 km) survey areas. In 1983 and 1984 the survey area extended 21 km from the southern limit of Melbourne Beach to Sebastian Inlet State Recreation Area.

immediately to the south. The surveys of 1982, 1983, and 1984, results of which are given in Table 1, proved that such was the case. Figure 4 presents the survey results for 1982 in terms of nesting density (nests/km). The lower portions of the bars depict actual counts of loggerhead nests, the upper portions represent additional numbers calculated as ratio estimates. In that part of the 1982 survey which corresponded to the 1981 study area, 1,679 clutches, or 181/km, were deposited. That is in contrast to 140/km in 1981. Overall loggerhead nesting performance varies somewhat from year

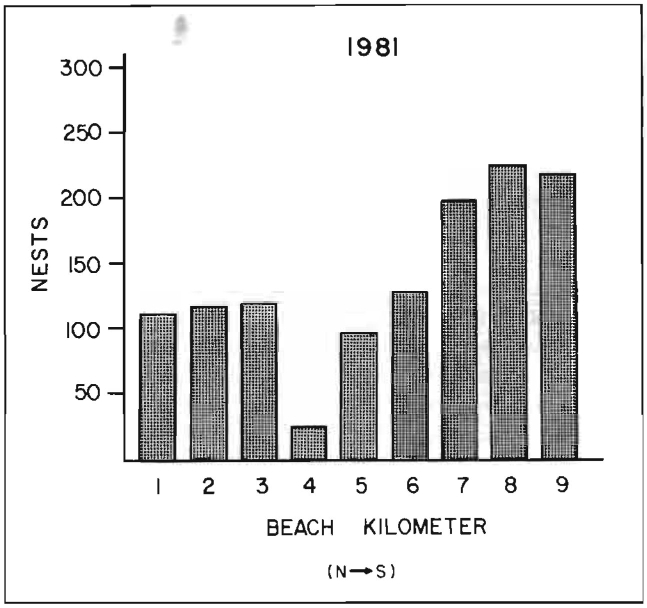

Figure 3—Loggerhead nesting densities (nests/km) in the Indialantic-Melbourne Beach survey area, 1981.

to year throughout the range and our estimates indicate that 1982 was a better year than 1981.

Over the entire 29 km surveyed in 1982, a count of 5,416 nests provided a ratio estimate of 9,674 nests, or 334/km. It is clear, considering these results, that our original (1981) study area did indeed bracket a transition zone between the more highly developed central section of Brevard County, where loggerhead nesting densities are moderately high, and the less thoroughly developed southern section, where densities reach extraordinary levels. Mean nesting density for the 21-km stretch from Melbourne Beach to Sebastian Inlet (which became the permanent survey area in 1983 and 1984) was 440 nests/km. That average is negatively affected by a distinct decrease that occurs, inexplicably, in the more southerly 3-5 km. It is clear that certain large segments of this area supported in excess of 600 nests/km in 1982 (Fig. 4).

1983 was another good year for loggerhead nesting in south Brevard County. Nesting and non-nesting emergence totals are given in Table 1 and densities by kilometer are shown in Figure 5. The mean density for the 21 km survey area was 449 nests/km.

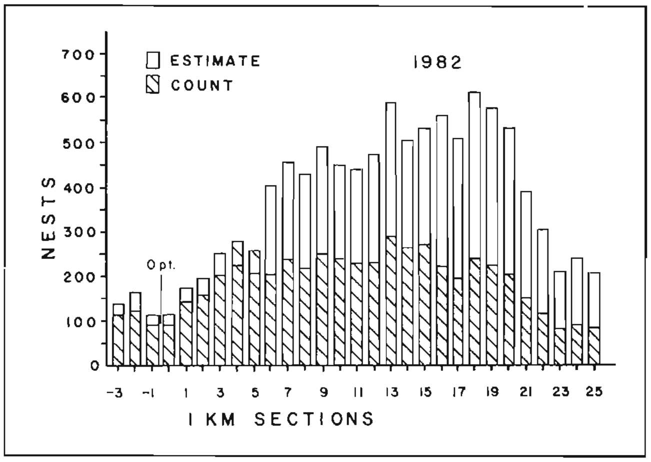

Figure 4—Loggerhead nesting densities (nests/km) in the 29-km survey area between Indialantic and Sebastian Inlet State Recreation Area, 1982. Study area subdivisions (1-km "sections") are designated by distance of northern section limit to "0 point," which is the eastern terminus of U.S. Highway 192 in Indialantic. Negative distances are north of the "0 point."

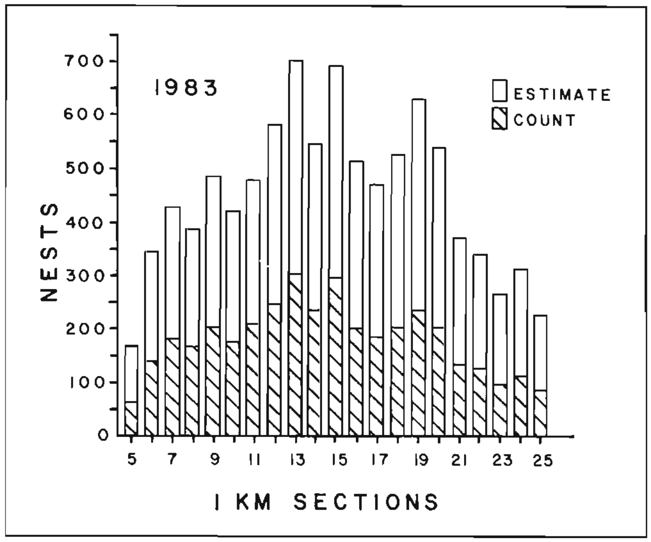

Figure 5—Loggerhead nesting densities (nests/km) in the 21-km survey area between Melbourne Beach and Sebastian Inlet State Recreation Area, 1983. Study area subdivisions (1-km "sections") are designated by distance of northern section limit south of the "0 point" (the eastern terminus of U.S. Highway 192 in Indialantic). Survey began at 5 km south of "0 point" in 1983.

The nesting performance of the south Brevard loggerhead colony fell somewhat in 1984. The totals given in Table 1 and the densities shown in Figure 6 translate to a mean density of 369 nests/km, which is significantly smaller (ANOVA, student's t: $P < 0.05$) than that for 1983, but still much greater than that of any other loggerhead nesting beach in the western hemisphere for which data are available.

In 1982 we observed a total of 47 green turtle nesting emergences and 30 non-nesting ones on the entire 29 km area. In 1983 we counted 43 *Chelonia* nests and 14 "false crawls," and in 1984 the count fell to 32 and 30, respectively. Relative to their small numbers, to begin with, green turtles continue to nest more actively later in August than do loggerheads. Our surveys became less frequent after 15 August each year, and, although it clearly had little effect on our loggerhead counts and estimates, we probably failed to observe some green turtle nesting during the second half of August. We have little basis upon which to estimate those numbers, but it seems unlikely that more than twice the number we observed (or somewhat less than 100 green turtle clutches) were actually deposited in any of the years from 1982 to 1984.

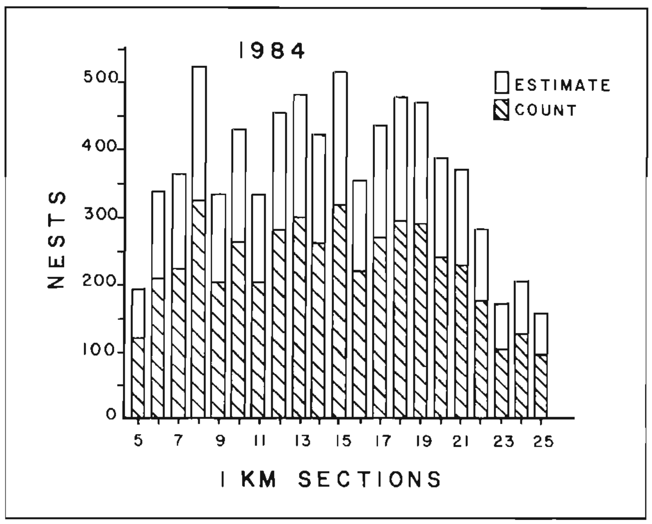

Figure 6—Loggerhead nesting densities (nests/km) in the 21-km survey area between Melbourne Beach and Sebastian Inlet State Recreation Area, 1984. Study area subdivisions (1-km "sections") are designated by distance of northern section limit south of the "0 point" (eastern terminus of U.S. Highway 192 in Indialantic). Survey area began at 5 km south of "0 point" in 1984.

DISCUSSION

In the appendix to the recently completed Recovery Plan for Marine Turtles (Hopkins and Richardson 1984), there is a compilation of loggerhead nesting densities for the entire southeastern United States. Many of the entries were taken from personal communications and unpublished reports, but it constitutes the most thorough summarization of U.S. loggerhead nesting densities thus far accomplished. The data presented there make it clear that the bulk of loggerhead nesting in this country occurs from Brevard County, Florida, south to Broward County, and that the three main areas of concentration are Jupiter Island/Juno Beach, Hutchinson Island, and south Brevard County. Among these, Hutchinson Island supports somewhat in excess of 100 nests/km·year, and the Jupiter Island/Juno Beach area supports slightly in excess of 200 nests/km·year (best year on record). Our results indicate that the more southerly 21 km of Brevard Conty supports between 350 and 450 nests/km·year. It is doubtful that any other beach on the rim of the Western Atlantic supports as much loggerhead nesting.

Unfortunately, depredation of marine turtle nests by raccoons (*Procyon lotor*) and other predators is moderate to excessive throughout the Southeast. Predation rates (on eggs) are commonly in excess of 70%, and nearly 100% are sometimes taken at the Kennedy Space Center and Everglades National Park (Schroeder 1981; Davis and Whiting 1977). In contrast to that, the loss to predators in south Brevard County appears to be exceedingly small, probably less than 5%. One of the most crucial elements in sea turtle reproductive strategy is the necessity to inundate the marine habitat with tremendous numbers of hatchlings, in anticipation of the massive losses to marine predators that are believed to occur. The combination of high nesting density and low predation rate seen in south

Brevard County make it one of very few places in this country where that strategy can work well. Therein lies its importance.

There is, however, a more modern threat to the sea turtle colony at south Brevard. The area is almost entirely in private ownership and is currently being developed at an explosive rate. With beachfront development comes artificial illumination on the dune front. Beginning with Daniel and Smith (1947) and McFarlane (1963), the disorientation of sea turtle hatchlings by artificial lighting is well documented in the scientific literature. Simply put, the hatchlings are unable to find their way to the surf upon emerging from the nest, and whole clutches are often lost to a single bright light. There is a very real need to focus attention on this problem and to promote measures that will maintain darkness as an attribute of the beach environment.

Our results indicate that the density of green turtle nesting in south Brevard County averages somewhat more than 1.5 nests/km · year. That seems paltry when compared with the loggerhead density, but there probably are no areas in this country that support substantially more nesting by this nearly extirpated species. The disastrous effects of artificial lighting on hatchlings apply to green turtles as well; however, there is reason to believe that adult green turtles are more wary of illumination and tend to avoid lighted sections of the coastline. At the same time, however, it also appears they are more prone to return, time and time again (at two- and three-year intervals), to virtually the same location on the coast (Carr and Ogren 1960; Ehrhart 1980). They are, in other words, not as vagile as loggerheads. Just how the few remaining members of this wary, but site-tenacious, species will respond to the increasing beachfront development occurring throughout its breeding range in this country is not possible to say. Insofar as the south Brevard colony is concerned, however, it seems unwise to count on the species shifting to other, less developed beaches, considering that the extent of those beaches is diminishing, that predation rates will be much higher almost anywhere else, and that other, less understood environmental factors may also be less suitable.

ACKNOWLEDGMENTS

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Size, Sex, and Seasonal Variations in Loggerhead Turtle, *Caretta caretta*, Aggregations at Cape Canaveral, Florida[1]

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ABSTRACT

Loggerhead turtles captured in the vicinity of Cape Canaveral, Florida, were predominantly subadults except during breeding and nesting seasons. A size-frequency distribution was bimodal; a group of subadult animals (mean carapace length = 69 cm) comprised 83% of the total captures, and a group of adult turtles (mean carapace length = 95 cm) made up the remaining 17% of the captures. This bimodality suggests that older subadults may be disproportionately sampled, or that they exhibit differential habitat preferences and leave the area with the onset of sexual maturity.

Analysis of the percent composition of adult males, adult females, and subadults on a monthly basis indicated that the population structure changes over the course of the year. Adult males are predominant during April and May, adult females are most abundant from May through August, and subadults are the most common during the remainder of the year.

[1]The information in this abstract is included in the following article: Henwood, T. A. In press. Movements and seasonal changes in loggerhead turtles, *Caretta caretta*, aggregations in the vicinity of Cape Canaveral, Florida (1978-84). (Biol. Conserv. 40.)

Movements of Loggerhead Turtles, *Caretta caretta*, in the Vicinity of Cape Canaveral, Florida, as Determined by Tagging Experiments, 1978-84[1]

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ABSTRACT

Loggerhead turtles, *Caretta caretta*, captured and tagged in the vicinity of Cape Canaveral, Florida (1978-83) were analyzed to determine movement patterns. Three distinct groups of turtles (adult males, adult females, and subadults) occurred in the study area and each was dominant at different times of the year. Adult males were most abundant in April and May, adult females were most common from May through July, and subadults constituted over 80% of the population during the remainder of the year. Separate treatment of the three groups was necessary because movements of one group into the area were apparently correlated with emigration of the remaining two. The data suggest that nesting females are short-term residents who migrate into the area at two- and three-year intervals and reside elsewhere during non-nesting years. Adult male turtles apparently do not migrate with the females, but may reside in the vicinity of Cape Canaveral nesting beaches throughout the year. Subadult turtles forage opportunistically along the Atlantic seaboard, possibly moving northward as waters warm in the higher latitudes and southward with the onset of winter. Evidence suggests that a resident population of subadults overwinters in the Canaveral area each year.

[1]The information in this abstract is included in the following article: Henwood, T. A. In press. Movements and seasonal changes in loggerhead turtles, *Caretta caretta*, aggregations in the vicinity of Cape Canaveral, Florida (1978-84). (Biol. Conserv. 40.)

Behavioral Patterns of Loggerhead Sea Turtles, *Caretta caretta*, in the Cape Canaveral Area as Determined by Radio Monitoring and Acoustic Tracking

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ABSTRACT

A radio monitoring and acoustic study on loggerhead sea turtles, *Caretta caretta*, was carried out in the vicinity of Cape Canaveral, Florida, in March and April 1982. Radio transmitters were attached to 19 turtles, providing information on surfacing behavior for a 35-day period, beginning on March 3. Sonic tags were placed on 10 of the turtles to monitor movement patterns in the Cape Canaveral ship channel. A specific frequency was assigned to each of the turtle radio and sonic tags. Radio tag information was received through a shore-based 23-channel spectrum analyzer, scanning each channel each 100 milliseconds. On each 100-millisecond scan, the maximum strength level for each frequency was recorded and the data were accumulated over a 27-second interval. At the end of each interval, data were recorded for each of the turtle frequencies, indicating whether or not a particular turtle was on the surface within a 10-15 mile range of the receiving tower. Sonic data were recorded from periodic surveys of the area from a small vessel using a mounted hydrophone with an effective listening range of 1/4 to 1/2 nautical mile. Four turtles were followed for 2 hours immediately after sonic tags were applied, and all four of the turtles moved directly offshore. Sonic tag failure rate exceeded 50%, and no data were obtained after 2 weeks. Limited returns indicate at least half of the turtles tagged stayed in the general area for up to one week. Radio tag data collected exceeded 90,000 records with substantial information being obtained from 14 of the 19 turtles. Data were still being obtained from four of the turtles when the experiment terminated on April 6. The mean number of turtle surfacings per hour was 1.3 ± 0.03 at the 95% confidence level.

Mean surface time per surfacing was 2.7 ± 0.22 minutes at the 95% confidence level. The percent surface time for the experiment was 6.0 ± 0.32 at the 95% confidence level. A diurnal pattern was noted for mean surfacings per hour and percent surface time, with approximately 8% of the time being spent on the surface during daylight hours and 4% of the time being spent on the surface during the nighttime hours. A trawl survey of the channel was conducted in late February 1982 to provide estimates of the population size. Aerial surveys were conducted in the area for a 10-day period, beginning on March 2, to combine with surfacing data obtained during the survey for comparison with the trawl survey population estimates. Results of eight aerial surveys over a 300-mile^2 area in the vicinity of Cape Canaveral from March 3-13, using the 6% surface time factor, indicate a population size of $5{,}733 \pm 1{,}283$ sea turtles at the 95% confidence level.

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Sea Turtle Nesting Trends at Kennedy Space Center and Cape Canaveral Air Force Station, Florida, and Relationships with Factors Influencing Nest Site Selection

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ABSTRACT

Baseline marine turtle nesting data, for the loggerhead turtle, *Caretta caretta*, in particular, have been collected at the Kennedy Space Center (KSC) since 1973 to assess the relative importance of the KSC beach in the maintenance of marine turtle populations in the southeastern United States. The data provide a monitoring tool for impact assessment related to the Space Transportation System operations at KSC. Marine turtle crawl counts conducted 1979 to 1984 on the 34-km study beach along KSC and Cape Canaveral Air Force Station demonstrate that high and low nest densities are consistently concentrated in two regions. The high and low nest density areas had significantly different means ($P<0.05$) of 94 nests/km and 39 nests/km, respectively, in 1984. Nest densities were compared with physical parameters of the beach face and nearshore zone. Total crawls were positively correlated with beach face slope ($r=0.86$), with slopes ranging from 3.0° to 12.5°, and negatively correlated with beach width ($r=-0.79$). Nearshore contours influence beach slope and may influence nest site selection. Yearly nest density estimates ranged from 30 (1980) to 106 (1983) nests per km.

INTRODUCTION

Baseline data collection, involving marine turtles along the coast of the Kennedy Space Center (KSC) and Cape Canaveral, Florida, was initiated in 1973 as part of NASA funded ecological studies required for the preparation of an environmental impact statement for the KSC. Prior to 1973, information regarding the status of marine turtles nesting along the expansive government-owned portion of the eastern Florida coast was virtually unknown or at least unpublished in the scientific literature (Ehrhart 1976). Preliminary research included tagging and measuring nesting females. Major baseline activities involving a variety of sea turtle research projects continued through 1979 to provide an assessment of the relative importance of the KSC area in the maintenance of sea turtle populations of the southeastern United States. They also provided baseline data against which subsequent studies, performed after the initiation of space shuttle launches, could be compared for impact assessment. Turtle tagging operations continued through the 1981 nesting season.

Carr and Carr (1977) established that the beach at KSC and the Cape Canaveral Air Force Station (CCAFS) is a primary rookery in the southeastern United States for the loggerhead turtle (*Caretta caretta*). Carr et al. (1982) reported that the Florida east coast nesting population is the largest within its range in the western hemisphere (Fig. 1). Aerial pelagic surveys of marine turtles indicated that loggerhead densities are greater in the vicinity of Cape Canaveral in the spring and summer than anywhere else along the entire U.S. Atlantic coast (Thompson and Powers 1985).

Realizing the importance of this beach, sea turtle crawl surveys were initiated in 1983 to document the distribution of sea turtle nests and activities along the secured KSC-CCAFS beach. The objective was to quantitatively compare crawl activities (i.e., nest densities) in areas adjacent to the Space Transportation System (STS) Launch Complex (LC) 39A with activities observed in nearby isolated sections of the beach that shared similar physical characteristics (Provancha et al. 1984).

Certain trends in nesting densities and apparent correlations with geophysical characteristics of the beach during the 1983 and 1984 surveys led the authors to analyze available nest density data from earlier years. This paper presents the combination of nesting data extracted from the 1979-81 turtle tagging projects as well as the 1983-84 crawl surveys that included physical measurements of the beach.

METHODS

Overall coverage of the various marine turtle studies at KSC extended from North lat. 28°24′00″ (Port Canaveral) to 28°47′30″ (Brevard/Volusia County line) (Fig. 2). In the years prior to STS launches (1973-80), tagging surveys were made from two to seven nights per week ending between 0100 and 0300 hours. The primary focus in these early studies was to obtain data on individual female turtles; since uniform coverage of the study area could not be met consistently, good nesting density estimates were often not attainable. Details of methods implemented during those years are found in Ehrhart (1979).

In 1979, general crawl data were reported for five beach zones or areas of varying lengths (Fig. 3). Area 1 extended 15 km along the KSC-Canaveral National Sheashore (CNS) beach, from the south Volusia County line to Camera Pad 10. Area 2 extended 9 km from Camera Pad 10 to the Playalinda barricade. Area 3, 17 km in length,

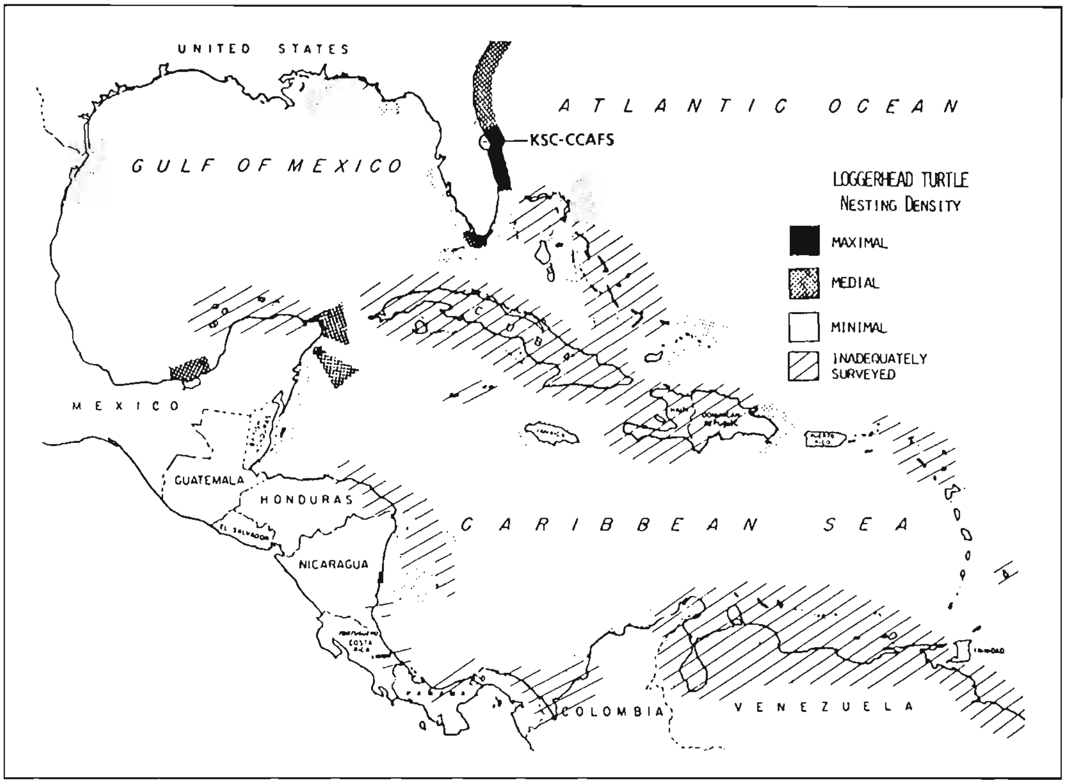

Figure 1—Distribution of loggerhead sea turtle nest densities in the western Atlantic Ocean and Caribbean Sea (after Carr et al. 1982).

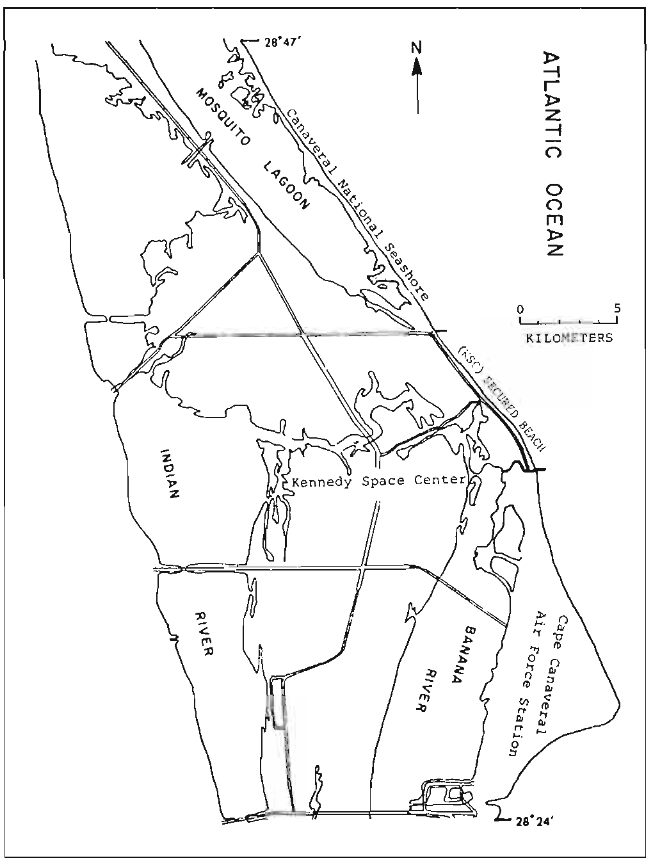

Figure 2—Marine turtle study beach 1973-84 extending along Kennedy Space Center and Cape Canaveral Air Force Station, Florida.

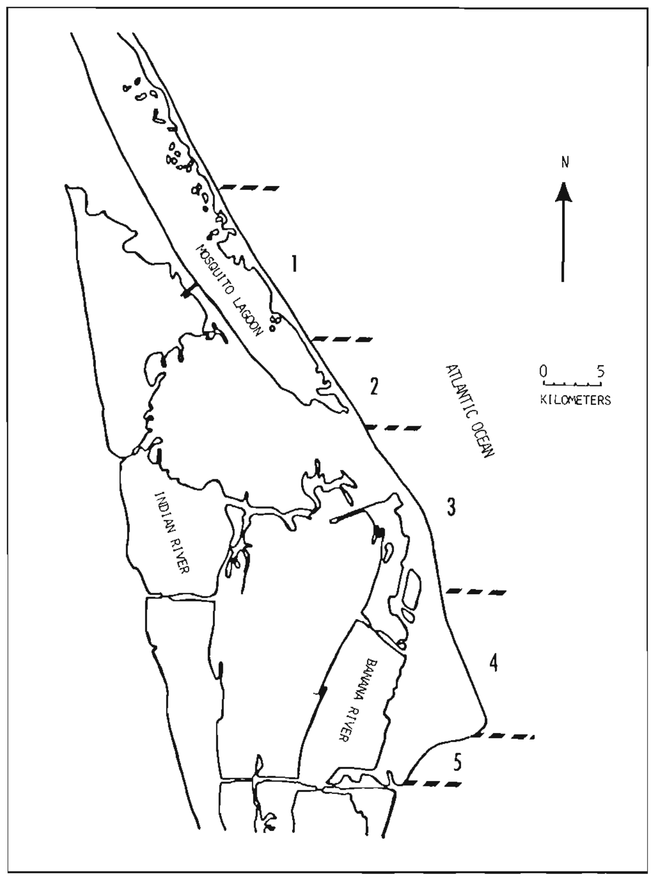

Figure 3—Location of the five major beach zones surveyed for sea turtle nests at Kennedy Space Center and Cape Canaveral Air Force Station, 1973-84.

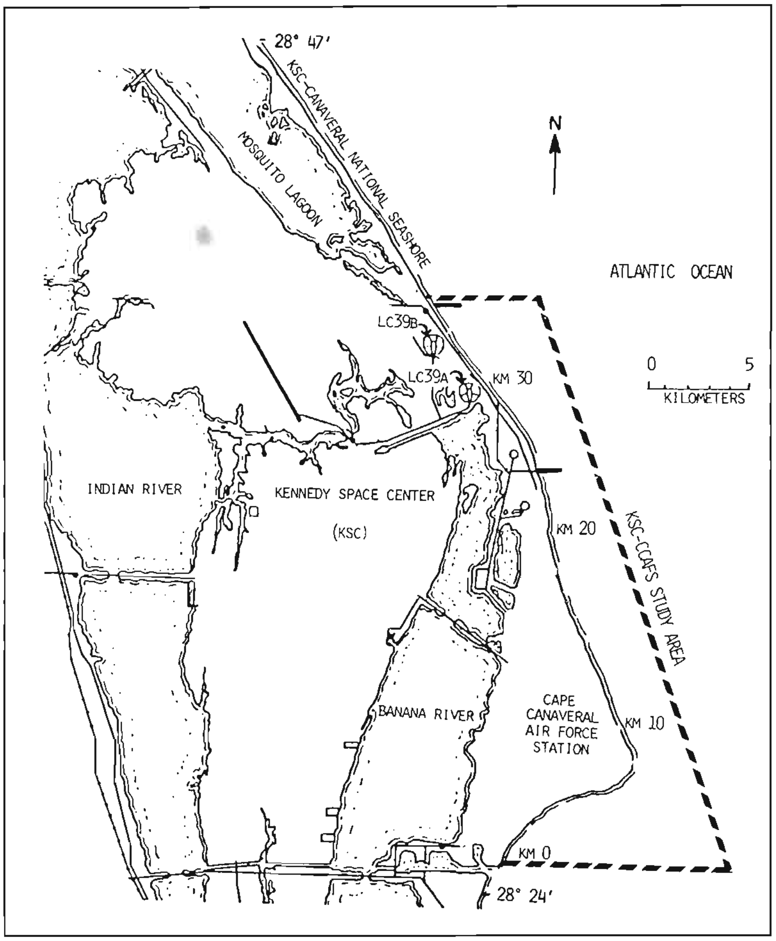

Figure 4—Location of the primary sea turtle nesting study area (km 0-34) along the Kennedy Space Center and Cape Canaveral Air Force Station Beach (1983-84).

was bounded by the Playalinda barricade and the riprap near Complex 34. South of this, Area 4 extended 11 km to Camera Road A. The southernmost zone, Area 5, extended 6 km from Camera Road A to Port Canaveral. More discrete (i.e., within 1 km) locations of the 1979 season crawls within each zone were not available. Consequently, mean nests per kilometer within each of the five areas were calculated by dividing the total number of nests/area by the number of kilometers within the area.

Research efforts were reduced in 1980 and 1981 but emphasized uniform coverage to yield better nest density estimates. However, due to logistical problems, some sections were surveyed less frequently than others. The 1980 and 1981 data, reported in 0.2-mile sections, were standardized to kilometers for comparison with data from 1983 and 1984 for the non-public or "secured" beach (km 0-34). Too few surveys were completed in 1981 at the km 0-7 beach area to make comparisons per kilometer. For each year, the number of nests observed within each kilometer was divided by the number of surveys conducted within the individual kilometer. This allows for within- and between-year comparability despite the lack of uniform coverage in 1980-81.

In 1983 and 1984, marine turtle monitoring was limited to morning "crawl counts" conducted by one or two observers on all-terrain motorcycles along the KSC-CCAFS beach, extending from Port Canaveral inlet (km 0) north 34 km to the southern boundary of Playalinda Beach (Fig. 4). False crawl and nesting data for that area north of km 34 were collected by CNS personnel during 1984. The KSC-CCAFS surveys were conducted after sunrise when most nesting activity had ceased. Data were collected during four consecutive days per week, or eight consecutive days per two-week period, from May through September. Eight survey days in 1983 and five in 1984 were considered tare days, and data gathered on those days were omitted from calculations. Tare days included the first day of an observation week when large numbers of "fresh" and "old" crawls were difficult to distinguish with confidence. The same observers were used both years to keep data collection methods consistent.

Data collected at each crawl included type (i.e., species, nest, false crawl), condition of nest (i.e., undisturbed, disturbed, depredated), location by kilometer, and comments regarding suggested source of predation. General conditions at the site of each crawl (i.e., body pit, thrown subsurface sand) were used to distinguish a true nesting crawl from a false crawl. Nests were not subjected to probing for verification of egg deposition. After notes were recorded at each crawl, tire tracks were made across the crawl near each nest in order to avoid recounts on the following day.

The 1983 and 1984 estimates were weighted by week to account for the change in intensity through the season. Total nests per kilometer for each week were estimated and weekly totals added to yield the overall estimates.

Quantitative field observations of physical beach parameters were limited to the area between the primary dune and the low tide mark. It is possible that basic oceanographic and shoreline data may also be utilized to assist in understanding the nesting distribution. When actual site-specific oceanographic measurements are not available, a certain amount of descriptive information can be extrapolated from inshore beach observations by applying basic beach process principles. The beach face and berm can yield information about the nearshore and littoral zone, as they are very sensitive in response to the forces of currents, waves, and winds (Bascom 1964). Beach slope and width were measured at each kilometer in October of 1983 and in April, July, and October of 1984. To insure comparability, measurements were conducted within one hour of low tide. Slope was determined, using a Suunto clinometer with an accuracy of $\pm 1°$, from the low tide line to the base of the primary dune. If no obvious dune was present, slope measurements were referenced to the point at which beach, sand, and vegetation interfaced. Beach width was measured at that distance along the sand surface, from the low tide line to the primary dune or first vegetation.

The penetrability or compactibility of the sand within each kilometer was considered a possible factor influencing the selection of nesting sites. The mean depth ($N=5$) of penetration of a metal rod (2 cm in diameter) using a standard weight (4.7 kg) was determined at each kilometer marker along the survey area. All penetrometer measurements were taken above the high tide line and seaward of the dune vegetation.

Nearshore bathymetry data were obtained from National Ocean Survey charts (NOAA 1979). Information on current patterns in the vicinity of Cape Canaveral was obtained from the literature.

RESULTS AND DISCUSSION

Species composition

In addition to the loggerhead turtles found here, two leatherback, *Dermochelys coriacea*, turtle nests were reported along this beach in 1983 and 1984, as well as one hawksbill turtle, *Eretmochelys imbricata*, that reportedly nested on the CNS portion of KSC in 1983 (R. Galipeau, Canaveral Natl. Seashore, pers. commun.). *Caretta caretta*, however, represent over 97.5% of the total crawls observed since 1973, with the west Caribbean green turtle, *Chelonia mydas*, comprising the balance. There is some fluctuation in the percentage of *C. mydas* each year as shown in Table 1.

Table 1—Yearly variation in numbers of green turtles, *Chelonia mydas*, nesting at Kennedy Space Center-Cape Canaveral Air Force Station, expressed as the percentage of all marine turtles nesting there.

Year	Percentage of turtles being *C. mydas*
1976	0.9
1977	1.1
1978	2.1
1979	1.4
1980	2.5
1981	1.2
1983	1.8
1984	1.1

Spatial and temporal trends

As stated earlier, the 1979 data were available only per beach subsection rather than on a per-kilometer basis. Figure 5 compares graphically the sea turtle nest densities from 1979 to 1984 in the five areas referenced in Figure 3. Although this graph shows considerably less variation than using data points for each kilometer, the groups of data for later years may be compared with the 1979 data. Area 4, which represents km 7-16 on CCAFS, consistently had the highest nesting densities, while Area 5 (km 0-6) had the lowest nest densities. All of these data are estimates, with the exception of Areas 1 and 2 in 1984, which are observed values based on surveys by CNS personnel during 95 mornings (almost all) of the 1984 season. All data suggest that nesting densities in 1980 were substantially lower over all areas than the other years, while 1983 densities were higher. The data also indicate that nesting densities in 1979, 1981, and 1984 were not statistically different.

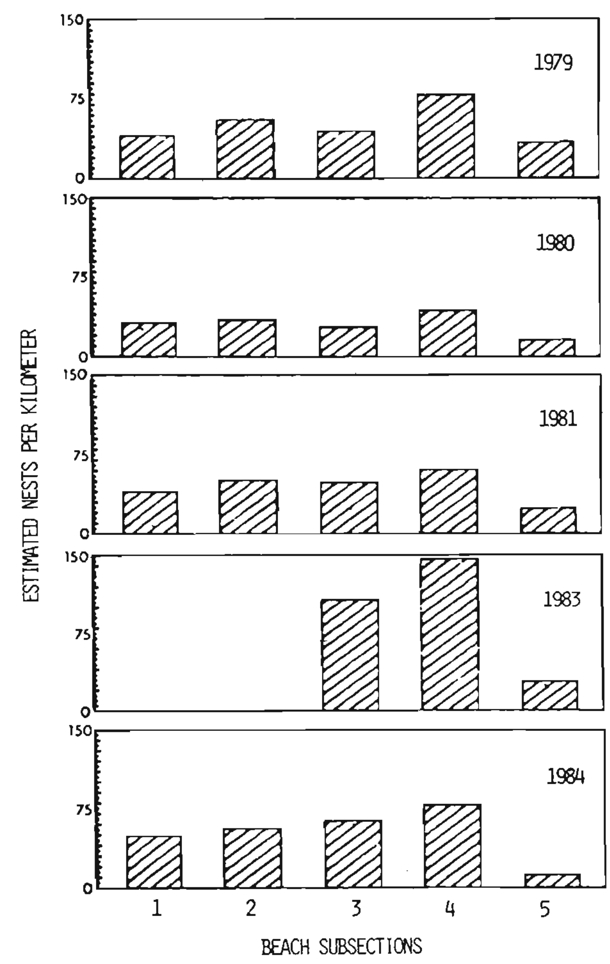

Figure 5—Comparison of nest densities within the five subsections of Kennedy Space Center-Cape Canaveral Air Force Station beach, 1979-84. No data were collected for zones 1 and 2 in 1983.

More detailed data are available for 1980-84 (Fig. 6). It is apparent that the distribution of nests is not random. The 1980 plot in Figure 6 does not have the same strong signature (bimodal distribution) that is evident in the following years. It does suggest that highest nest densities occur between km 10 and km 16 (previously clumped within Area 4) and lowest densities from km

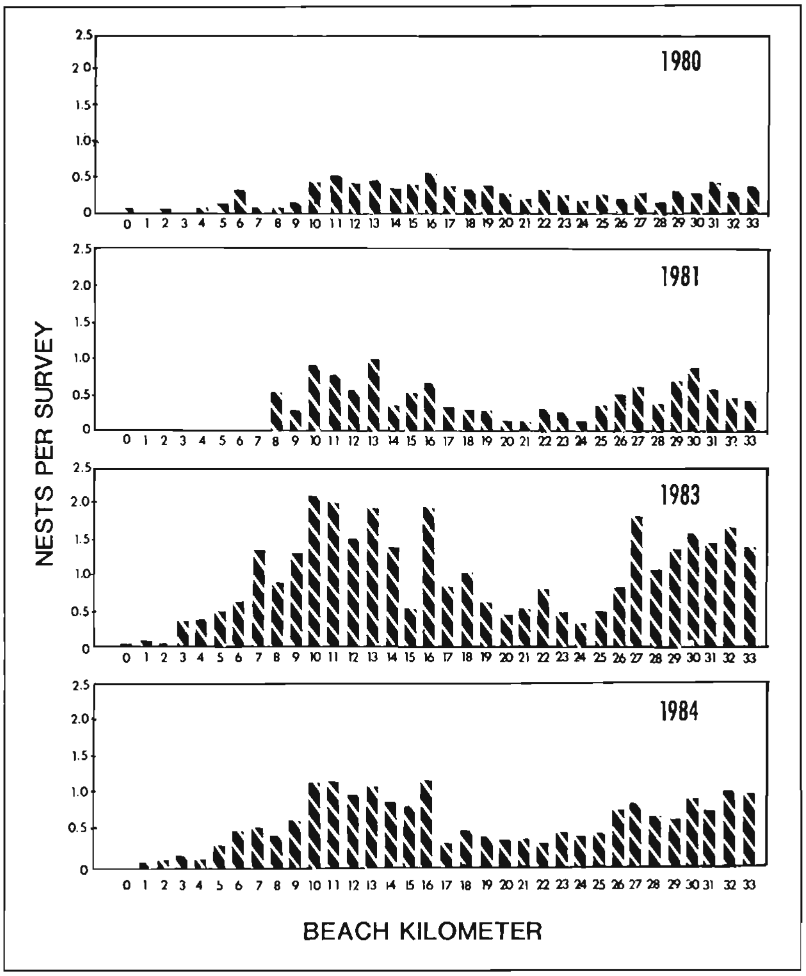

Figure 6—Spatial and temporal trends of sea turtle nesting at Kennedy Space Center and Cape Canaveral Air Force Station, 1980-84. Number of nests per survey effort at each km during the four survey years. Kilometers 0-33 extend from Port Canaveral north to Canaveral National Seashore. Insufficient data were collected for kms 0-7 in 1981.

0-9. Despite the reduced number of surveys in 1981, the 1983 trends reported by Provancha et al. (1984) are observable in the 1981-84 data. The general trend shows a very gradual increase in nest density as one moves north from Port Canaveral (km 0) until a peak occurs in nesting just north of the tip of Cape Canaveral, where it is most obvious between km 10 and km 16. After this peak, there is a significant ($P < 0.05$) decline in nest densities for about 8 km northward along the False Cape. North of False Cape from km 26 to km 33 in the vicinity of the shuttle launch complexes, another increase in nest densities occurs, though not quite as high as that seen to the south. The lack of sensitivity in the clumped data in Figure 5 is most apparent when comparing Figure 5's Area 3 with Figure 6, where Area 3 is found between km 17 and 33. The distinct low, then high, nesting densities seen within Area 3 are not visible in Figure 5. The relative change in number of nests between 1981 and 1983 is consistent with that reported by Harris et al. (1984) for 14 other beaches in Florida. 1983 appeared to be a "good" year for sea turtle nesting, while total emergences and number of nests in 1984 were notably lower. This was similar to observations in south Brevard County (Ehrhart, pers. observ.) and Hobe Sound (F. Lund, Univ Fla., pers. commun.).

Nests per kilometer

The mean nest density for 1984 in the high nest-density areas was 94 ± 19 nests/km, while the mean for the low nest-density area along the False Cape was 39 ± 10 nests/km. Using an approximate t-test (Sokal and Rohlf 1969) performed when variances are unequal, these means are significantly different ($P < 0.05$). Much of the nesting data is summarized in Table 2. The highest nest densities occurred in 1983, with the mean for km 0-34 being 106 ± 65 nests/km, while 1984 had about half as many (56 ± 35 nests/km). The estimated nest/km range for the entire beach in 1983 was 2.4 (km 0) to 226 (km 10) while the observed range was 1-93 nests/km. The 1983 nesting was similar to the mean estimate of 116 nests/km at Hutchinson Island, Florida, during five sample years between 1971 and 1979 (Williams-Walls et al. 1983).

The years 1979 and 1984 were the most similar in comparing overall nest density estimates for km 0-34; 51 nests/km in 1979 and 56 nests/km in 1984. The total number of estimated nests along the beach in a given year ranged from a low of 833 in 1980 to 3,703 in 1983.

As stated earlier, the second peak in nesting densities occurred in the vicinity of the shuttle launch complexes between km 26 and 33. LC-39A is located approximately 0.7 km west southwest of km 29 and 30. The only shuttle launch that occurred during the summer of 1984 was on 30 August near the end of the nesting season. Two shuttle launches occurred during the 1983 nesting season and consequently the pad was illuminated from 26 May to 18 June and from 2 July to 30 August, for a total of 84 nights or 79% of the census period. Based on nest distributions over the season, the data suggest that nesting females were not avoiding the beach areas where activities (i.e., lights) from LC-39A might be expected to have the most impact. In fact, this subsection of beach

Table 2—Summary of marine turtle nesting data collected 1979-1984 at Kennedy Space Center and Cape Canaveral Air Force Station.

Year	Survey area (km)	Nests Est. (Observ.)	False Crawl Est. (Observ.)	NFCR*	Total Emergence Est. (Observ.)	Number of surveys	Mean nests/km Est. (Observ.)
1979[1]	0 - 34	1,728 (1,200)	1,713 (143)	1:0.99	3,441 (1,343)	74	51 (35)
1980[1]	7 - 34	833 (683)	—	—	—	64	30 (24)
1981[1]	7 - 34	1,265 (417)	1,080 (265)	1:0.85	2,345 (682)	29	45 (14)
1983[2]	0 - 34	3,703 (1,532)	2,420 (999)	1:0.65	6,123 (2,531)	53	106 (45)
1983[2]	7 - 34	3,506 (1,451)	—	—	—	53	125 (51)
1983[2]	10 - 34	3,129 (1,295)	—	—	—	53	130 (53)
1984[2,3]	0 - 34	2,078 (1,141)	—	—	—	—	56 (33)
1984[2,3]	7 - 34	2,004 (1,088)	—	—	—	—	71 (38)
1984[2]	10 - 34	1,914 (1,036)	1,332 (720)	1:0.70	3,248 (1,756)	65	82 (44)

[1] = Nightly tagging/Ehrhart
[2] = Morning crawl counts/Provancha
[3] = Morning crawl counts/CCAFS-FWS

*NFCR = Nest to false crawl ratio
Dashes indicate no data available.

still appears to be highly suitable for nesting and is part of a section that is "preferred" by nesting females. No hatchling orientation landward (towards LC-39A) was observed in 1983 or 1984.

False crawls

A large number of false crawls relative to nesting crawls on a given stretch of beach might indicate a constant source of disturbance in the vicinity and/or that the females are selecting nests sites after emergence. With few exceptions, the false crawl densities followed the same spatial trend as the nesting densities. The low nest-density area along the False Cape corresponded to low false-crawl densities, suggesting that females were "selecting against" this area prior to emergence.

The ratio of nests to false crawls (nfcr) along the beach for the various years is reported in Table 2. In 1983 and 1984 false crawls above and below the hightide line were added together to yield a total for each km. The mean nfcr ratio was 1:0.7 for the two years, varying from 1:0.2 to 1:14.2. The lowest nfcr ratio (1:14.2) occurred in 1983 at km 2 near Port Canaveral. The beach sections in the vicinity of LC-39A (km 29, 30, 31) had nfcr ratios slightly lower than the mean in 1984 at 1:1.4, 1:0.85, and 1:0.95, respectively. In 1983, km 29 and 31 had nfcr ratios at the mean while km 30 had an nfcr ratio below the mean at 1:1.08. Whether or not these data can be used as indicators of habitat suitability change is questionable. In areas where obvious nesting obstructions occur, such as riprap, the nfcr ratio is typically below the mean.

Numbers of nesting females

It was not rare to find a female nesting after sunrise in 1983 and 1984. This agrees with observations by Fritts and Hoffman (1982) of diurnal nesting in Brevard County. The data from 1979-81 may represent relatively low estimates as data were generally collected before 0300 hours and late morning crawls were not included.

Determining the actual numbers of females nesting on the beach using morning crawl surveys is impossible. The mean within-season renesting frequency is subject to variation from year to year (Ehrhart 1979; Carr et al. 1982; Richardson and Richardson 1982; Hughes 1982). However, by applying the renesting mean of 2.5 for the KSC loggerheads derived by Ehrhart (1979), an estimate can be obtained. Assuming there are 2.5 nests/female each season, estimates of 3,703 nests in 1983 and 2,078 nests in 1984 yielded 1,481 and 831 females nesting in the KSC-CCAFS study area in 1983 and 1984, respectively.

Physical parameters

Mortimer (1982) and Caldwell (1959) attempted to correlate nesting density with various physical characteristics of the beach and nearshore zone as well as other environmental factors. Caldwell (1959) reported no correlation between nesting activity and the stage of the moon or tide, and concluded that physical features of the beach were apparently the most important factors in determining the degree of nesting activity. He described six beach types characterized by several parameters and concluded that turtles preferred to nest on high beaches backed by rounded dunes. Mortimer (1982) concluded that sand types were probably less important in the selection of nesting beaches by green turtles than were the slope and offshore configuration of the beach, although slope measurements were not reported. Mortimer successfully correlated beach length with nesting density ($r=0.92$) at Ascension Island. Williams-Walls et al. (1983) were unable to consistently correlate beach width and subtital characteristics with nesting density at Hutchinson Island.

Least squares curve fit analyses (LSCFA) of the 1983 data demonstrated that nesting densities did increase with beach slope ($r=0.83$) but also that the error of regression was directly related to slope. The sand in these high nest-density sections also appeared to be coarser and the surface less resistant to penetration. Komar (1976) and Bascom (1964) explained that coarse sand beaches are generally steeper in slope than fine sand beaches. The characteristic slope of a beach face is the result of several semi-independent factors acting together, including grain size, wave energy level, wave steepness, sediment sorting, water table level in the beach, and tidal stage. These data are involved in the general description of high-energy and low-energy beaches. Sections of the KSC-CCAFS seashore that are high-energy beaches were found to correspond with highest nest densities, and low-energy beaches corresponded to low nest densities in the vicinity of the False Cape.

The beach face slopes measured in July 1984 (during the peak of the nesting season) ranged from 3° to 12.5° and the width measured 25 to 74 m. Figure 7 shows the relationship between beach

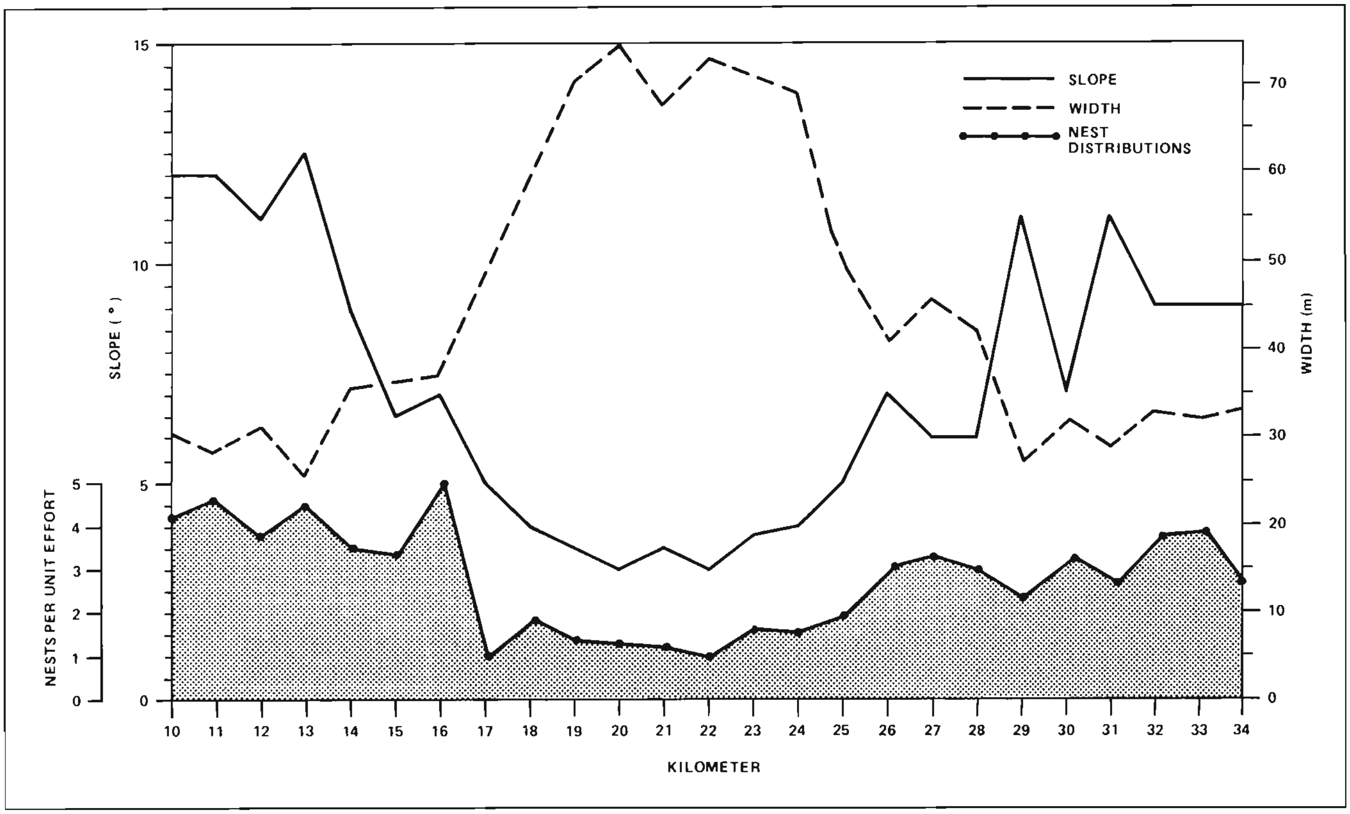

Figure 7—Relationships between sea turtle nest densities, beach slope, and beach width at Kennedy Space Center-Cape Canaveral Air Force Station, July 1984. Nests per survey represent relative nest density.

slope, width, and nesting densities at KSC-CCAFS. The LSCFA r-value for July 1984 was 0.81 for slope and nest density, while the correlation of slope to total emergences was higher ($r = 0.86$). The slope and width are highly correlated (inversely) to one another as expected. Total emergence was negatively correlated ($r = -0.79$) with beach width. Thus, females appear to select nesting areas prior to emergence. When the false crawl/total emergence ratio was compared with beach slope, no correlation was found.

The sand resistance or compaction and nesting densities for each km are shown in Figure 8. The data for kms 13, 14, and 15 deviate from the general trend for the entire beach and cannot be explained. LSCFA showed significant but low correlation for these parameters ($r = 0.54$). Sand resistance measures the relative ease of penetrating the sand which may in turn relate to grain size and sorting (two parameters which were not measured). The mean sand penetrability for the high nest-density sections was 11.1 $\pm$ 2.0 (cm) while that for the low nest-density sections was 8.4 $\pm$ 1.0 (cm). Bascom (1964) and Komar (1976) reported profile characteristics that are normally associated with the characters measured at our two beach types (high nesting density vs. low nesting density), and thus we can form an extrapolated but potentially more insightful description of a "preferred" nesting beach along the KSC-CCAFS shore. Such a description is outlined in Table 3.

The depth contours within 3 nautical miles of the 1984 study beach (km 10-34) are shown in Figure 9. It is striking to note that the kms with low nest densities are concentrated along the False Cape and delineated by a long, trenchlike 35-ft (10.7 m) isobath that is approximately 0.5 km east of the False Cape and bound to the east by Chester Shoals. A marked contrast is seen in the area immediately south (just north of the tip of Cape Canaveral). This section has consistently had the highest nest densities within the study area. The isobaths are serrated and the profile is a gradual seaward slope not reaching 35-ft depths within the first nautical mile. The intermediate nest densities occur to the north of the False Cape, on KSC, where a 35-ft isobath occurs relatively nearshore but is highly branched. Another perspective is shown in Figure 10. Depth profile comparisons were made for the low and high nest-density areas by plotting the profile from a point within a representative kilometer from each area type. Kilometer 10 represents the high nest-density area, km 23 represents the low, and km 29 represents the medium-to-high nest-density area. Notice the relatively steep slope of km 23 when compared with km 10. This would fall into Komar's (1976) category of "less shallow nearshore" listed in Table 3.

Literature reviews and personal communications with meteorologists and oceanographers familiar with the southeastern U.S. coast revealed that very little detailed information pertinent to the study area has been collected over the last 20 years. Most of the nearshore data from other areas cannot be assumed to relate to the study area, especially considering local influences from the projection of the Cape itself. A special study, similar to that done with green turtles at Tortuguero (Meylan 1978), would have to be implemented to obtain the data necessary to address the role of currents on sea turtle movement to Cape Canaveral nesting sites.

The data that have been collected in the vicinity of Cape Canaveral have shown that it is located in a "meteorological transition zone" with an offshore bathymetry of complicated shoals and sediments ranging from silt to hard reef formation (USAEC 1970). The continental shelf lies approximately 50 km east of the Cape. Blanton et al. (1981) reported topographically induced upwelling just north of Cape Canaveral. They reported that the regions where

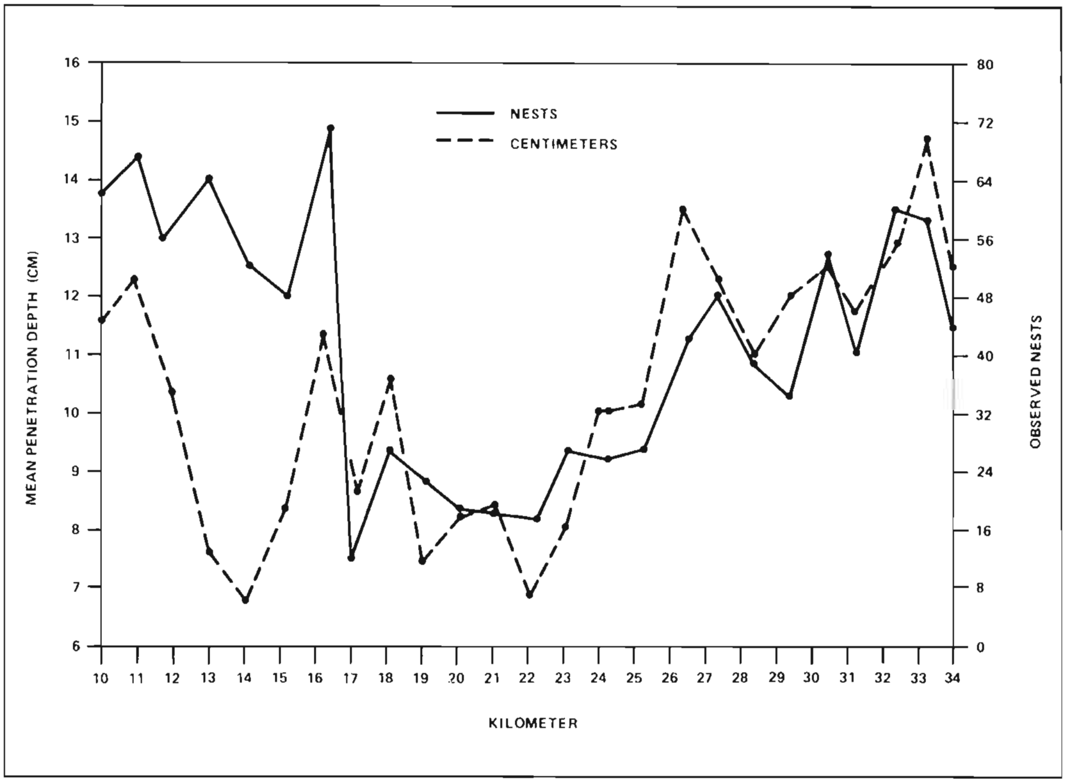

Figure 8—Comparison of nest densities and relative sand penetrability or resistance (cm) at km 10-34, Kennedy Space Center-Cape Canaveral Air Force Station, 1984.

Table 3—Beach profile characteristics associated with high and low nest-density beaches at Kennedy Space Center-Cape Canaveral Air Force Station in 1984. Associations made by actual measurement (m), visual observation (o), or extrapolations (E) from Komar (1976).

High nesting (km 10-17 and 26-33) $\bar{x}$ = 94±19 nests/km	Low nesting (km 18-24) $\bar{x}$ = 39±10 nests/km
[m]Steep slope $\bar{x}$ = 9±2°	[m]Mild slope $\bar{x}$ = 4±0.9°
[m]Narrow beach $\bar{x}$ = 33±5.6 m	[m]Wide beach $\bar{x}$ = 64±9.9 m
[o] Coarse sand	[o] Fine sand
[o] Distinct berm	[o] No distinct berm
[o] Shallow nearshore	[o] Less shallow nearshore
[E] High percolation rate	[E] Low percolation rate
[E] Low wave-energy level	[E] High wave-energy level
[E] Low wave steepness	[E] High wave steepness
[E] Few or no longshore bars	[E] Many lonshore bars
[E] Onshore sediment transport increased	[E] Onshore sediment transport decreased

isobaths diverge (north of capes and shoals) "force the flow of shelf water to change vorticity and induce upwelling." Atkinson and Targett (1983) found that fish concentrations were highest in areas of pronounced upwelling off Cape Canaveral, south Georgia, and South Carolina during their survey which extended from Cape Canaveral to Cape Hatteras. Thus, the waters off Cape Canaveral are apparently highly productive and constitute what might be referred to as a biological "hot spot."

The concentrated biological activity in the area could provide several advantages to turtles. It may serve as a strong signature that assists in locating the east central Florida beaches. If nesting females feed in the nesting habitat, this area should provide excellent foraging grounds. The area would simultaneously have possible disadvantages with likely increased concentrations of predators and increased incidental conflicts with fishermen.

Nontidal drift experiments off Cape Canaveral were conducted by Woods Hole Oceanographic Institution during 1962. The experiments showed that a northerly nontidal current is present from November to June and a southerly nontidal current exists from July to October (Bumpus 1964). This reversing nature was said to increase the possibility that "introduced materials" will remain in the area. This idea was supported by Leming (1979), who reported that the projection of the Cape causes "interruption and eddying" which in turn cause repetitive settling of scallop larvae off Cape Canaveral. In early spring, Bumpus (1964) found little stratification and no dynamic current within 16 km of shore. A southerly component next to the shore was found that extended as far south as the eastern tip of the Cape and then extended offshore. A northerly component ran along Cocoa Beach and then extended offshore at Port Canaveral south of the Southeast Shoal (Fig. 11). Based on this description, one might speculate that if nesting sea turtles are

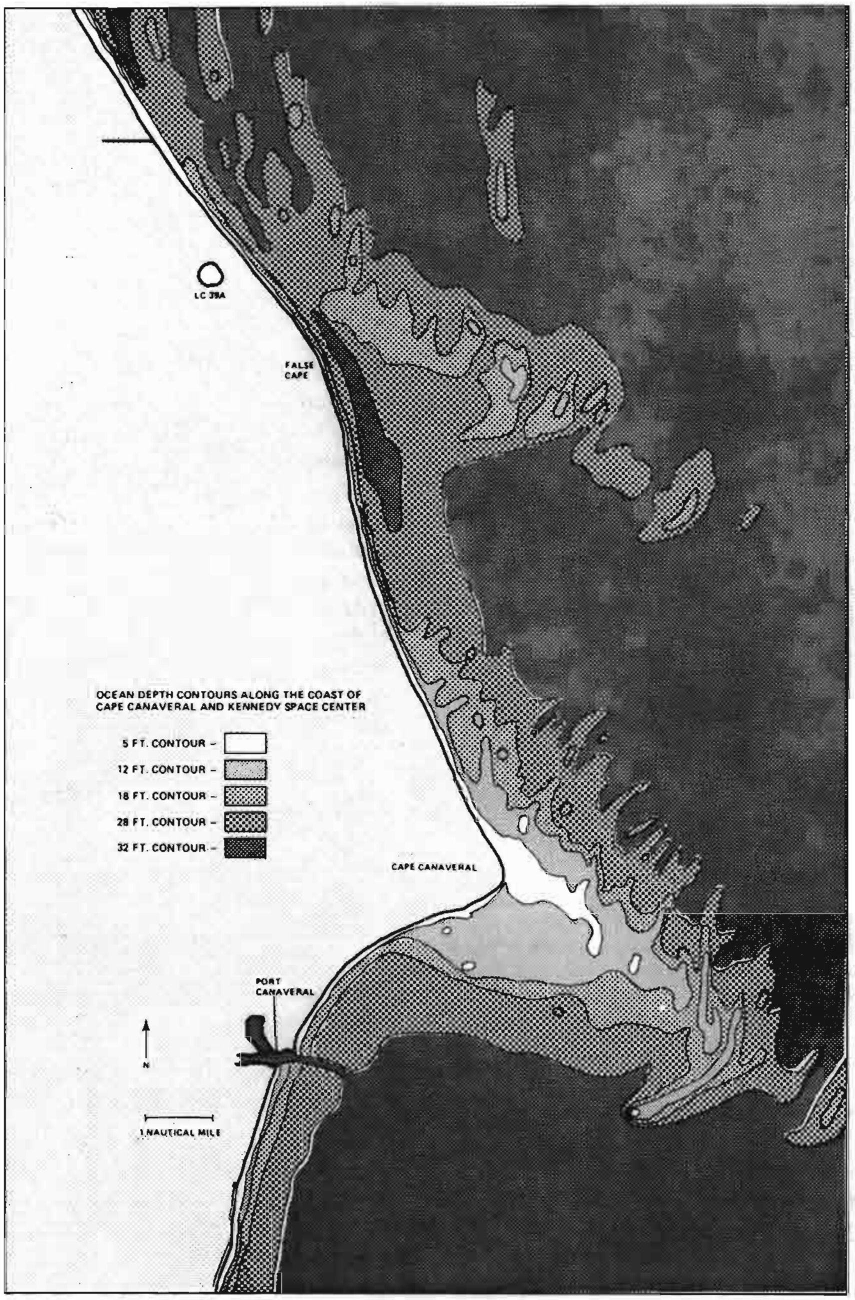

Figure 9—Nearshore contours along the Kennedy Space Center-Cape Canaveral Air Force Station beach within 3 nautical miles.

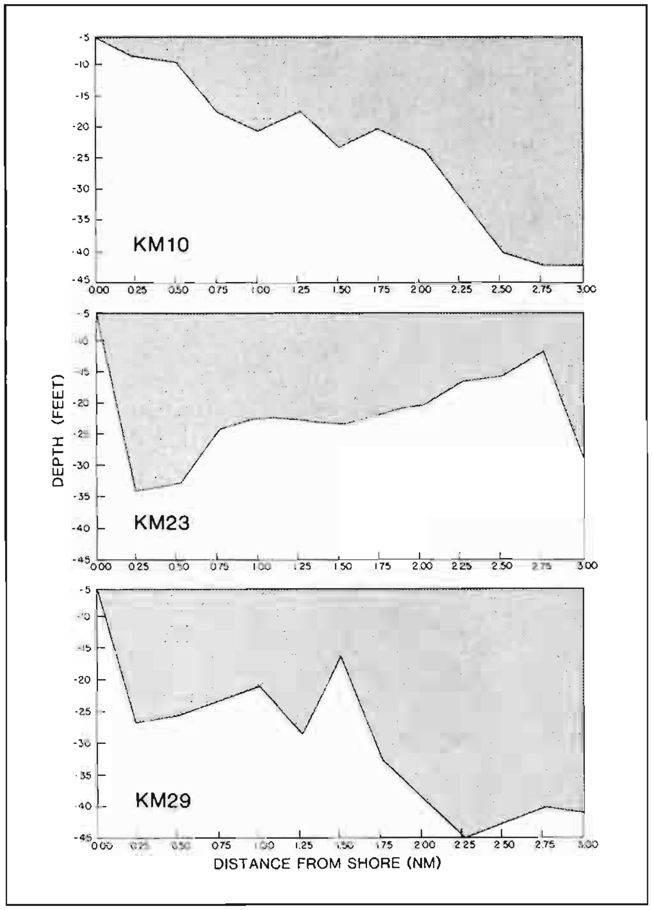

Figure 10—Depth profiles for high and low nest-density beaches at Kennedy Space Center-Cape Canaveral Air Force Station, where km 10 represents high, km 29 represents medium, and km 23 represents low nest-density beach.

strongly influenced by such currents, it could explain the relatively low numbers of crawls found south from the tip of the Cape to Port Canaveral. This is not to negate the possibility that the high level of human activity at and south of the Port may be a stronger influence on nesting. These current patterns also lead one to wonder what effect they have on local hatchlings during the migration away from the beaches.

SUMMARY

The 1979-84 sea turtle nest density estimates for the KSC-CCAFS range from 30 nests/km in 1980 to 106 nests/km in 1983. An estimated 1,481 (1983) and 831 (1984) females nested on the secured or "non-public" KSC-CCAFS beach (km 0-34). The nesting distribution was not random and was repeated each year, with the highest nest densities found in two peaks. One peak was seen in an 8-km section of KSC beach that was in the vicinity of the STS launch pads; the other consistently higher nest density peak was seen at a 7-km section of beach originating just north of the easterly tip of Cape Canaveral. The two peaks were separated by a relatively low nest-density area in the region of the False Cape. A second low nest-density area repeatedly occurred at the south end of the study area near Port Canaveral. The data indicate that the beach near LC-39A is part of a section that is suitable for nesting and could be referred to as "preferred," as there were no obvious indications of avoidance by nesting females.

Total emergences and nest densities were correlated to beach slope and width in most cases. Steeply sloped beach sections had higher nest densities ($r = 0.83$) and higher total emergences ($r = 0.86$). Sand compaction or resistance showed a statistical correlation of ($r = 0.54$). Offshore contours may also play a part in nesting beach site selection. A gradual increase in depth seaward defines the depth contours for the beach section with the highest nest densities (and steep beach face slope). The low nest-density area bordered by the two peaks in nesting was characterized by a nearshore "trough" or drop off, bordered to the east by shoals.

As shown by Bascom (1964) and Komar (1976), beach slope is highly correlated to a variety of offshore semi-independent factors. Because of the slope and total emergence relationship, one would conclude that nest site selection is determined prior to emergence and is influenced by one or more offshore parameters that are correlated to steep beach slope (i.e., depth contours, wave energy). These offshore characteristics appear to be cueing KSC-CCAFS female loggerhead turtles to their nest sites which coincidentally are steeply sloped beaches, or perhaps the turtles are using the offshore cues to "select for" a steeply sloped beach.

The current patterns in the vicinity of Cape Canaveral may motivate sea turtles to utilize this section of the Brevard County coastline rather than immediately south or northward. The eddying created by the currents may also play a role in inhibiting emergences just south of the tip of Cape Canaveral.

ACKNOWLEDGMENTS

We greatly appreciated the support from Paul Buchanan, William Knott, and Albert Koller, Jr. (NASA, KSC, Biomedical Office contracts NAS10-10285 and NAS10-8986) without whom this monitoring project would not have been possible. Ross Hinkle and Mark Provancha (The Bionetics Corporation) and Paul Raymond (National Marine Fisheries Service) were sources of constant encouragement as well as dedicated field observers. The interest and assistance from KSC Security and CCAFS Security personnel were invaluable. We thank R. Galipeau (CNS) for graciously summarizing the CNS data for us. M. Mercandante and B. Finger (USFWS Coop Unit/CCAFS) made nest counts on the CCAFS beach for a predator control study, and we appreciated the open lines of communication as we shared part of the study area. We acknowledge the impressive efforts put forth by the "turtle crews" made up of University of Central Florida students and USFWS-MINWR personnel from 1973 to 1981. C. T. Gaetz (The Bionetics Corporation) set up our database and skillfully performed the statistical analyses. T. Layer (EG&G) provided assistance with graphics. M. Provancha and Nat Frazer (University of Georgia) provided great assistance in review of this manuscript. The quality of the final draft was improved by an anonymous reviewer. The Florida Department of Natural Resources is acknowledged for funding contributions in 1979.

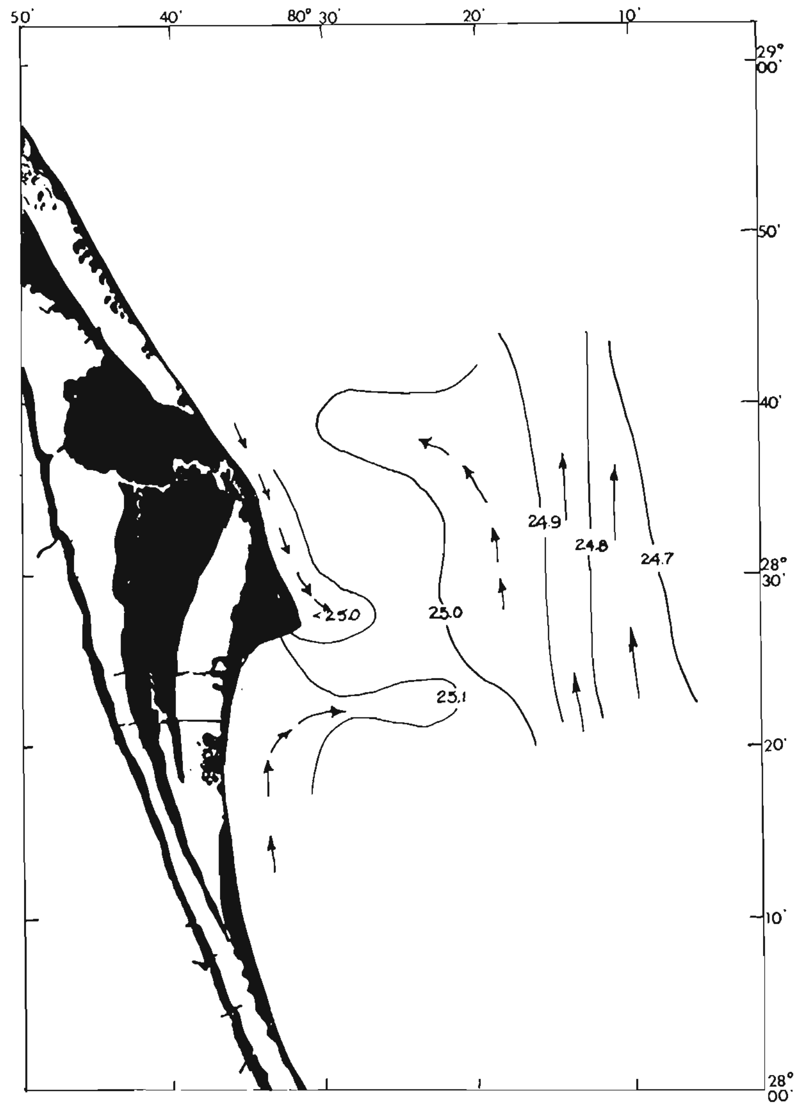

Figure 11—A plot of the distribution of O_t at 10 meters in the vicinity of Cape Canaveral, Florida, spring 1962 (from Bumpus 1964).

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Distribution of the Loggerhead Turtle, *Caretta caretta*, and the Leatherback Turtle, *Dermochelys coriacea*, in the Cape Canaveral, Florida Area: Results of Aerial Surveys

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ABSTRACT

Aerial surveys were conducted in the Cape Canaveral, Florida, area from the shoreline to the western boundary of the Gulf Stream to provide distributional and numerical abundance data on marine turtles over a three-year period (March 1982-August 1984). The two most commonly sighted species were the loggerhead turtle, *Caretta caretta*, and the leatherback turtle, *Dermochelys coriacea*. A total of 2,346 loggerheads and 128 leatherbacks were sighted in the study area. Peak sightings of loggerheads occurred during the spring and summer surveys. Seasonal distribution trends of leatherbacks were more pronounced; 90.6% of all leatherback sightings occurred during the summer surveys. Loggerheads were sighted in both innershelf (0-20 m) and midshelf (20-40 m) waters during all seasons except winter, when they appeared to concentrate on the midshelf. Leatherbacks were sighted primarily on the midshelf. Both species were rarely sighted in waters exceeding 60-m depth.

INTRODUCTION

Evidence accumulated over the past decade has established the significance of the central east coast of Florida (including Cape Canaveral and surrounding waters) as an important marine turtle habitat. Research has focused primarily on the nesting population of loggerhead turtles, *Caretta caretta*, because of the accessibility of females when they come ashore. Aerial and ground surveys of this area's beaches have provided data used to estimate the annual numbers of nests and nesting females. The magnitude of these estimates supports the importance of this region as the largest loggerhead nesting aggregation in the western hemisphere (Lund 1974; Carr and Carr 1978; Bjorndal et al. 1983; Hopkins and Richardson 1984; Murphy and Hopkins 1984; Raymond 1984; Shoop et al. 1985; Ehrhart and Raymond 1987).

In addition to the importance of the nesting beaches, the Indian River system has been identified as a developmental habitat for immature loggerhead and green turtles, *Chelonia mydas* (Mendonca and Ehrhart 1982; Ehrhart 1983). Concentrations of loggerheads in the Port Canaveral channel prompted the National Marine Fisheries Service, Southeast Fisheries Center (NMFS/SEFC), to conduct intensive trawling surveys in this area to define seasonal occurrence, provide population estimates, and collect other biological information on turtles inhabiting the channel (Butler 1983; T. Henwood, Pascagoula Lab., Natl. Mar. Fish. Serv., NOAA, Pascagoula, MS 39567, pers. commun. May 1985). The aggregation sampled in the Port Canaveral channel is the most concentrated ever reported for any marine turtle species in a non-nesting habitat (Carr et al. 1981).

Information collected on populations which are accessible on nesting beaches, captured in shallow lagoons, or concentrated in channels is augmented by data obtained from aerial surveys of the adjoining pelagic habitat. Aerial surveys conducted by Carr and Carr (1978) and Fritts et al. (1983) provided initial information on marine turtle distribution in waters off selected areas of the east coast of Florida.

In April 1982, a three-year aerial survey research program was developed and initiated by the NMFS/SEFC (Southeast Turtle Survey - SeTS). This was the first program specifically designed to collect data and provide information on marine turtle distributions, numerical abundance, and seasonality of occurrence in the pelagic environment off the southeast United States from Cape Hatteras, NC, to Key West, FL. In this paper we address distributions of only the two most commonly observed species within the SeTS study area: the loggerhead, *Caretta caretta*, and the leatherback, *Dermochelys coriacea*. While the entire SeTS study area encompasses approximately 56,000 km^2 (30,000 nmi^2), the present paper is limited to sightings within the Cape Canaveral area, which is treated as a subsample of the entire SeTS effort (Fig. 1).

METHODS

Study area

The Cape Canaveral area, as we define it, encompasses the pelagic area between 27°00′N and 30°00′N, extending from the shoreline to the approximate western boundary of the Gulf Stream (Fig. 2). The total survey area is approximately 10,190 km^2 (5,500 nmi^2).

The topography of the continental shelf is relatively simple throughout the study area, consisting of a broad shallow shelf with

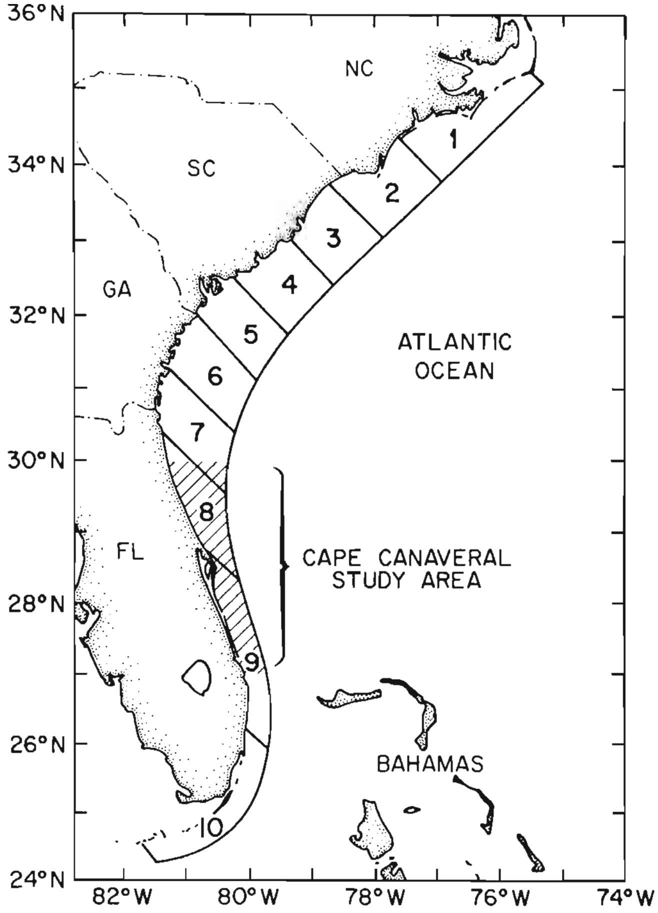

Figure 1—Southeast turtle survey (SeTS) sampling area, Cape Hatteras, NC, to Key West, FL (survey blocks 1-10). In the present study, data collected from the Cape Canaveral area (indicated by cross hatching) are examined.

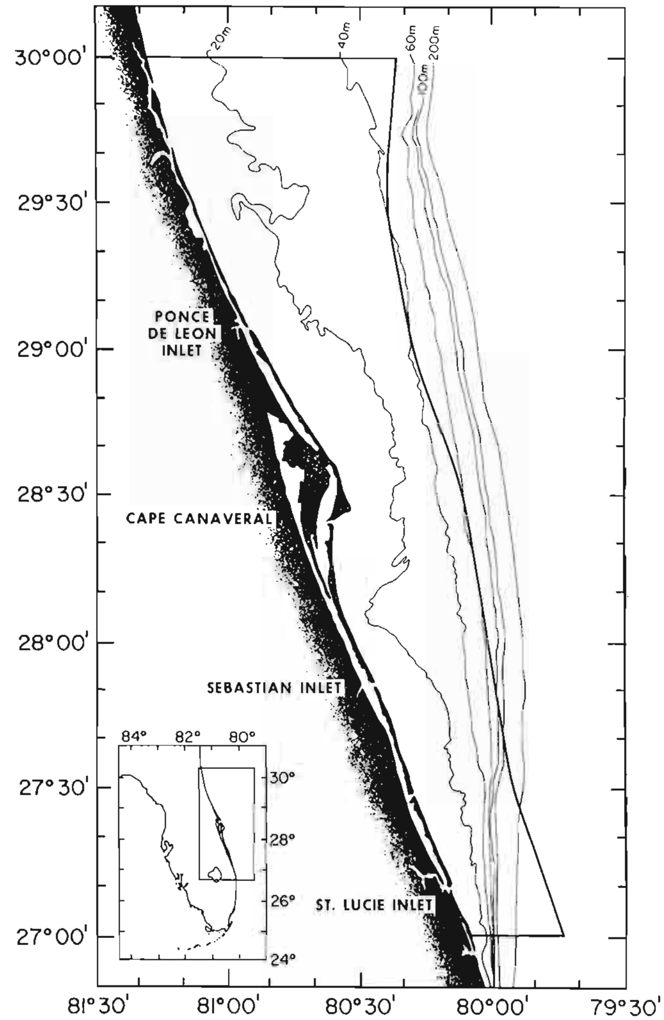

Figure 2—The Cape Canaveral study area, central east coast of Florida. Bathymetric contours are indicated in meters.

a primarily sandy bottom that slopes gently to a rather sharp shelf break at about 75 m depth (Lee and Atkinson 1983). The study area is represented primarily by the inner shelf from the shoreline to the 20-m isobath and by the middle shelf from the 20-m to 40-m isobath. In the southern portion of the study area, below 27°30′N, much deeper waters occur (Fig. 2).

Sampling design

Nine seasonal surveys were conducted in the study area from April 1982 to August 1984. Season, year, and actual flight dates are summarized in Table 1.

Flight lines were randomly selected for each survey from transect lines placed one nautical mile apart throughout the study area. The initial level of effort was to sample 8% of the study area during each seasonal survey. This level of effort was expended in the Cape Canaveral area for eight of the nine surveys. The level of effort was reduced by 50% (4% effective sampling area) during the fall 1983 survey to accommodate limited funding. The actual transect lines selected and sampled during the summer 1984 survey are shown in Figure 3. Transects were oriented in a northwest to southeast direction to minimize the effects of glare and optimize coverage over all depth strata. Three days were utilized to complete the transects within the Cape Canaveral area during each seasonal survey. Transects were not replicated within a survey.

Table 1—Season, year, and flight dates of pelagic aerial surveys in the Cape Canaveral study area.

Season and survey year	Flight dates
Spring 1982	21, 22, 27 April
Summer 1982	19, 21, 24 July
Fall 1982	19, 22, 25 October
Winter 1983	24, 25, 26 January
Spring 1983	21, 22, 27 April
Summer 1983	18, 19, 21 July
Fall 1983	4, 5, 13 November
Spring 1984	29 April, 1, 5 May
Summer 1984	27, 28, 29 July

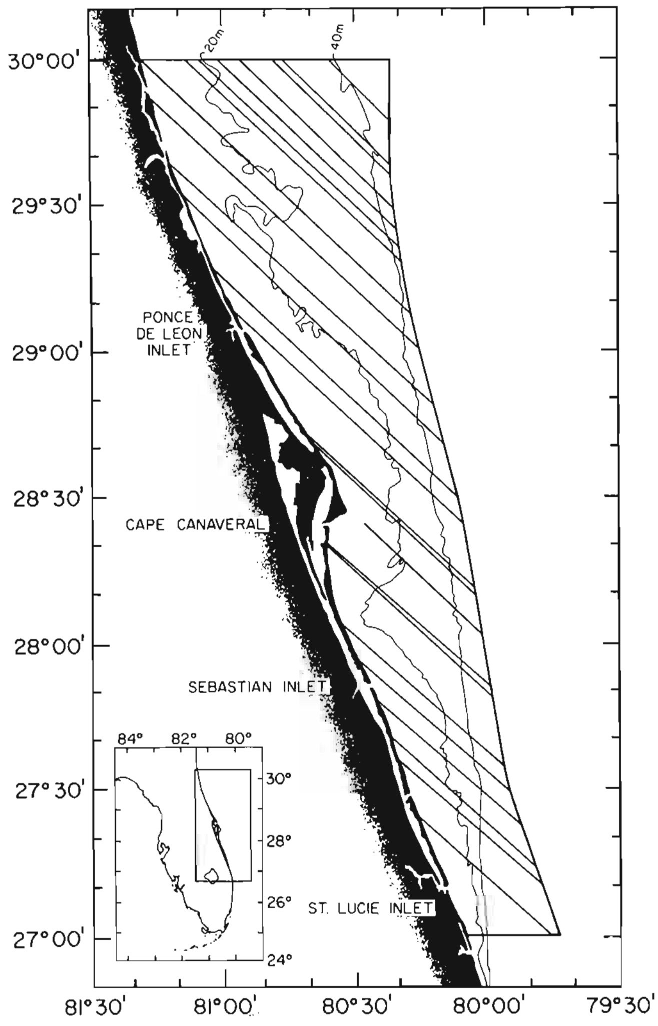

Figure 3—Transect lines selected and sampled in the Cape Canaveral area during the summer 1984 survey.

Surveys were flown in a Beechcraft AT-11 twin engine aircraft equipped with a plexiglass and glass bubble observation nose. The bubble nose allows a direct and unobstructed view of the trackline. In addition to a pilot and copilot, four observers were aboard for each flight. Sightings were reported by the observers stationed in the observation bubble. Observers rotated through the bubble approximately every hour to minimize observer fatigue over an average eight-hour survey day. Survey altitude was maintained at 152 m (500 ft) and transects were flown at a groundspeed of approximately 222 km/h (120 kn).

A Hewlett Packard 85 (HP-85) microcomputer with an internal clock was utilized for direct entry of environmental data, sighting data, and transect information. Positions, as latitude and longitude, were determined with a TDL 711 LORAN C navigational system, and sea surface temperature was sampled by use of a Barnes PRT radiometer. Direct inferfacing of the HP-85 with the LORAN C and radiometer enabled automatic entry of position and sea surface temperature at one-minute intervals or on demand at each sighting.

All sightings were assigned a species identification reliability code of positive, probable, or unsure. Only positive species identification sightings of loggerheads and leatherbacks were used in this analysis.

RESULTS AND DISCUSSION

Caretta caretta

A total of 2,346 positive reliability sightings of loggerhead turtles were recorded during the nine seasonal surveys. The distributions of loggerheads within the study area (by season) are shown in Figures 4-7. Figure 8 summarizes seasonal trends of *Caretta* sighted over the three-year survey period.

The probability of observing a turtle (i.e., recording a sighting) on a transect line is influenced by a multitude of factors. These include but are not limited to environmental variables such as sea state, sun glare, time of day, water depth, and water temperature. Biological factors which may influence distribution include reproductive activity, feeding ecology, prey distribution and abundance, time spent at the surface, and physiological constraints. Undoubtedly, some combination of these and other factors influence turtle distributions in a specific area. The experimental design and field implementation of our aerial surveys in the Cape Canaveral area allow comparisons of spatial distributions among surveys based on the assumption that the environmental variables of sea state, sun glare, and time of day do not differ significantly among these surveys. A detailed analysis of the effects of these and other factors on turtle sightability will be published elsewhere.

Over the course of the study period, loggerheads were sighted in all parts of the Canaveral study area. Notably, loggerhead sightings were infrequent in the southeast corner of the study area, east of the 100-m isobath, where only 22 of 2,346 sightings (0.9%) occurred. While most of the study area's eastern boundary approximately follows the 40-60 m isobaths, water depth increases rapidly in the southeast corner where the main axis of the Gulf Stream actually enters the study area from the south. A lack of sightings in the Gulf Stream axis and associated deeper waters was similarly observed and reported by Hoffman and Fritts (1982). Our data support their hypothesis that this distributional pattern most likely reflects limited availability of prey items and an avoidance of the northward flow of the Gulf Stream.

Sea surface temperatures recorded in the Canaveral study area ranged from a low of 13°C during the winter 1983 survey to a high of 31°C during the summer 1982 survey. Loggerheads were observed primarily in the midshelf waters of the study area during fall and winter surveys (Figs. 5, 6C). In contrast, the distribution of sightings appears more uniform over midshelf and innershelf waters during the spring and summer surveys. Temperatures recorded from the innershelf waters (west of the 20-m isobath) during the winter 1983 survey were consistlently below 20°C, and only 14 of 68 turtles (20.6%) were sighted in those inshore areas. A steady increase in sea surface temperature was recorded as we sampled offshore along the transect lines.

Temperatures at which marine turtles begin to exhibit cold stunning behavior have been reported as 9.5°C by Schwartz (1978) for captive *Caretta* and between 4°C and 7°C by Ehrhart (1980) for loggerheads in the Indian River complex, Florida. Although the minimum temperature we recorded on the innershelf during the winter 1983 survey (13°C) is higher than both cold-stun temperature limits, the winter distributional pattern may indicate a preference for warmer Gulf Stream boundary waters over the midshelf.

Distributions during the fall 1982 and fall 1983 surveys yielded similar results, with turtles apparently concentrating in the midshelf waters (Figs. 5A, 6C). The sea surface temperature ranges recorded for both fall surveys (21°C to 24°C) were equal to or very similar to ranges recorded for the spring 1982, spring 1984,

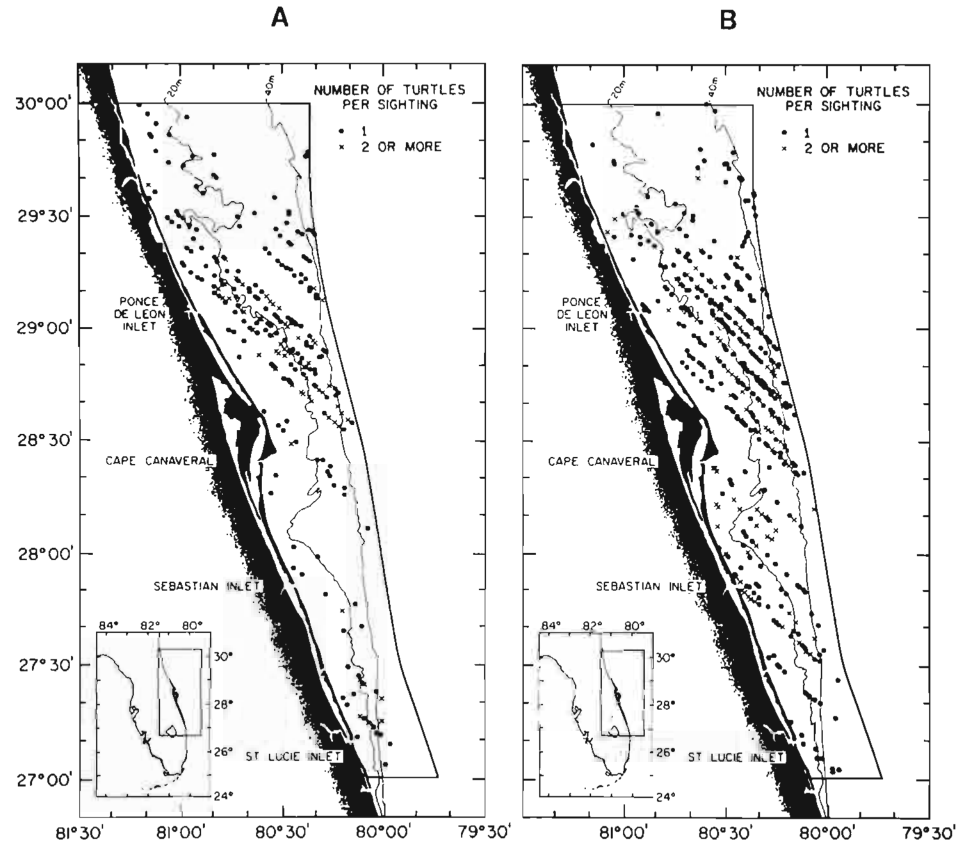

Figure 4—Distribution of *Caretta caretta* sightings in the Cape Canaveral area, spring 1982 (A) and summer 1982 (B).

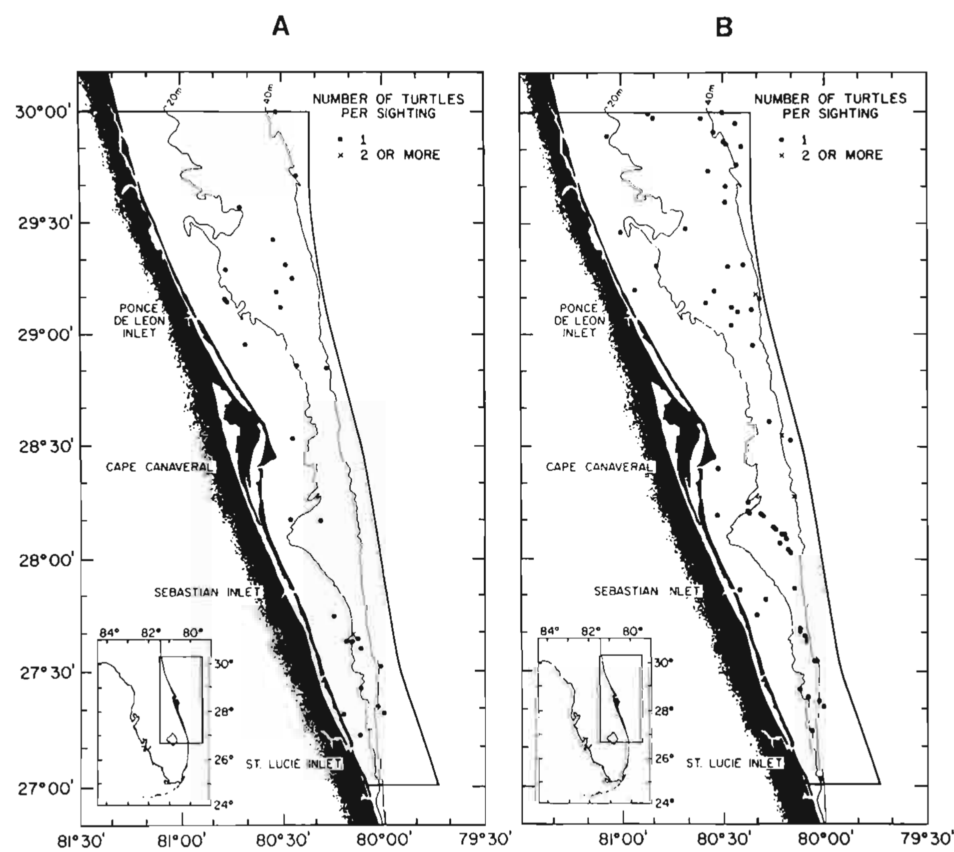

Figure 5—Distribution of *Caretta caretta* sightings in the Cape Canaveral area, fall 1982 (A) and winter 1983 (B).

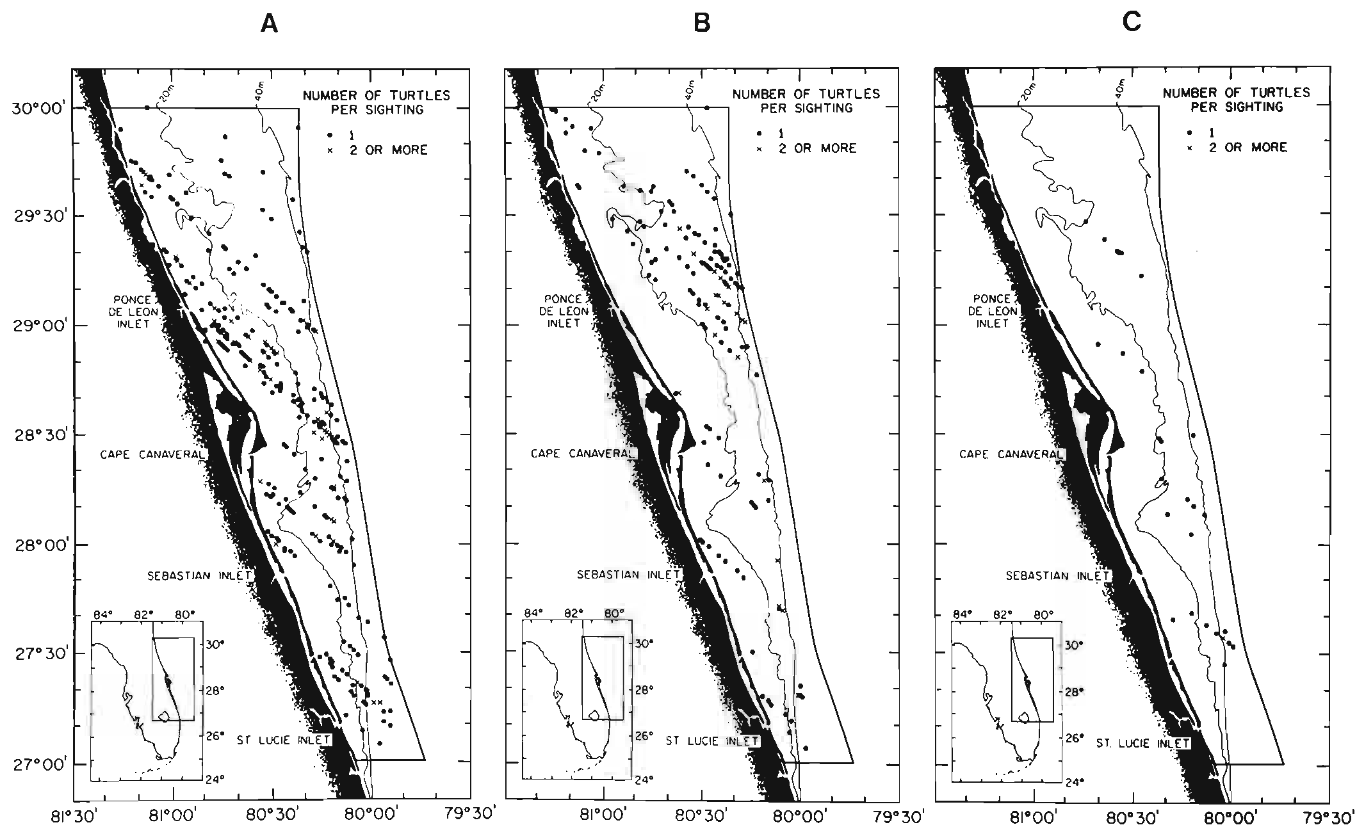

Figure 6—Distribution of *Caretta caretta* sightings in the Cape Canaveral area, spring 1983 (A), summer 1983 (B), and fall 1983 (C).

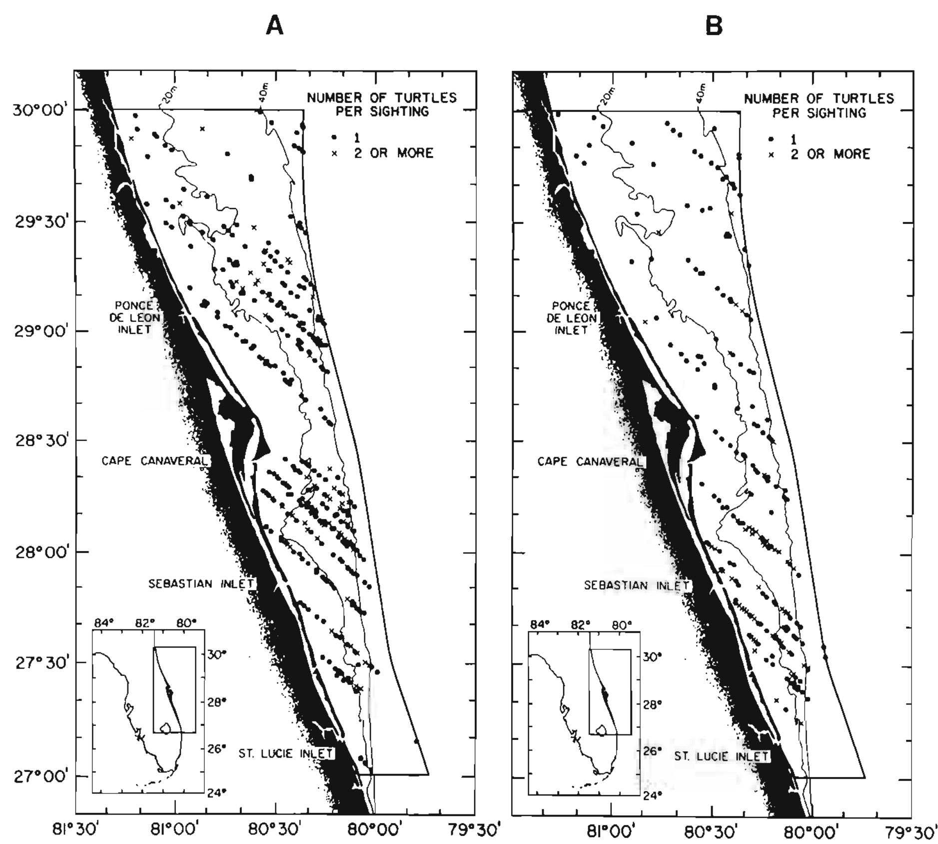

Figure 7—Distribution of *Caretta caretta* sightings in the Cape Canaveral area, spring 1984 (A) and summer 1984 (B).

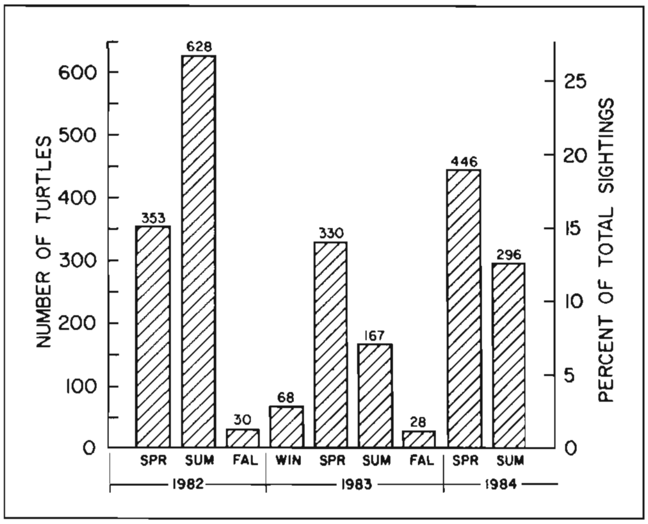

Figure 8—**Seasonal distribution of *Caretta caretta* sightings in the Cape Canaveral area, spring 1982 through summer 1984.**

and summer 1984 surveys. Therefore, it seems less likely that temperature was the primary factor influencing the fall spatial distribution within the study area.

Figure 8 illustrates seasonal trends in numbers of loggerheads sighted over the three-year survey period. Our results indicate that the greatest numbers of loggerheads occur during the spring and summer months, with sightings decreasing to much lower numbers during fall and winter. Fritts et al. (1983) reported similar seasonal shifts in this area from bimonthly surveys completed over a one-year study period.

Loggerheads nest on the beaches of the Cape Canaveral area from April to September with peak nesting occurring during June and July. Our survey results, which show sightings peaking during spring and summer and falling off during fall and winter, support the idea that reproductively active loggerheads migrate into the area during the nesting season and move out of the area when nesting activity has concluded.

Ranking our surveys from highest to lowest based on total sightings combined for spring and summer, 1982 ranks first (1,011 sightings), 1984 second (742 sightings), and 1983 third (593 sightings). In terms of loggerhead nesting activity, 1982 and 1983 were both considered "good" years, although 1983 was considered slightly better than 1982 (L. M. Ehrhart, Dep. Biol., Univ. Central Fla., Orlando, FL 32816, pers. commun. June 1985). Thompson (1983) and Murphy and Hopkins (1984), using aerial crawl counts, estimated the total number of loggerhead nests deposited on the southeast U.S. coast (Cape Hatteras to Key West) as 57,767 and 58,016 for the 1982 and 1983 nesting seasons, respectively. Comparable total estimates for the number of nests deposited during the 1984 nesting season are not available, but nesting activity was not considered as "good" as the previous two years (L. M. Ehrhart, Dep. Biol., Univ. Central Fla., Orlando, FL 32816, pers. commun. June 1985). Thus, between survey years, seasonal trends in turtle distribution and abundance, as indicated by our aerial observations, do not reflect annual trends in numbers of nests deposited or numbers of nesting females.

Preliminary results of a size class experiment, conducted during the summer 1984 survey, indicate that the majority of loggerheads sighted during the SeTS effort fall in the 60-90 cm range (straight line carapace length). The mean straight line carapace length reported for nesting females in the Cape Canaveral area is just above the upper limit of our most frequently sighted estimated size range for sightings (Ehrhart 1980; Raymond 1984). Based on these results, we consider most of our sightings to be subadult turtles, although we recognize that reproductively active turtles are responsible for some portion of the pronounced increase in sightings during spring and summer. The presence of subadults in the study area is probably strongly influenced by the distribution and abundance of prey items.

Butler (1983) investigated seasonal abundance of *Caretta* in the Port Canaveral ship channel during a one-year period. The highest abundance of loggerheads was found during February 1982 and the lowest during August 1982, an inverse of our seasonal abundance results for the adjoining pelagic habitat. The possible relationship between these seasonal concentrations in the Port Canaveral channel and seasonal trends in the adjoining pelagic habitat as indicated by our aerial surveys cannot yet be determined.

Dermochelys coriacea

A total of 128 positive reliability sightings of leatherback turtles was recorded in the Cape Canaveral area during our survey period. The distributions of *Dermochelys* within the study area (by season) are presented in Figures 9-12. Seasonal trends are summarized in Figure 13.

Seasonal trends of leatherbacks were pronounced, with 116 of 128 sightings (90.6%) occurring during the summer surveys. Of the remaining 12 sightings, nine (7.0%) were recorded during the spring surveys and three (2.3%) were recorded from the fall and winter surveys. Notably, almost half of all *Dermochelys* sightings (45.3%) over the entire survey period were recorded during the summer 1983 survey.

Leatherbacks were distributed primarily north of the tip of Cape Canaveral (28°30'N) during the summer 1982 and 1983 surveys, but were more evenly distributed north to south in the study area during the summer 1984 survey (Figs. 9B, 11B, 12 B). During all surveys, leatherbacks were distributed primarily over the midshelf waters, 94.5% of all sightings occurring east of the 20-m isobath. Leatherbacks, like loggerheads, were not sighted in the southeast corner of the study area east of the 40-m isobath where the Gulf Stream axis and associated deeper waters occur.

Within the Cape Canaveral study area, leatherbacks regularly nest in small numbers along the beaches south of Port Canaveral. Nesting activity commences in April and continues through July. During 1982, 1983, and 1984, respective totals of 45, 31, and 44 leatherback nests were reported for the Florida east coast (Harris et al. 1984; B. A. Harris, Fla. Dep. Natl. Resour., Bur. Mar. Res., St. Petersburg, FL 33701, pers. commun. July 1985). Year-to-year trends in *Dermochelys* nesting activity are difficult to evaluate because of the temporal and spatial variability in beach coverage. It is unclear whether our sighting peaks for leatherbacks during the summer season (late July) partially suggest reproductively active individuals present at the termination of the nesting season.

Migratory routes of *Dermochelys* remain undetermined, but previous authors have suggested, as we concur, that seasonal movements are strongly influenced by the abundance and distribution of coelenterates, the preferred food item of this species (Pritchard 1971, 1976; Lazell 1980; Shoop et al. 1981). The clumping effect evident during our summer surveys probably reflects a concentration of individuals in areas where this resource is most abundant.

A comprehensive and more detailed analysis of *Dermochelys* distribution and abundance in the entire SeTS area (Cape Hatteras, NC, to Key West, FL) is currently in preparation and will be published elsewhere.

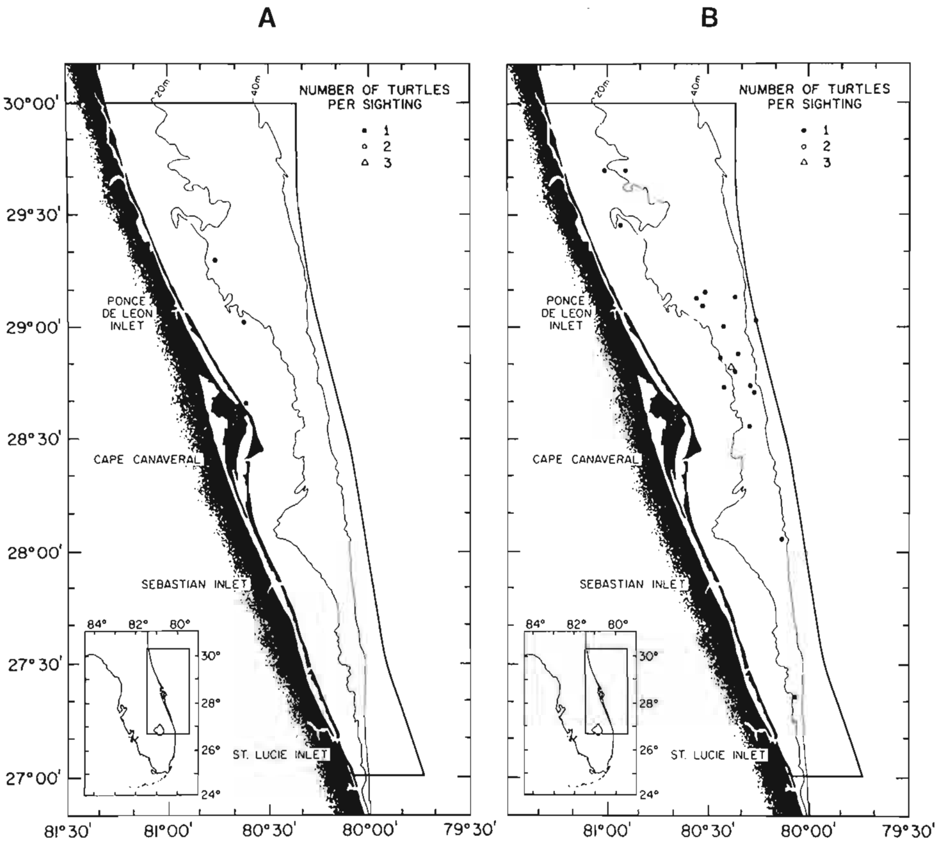

Figure 9—Distribution of *Dermochelys coriacea* sightings in the Cape Canaveral area, spring 1982 (A) and summer 1982 (B).

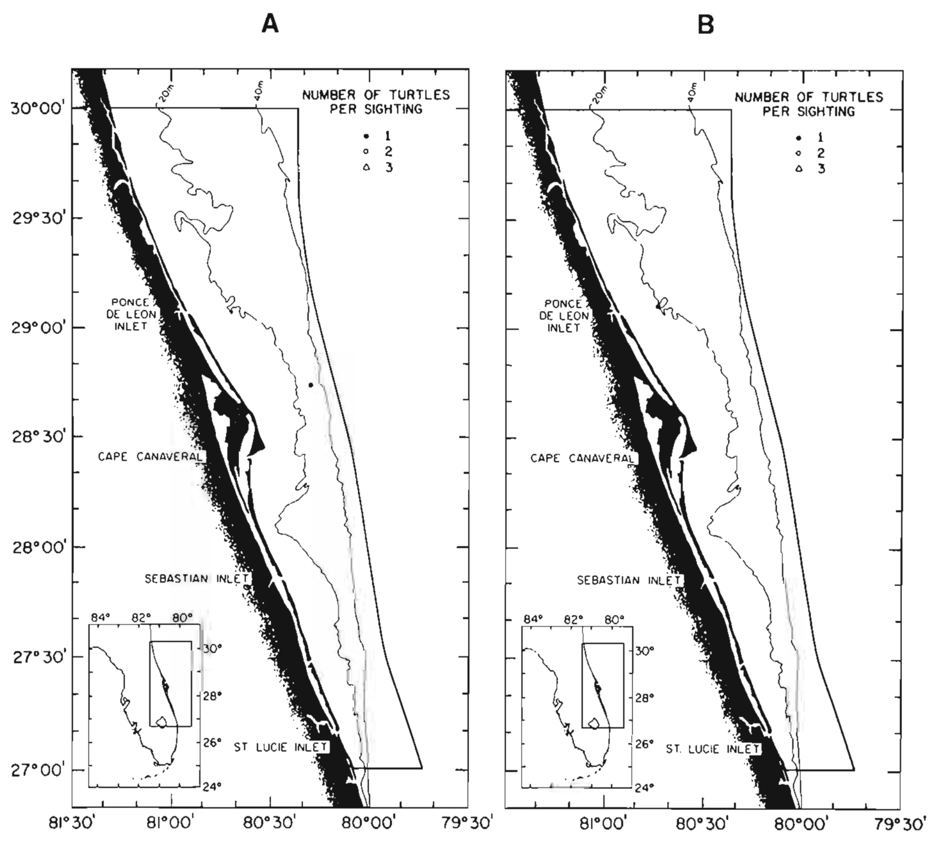

Figure 10—Distribution of *Dermochelys coriacea* sightings in the Cape Canaveral area, fall 1982 (A) and winter 1983 (B).

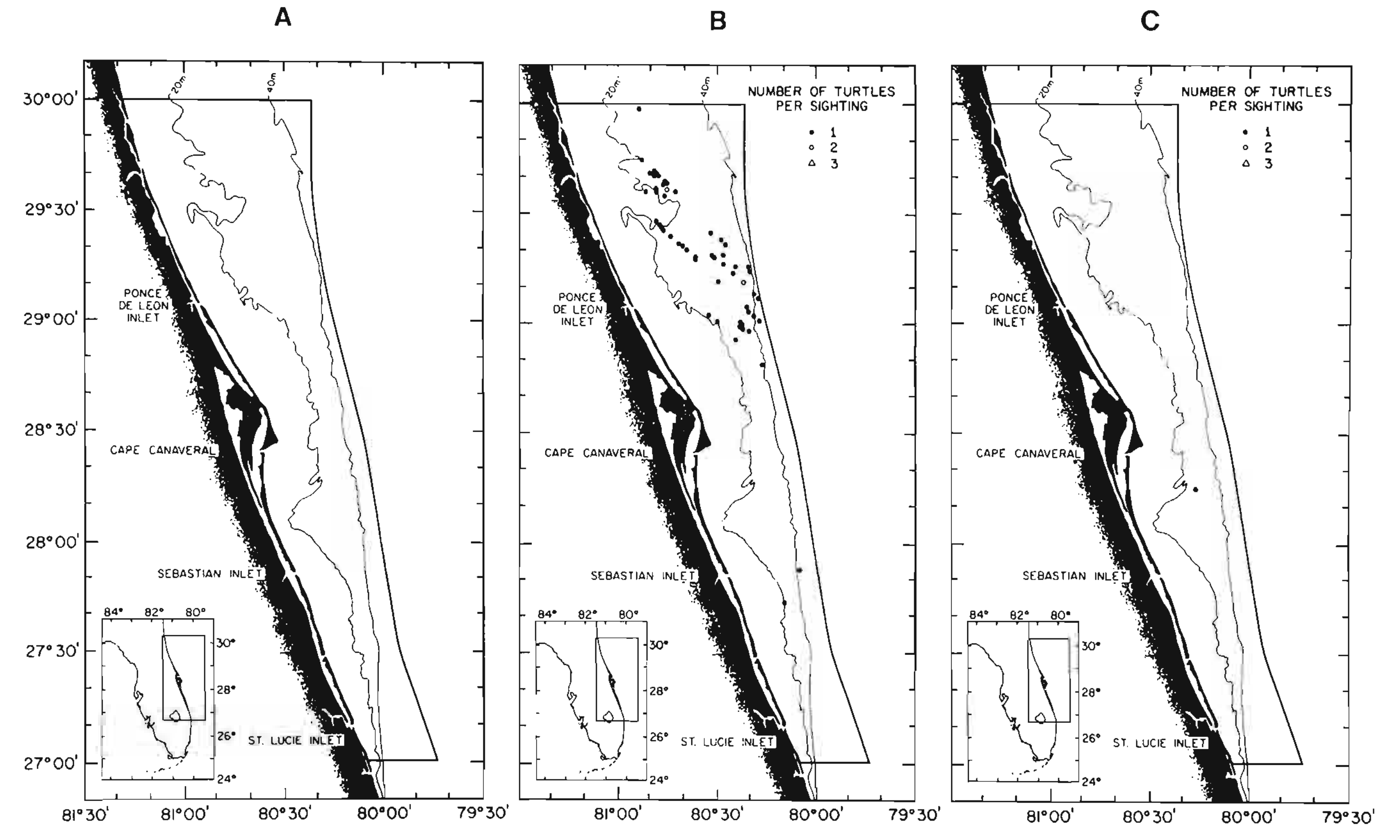

Figure 11—Distribution of *Dermochelys coriacea* sightings in the Cape Canaveral area, spring 1983 (A), summer 1983 (B), and fall 1983 (C).

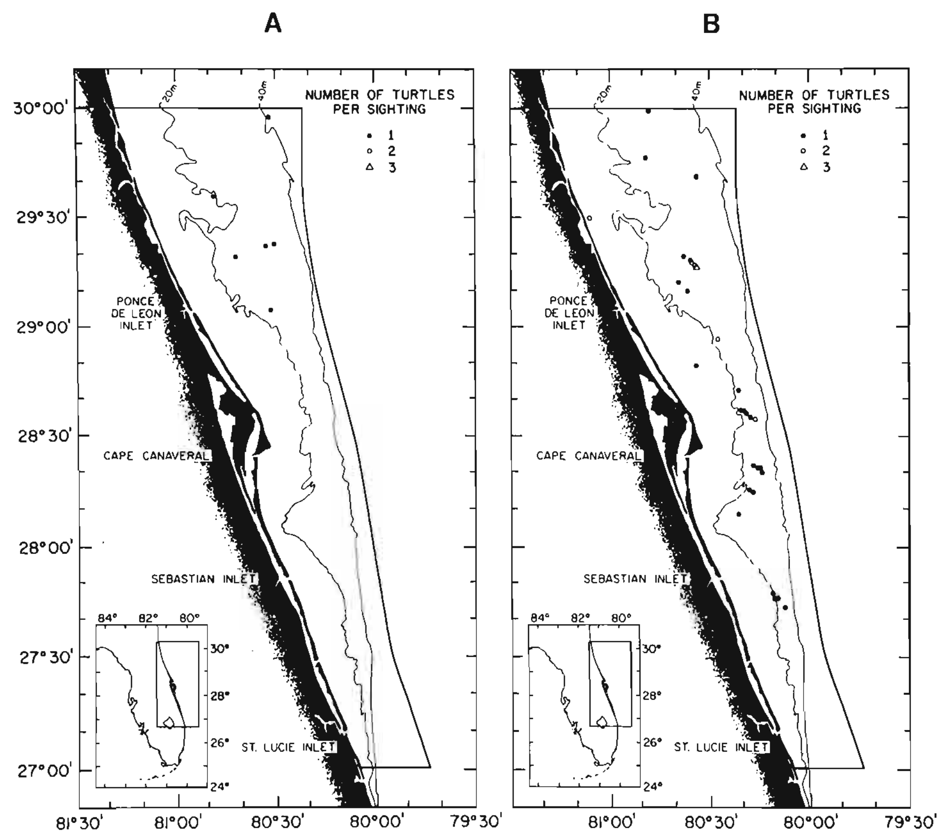

Figure 12—Distribution of *Dermochelys coriacea* sightings in the Cape Canaveral area, spring 1984 (A) and summer 1984 (B).

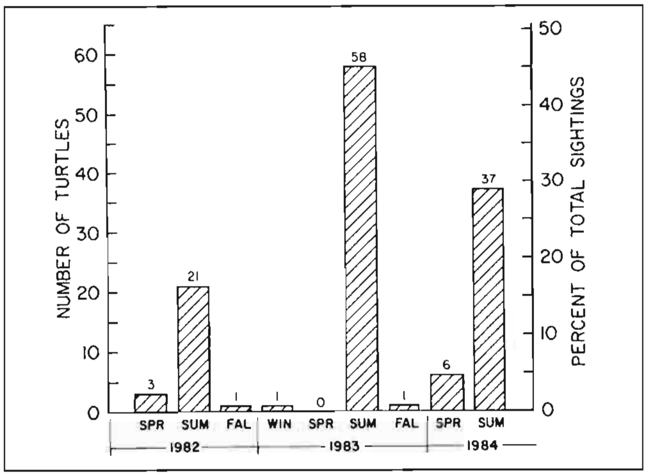

Figure 13—Seasonal distribution of *Dermochelys coriacea* sightings in the Cape Canaveral area, spring 1982 through summer 1984.

ACKNOWLEDGMENTS

These surveys were completed under contracts NA-82-GA-C-00012 and NA-83-GA-C-00017 to Aero-Marine Surveys, Inc. We are especially grateful to pilots John Olson and Paul Gilman. C. Robert Shoop and Thomas J. Thompson served as principal investigator and chief observer, respectively, during the first survey year. Sincere appreciation is extended to Stevie Chestnut, Geoff LeBaron, Tom Carr, Fred Fairfield, Carol Price, Bob Kenney, and Peter Sorensen for their many hours of dedicated observation. Amy Webster provided invaluable assistance with data reduction and editing. Dave Senn expertly drafted all of the figures and provided valuable advice. Joseph Powers, Nat Frazer, and an anonymous reviewer reviewed the manuscript and provided helpful suggestions.

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Amelioration of Maintenance Dredging Impacts on Sea Turtles, Canaveral Harbor, Florida

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ABSTRACT

The Corps of Engineers is the federal agency responsible for maintaining federal waterways and harbors. Maintenance dredging of the Canaveral entrance channel to Port Canaveral impacts sea turtles, as a result of their high population densities in the channel. The Canaveral entrance channel was originally constructed in the 1950's and presently is used by commercial fishermen, cruise ships, and the U.S. Navy. The channel is maintained at −44 feet for the Navy's Trident submarines. Maintenance dredging is by hopper dredge, with offshore disposal, and is needed once every 1-2 years, depending on shoaling rate, which is directly related to frequency and severity of storm events. A sea turtle/dredging task force was established in 1981 to generate and review methods to reduce the number of sea turtles taken during maintenance dredging. The task force has reviewed different types of dredge dragheads, potential methods of displacing sea turtles from the channel, and determined the distribution of sea turtles in and around the channel, in cooperation with the National Marine Fisheries Service. The results, to date, indicate that use of the "California" type draghead and dredging during the months of September, October, and November will reduce the take of sea turtles, to the extent possible. The Corps has placed a sampling basket on the dredge overflow to determine the level of take. Depending on sea turtle density, the dredges take approximately 0.02 to 0.06 sea turtles per dredging hour.

INTRODUCTION

The Corps of Engineers is the Federal agency responsible for maintaining Federal waterways and harbors. After a channel is constructed, some type of maintenance dredging at various frequencies, ranging from annual to every 10 years, is necessary. The Jacksonville District, Corps of Engineers, maintains Canaveral Harbor, and the Corps maintenance dredging of the entrance channel typically results in mortality of sea turtles. Pursuant to the Endangered Species Act of 1973 (ESA), the Corps has consulted with the National Marine Fisheries Service (NMFS) and Fish and Wildlife Service (FWS) to determine necessary precautions to be taken during maintenance dredging. The Corps also discussed this conflict between maintenance dredging and endangered species protection with the Florida Department of Natural Resources (DNR) and other concerned parties.

To provide a specific forum to discuss maintenance dredging of the Canaveral Harbor Entrance Channel and the resulting impacts on sea turtles, the sea turtle/dredging task force was established in May 1981. Members of the task force include representatives from the Corps, NMFS, FWS, DNR, and the U.S. Navy. The task force has proven to be an excellent method of providing information, investigating additional ways to reduce impacts of dredging on sea turtles, and resolving potential agency conflict on the most appropriate course of action by the Corps.

HISTORY OF CANAVERAL HARBOR

Cape Canaveral is located on the east coast of Florida approximately midway between Jacksonville and Miami. The Cape is an eastern extension of the shoreline which forms a natural protected area from winds of all points of the compass except southeast. Protection from the north and west is provided by the curved shoreline; protection from the northeast and east is by a southeasterly extending shoal approximately 8 miles long originating at the easternmost point of the Cape. Mariners have used this natural harbor, known as Canaveral Bight, for many years (Bukar 1978). As early as 1889, local interests were advocating a deep harbor on the shore of Canaveral Bight (House Doc. 367). The Port Canaveral Terminal Company received a permit from the War Department for construction of docking facilities along the shore of Canaveral Bight in 1926. However, the general economic problems in the Nation and the State of Florida precluded this development. In 1929, the Florida Legislature created the Canaveral Harbor District with taxing authority in Brevard County. The Canaveral Harbor District also tried, unsuccessfully, to finance construction of port facilities.

In 1933, the Atlantic Peninsula Corporation received a War Department permit to construct a pier, breakwater, seawall, and dredge a channel to deep water (House Doc. 367). The Atlantic Peninsula Corporation was also unsuccessful in attempts to raise funds for construction. In 1939, the Florida Legislature abolished the Canaveral Harbor District and created the Canaveral Port District. The Atlantic Peninsula Corporation and the Canaveral Port District were the prime movers in bringing the need for facilities at Canaveral to the attention of Congress and the Corps (Bukar 1978). The plans of these two groups were more extensive than a pier on the shoreline and a channel to deeper water. They advocated basically what exists at Canaveral today.

In August 1941, the Army Board of Engineers submitted, through the Secretary of War, a recommendation for a Federal project at

Canaveral (House Doc. 367). This proposal involved a 27-foot-deep turning basin on the eastern side of the Banana River, a 27-foot-deep channel through the Barrier Island to deep water, and jetties on the seaward side of the Barrier Islands. The proposed project also included a lock and an 8-foot-deep barge canal to the Intracoastal Waterway. After creation of Canaveral Port Authority by the State in 1947 to represent the non-Federal interests, construction of the 27-foot-deep channel began in 1950. Construction dredging was complete in 1952, but considerable maintenance dredging was required during 1953 prior to completion of the jetties. The entrance channel was deepened to 37 feet in 1961 and 44 feet in 1976, to accommodate the Navy's Poseidon submarines. Table 1 lists the dates and cubic yards of material removed during maintenance and construction dredging of the entrance channel.

Under normal conditions, in the absence of major storms along the east coast of Florida, the entrance channel requires minor maintenance dredging annually. However, as evidenced by the passage of Hurricane David in 1979, and the tropical storms Diana and Isadora in 1984, such storms can rapidly increase shoaling in Canaveral Harbor Entrance Channel. The two storms in 1984 placed approximately 1.7 million yards^3 of material in the channel. In addition to the two tropical storms in 1984, the unnamed "Thanksgiving Day storm" added another 800,000 yards^3 of shoaling.

Such wide fluctuation in shoaling rate as a result of presence or absence of storms causes difficulty in planning maintenance dredging. For example, in 1984 the Corps planned to remove approximately 1 million yards^3 of material from the entrance channel with one dredge, the *McFarland*, during November and December. As a result of the three storms in 1984, the *McFarland* worked from late October 1984 through January 1985, and an additional contract dredge worked from December 1984 through January 1985. The combined dredges removed approximately 2.6 million yards^3, or almost three times the amount of material indicated by the August 1984 survey.

SEA TURTLE DREDGING TASK FORCE

As stated above, the sea turtle/dredging task force was created in 1981 in an effort to resolve concerns raised by NMFS over the large take of sea turtles during the 1980 maintenance dredging, and to define and evaluate methods to reduce impacts on sea turtles during maintenance dredging of Canaveral Harbor Entrance Channel. A total of 77 sea turtles were documented as taken during the 1980 removal of approximately 2.5 million yards^3 of material (Joyce 1982). Early in the life of the task force, the following five items were identified:

(1) Investigating the configurations and relative threat to sea turtles of various types of dredge dragheads;

(2) designing and testing modifications to hopper dredge dragheads;

(3) determining the frequency and distribution of sea turtles in key navigation channels of Florida's coast;

(4) conducting radio-tracking studies on sea turtles in the navigation channels; and

(5) investigating various sensory stimuli to repel turtles from the channel to be dredged or from the vicinity of the dredge.

Items 1 and 2 above were investigated in 1981 and 1982 (Joyce 1982). The two dredge dragheads looked at extensively were the "IHC" and "California" types. The IHC type was used on the contract dredges and the California type was used on the Corps dredge *McFarland*. Data from the 1980 dredging indicates a taking rate of approximately 1/2 that of IHC by the California type. The two types of dredge draghead are shown in Figure 1, with the basic differences, considered to be salient to the question of sea turtle impacts, indicated. The deflector system indicated in Figure 1 was an attempt to get sea turtles out of the way as does a "cow catcher" on a train. Unfortunately, the deflector (although constructed of 1-inch steel) could not withstand the physical effects of being pulled along the bottom, and broke during the first testing.

Table 1—Maintenance dredging and new construction dredging, Canaveral Harbor Entrance Channel, Florida.

Period	Maintenance (yd^3) Total	Maintenance (yd^3) Avg./yr.	New construction (yds^3)	New depth (ft)
1953-57	1,857,000	371,400		27
1957			2,529,000	37
1958-73	12,669,000	791,813		
1974-76	1,819,000	606,333	5,713,000	44
1977-83*	4,358,000	662,571		
1984**	2,657,000			

*At least 1.5 million yds^3 in 1979, the result of Hurricane David.

**Nearly 2.5 million yds^3 in 1984, the result of two tropical storms and the "Thanksgiving Day" storm.

The consensus of the task force is that sea turtles are most vulnerable when the dredge draghead is being lowered into the sediment. The apparent advantages of the California-type draghead are the large flat-bottom surface, and the location of the intake for sediment approximately 1 to 2 feet below the sediment surface. Recent observations suggest that sea turtles may also be taken when the dredge is working in areas where shoaling is not uniform along the bottom but instead is in short reaches, or what the Corps calls spot shoaling. In these instances, the draghead is set at a prescribed depth and will pass in and out of the shoal material. The reaches are too short and close together to turn the dredge pumps off and on.

Considerable effort went into sampling Canaveral Harbor Entrance Channel and other Florida east coast channels and radio tracking of sea turtles in a cooperative effort by the Corps and NMFS to determine turtle density. These results are reported elsewhere. The key findings from these studies are that the Canaveral Harbor Entrance Channel is very attractive to sea turtles, has large numbers of turtles, especially during winter, and that sea turtles trawled from the channel and released 5 to 10 miles away often return (Butler unpubl.). The channel is apparently attractive to sea turtles because of the relief, soft bottom, and low current. This information is vital to the task force because it is now well established that large numbers of sea turtles, particularly loggerheads, are in the channel, especially seasonally, and that impacts on sea turtles from dredging may be reduced by the timing of dredging. The abundance data goes beyond indicating high numbers of turtles in the winter. Although the number of turtles is lower in the late summer, many of these are egg-laden females (F. Berry, Southeast Fish. Cent., Natl. Mar. Fish. Serv., NOAA, Miami, FL 33149, pers. commun.). Therefore, high numbers of sea turtles are in the channel from December or January (depending on water temperature) through April, possibly as a refuge from cold water temperatures, while mating and egg-laden sea turtles are in the channel from May through August. The task force has reviewed this information and determined that the least damaging time to dredge Canaveral Harbor

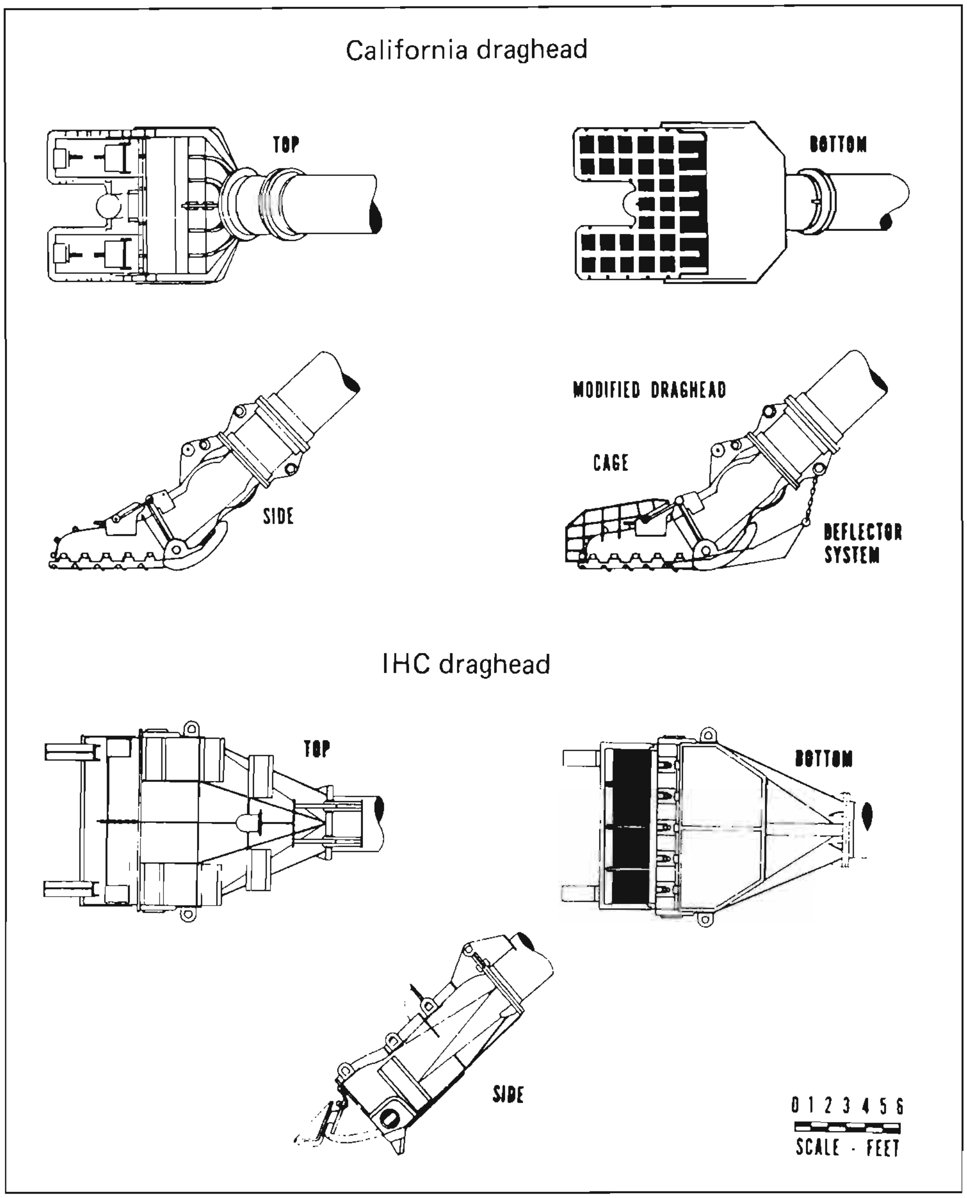

Figure 1—California and IHC dredge draghead types. Both draghead types are towed through the bottom sediment from left to right, as shown. Note the greater intake surface area (shaded portion) and large flat area on the leading edge of the California draghead, and the experimental deflector system, labeled "modified draghead."

Entrance Channel is during the months of September through November. Furthermore, the consensus of the task force is that this timing of dredging may be one of the most feasible and effective mitigative measures.

Dredging during September through November has not been traditionally scheduled because of an effort to schedule dredging after the latest likely tropical storm, i.e, November through January. The Corps is now committed to scheduling maintenance dredging of Canaveral Harbor Entrance Channel during September through November, to the extent possible.

Work on the fifth item of the task force's original agenda has begun. During December 1984, a test was conducted on a sonic pinger as a method of frightening sea turtles. This test was a result of discussions at the July 1984 task force meeting about the repulsive attributes of sonic pingers on sea turtles. In a prior study for Florida Power and Light Company, J. O'Hara (Environ. Chem. Sci., Inc., Aiken, SC, unpubl. data) found that sea turtles would avoid a sonic pinger set in a canal. The data from the December 1984 test of the pinger pulled at various depths in Canaveral Harbor Entrance Channel was inconclusive, however, because of an unexpected absence of sea turtles in the channel. Although inconclusive, the test suggests that the pinger would not be effective in keeping sea turtles away from the advancing dredge draghead. O'Hara feels that the sea turtles may have avoided the pinger in the canal in south Florida because of physical discomfort rather than fright. This would explain the avoidance observed in the south Florida canal, and lack of avoidance in the Canaveral channel study. In the Canaveral study, the sea turtles did not avoid the sampling nets because the pinger and nets were moving through the water. Their discomfort apparently did not occur until they were near or in the net.

A second possible method of dislocating sea turtles from the front of a draghead is the use of electrical current. During the July 1984

Table 2—1984 dredging of Canaveral Harbor Entrance Channel, Florida.

	Sugar Island		*McFarland*	
	With observer	W/O observer	With observer	W/O observer
No. documented taken	6	3	3	1 (alive)
% dredging time	34	66	23	77
Total dredging days	14	27	18	60
Total dredging hours	111	216	102	340
Total yds^3 dredged	394,212	765,235	344,503	1,153,335
Estimated no. turtles/ dredging hours	0.054	0.014	0.029	0.003

Table 3—Comparison between 1980-81 and 1984 dredging of Canaveral Harbor Entrance Channel, Florida.

	1980-81		1984	
	Contract dredge*	*McFarland***	Contract dredge**	*McFarland***
Total yds^3 dredged	1,996,447	490,780	1,159,447	1,497,838
Total dredging hours	892	159	327	442
Estimated no. turtles/ dredging hours	0.080	0.038	0.028	0.009

*IHC type.
**California type.

task force meeting, E. F. Klima of the NMFS Galveston, TX, Laboratory presented information on his work with electrical current on shrimp. This possible method of mitigating dredging impacts on sea turtles is yet to be investigated.

1984 DREDGING

The Corps performed maintenance dredging of the Canaveral Harbor Entrance Channel during the period late October 1984 through January 1985. Table 2 indicates the activities and take of sea turtles by the Corps dredge *McFarland* and the contract dredge *Sugar Island*. Both dredges were equipped with the California-type draghead. The take of sea turtles was documented differently aboard the two dredges because of the differences in design. The sampling area on the *McFarland* was approximately 48 feet^2 of horizontal screening, while that of the *Sugar Island* was approximately 160 lineal feet of vertical screening. The greater sampling area on the *Sugar Island* probably accounts for the higher documented take by that dredge. Review of the contract dredge data suggests that the take was higher as a result of the draghead being in open water above the sediment or leaving and re-entering the sediment. This observation could be a result of the draghead physically encountering more turtles at the sediment water interface or some attraction of sea turtles to the draghead resulting from sound or water movement. The take per dredging hour is much lower than that observed in 1980; however, this is undoubtedly a result of lower population densities in the channel in 1984 (Table 3). A very mild fall in 1984 most likely contributed to lower population levels. Water temperature must reach certain levels before sea turtles seek the refuge of the channel (R. Witham, Fla. Dep. Nat. Resour., Jensen Beach, FL 33457, pers. commun.). Continued monitoring of the sea turtle take will add information from which to make management decisions.

CONCLUSIONS AND FUTURE DIRECTIONS

The sea turtle/dredging task force has been a model for productive interagency action. Tasks normally requiring lengthy and time consuming coordination were handled in a productive and orderly manner. The situation at Canaveral Harbor involves maintaining a channel of significant national defense importance, while attempting to reduce impacts, to the maximum extent practicable, on the endangered sea turtles. Fortunately, the most common species, the loggerhead, is also the least endangered of the three species occuring in the channel. The Corps will continue efforts to reduce impacts on loggerheads, realizing that the beaches near and south of Canaveral are very important nesting beaches. The green sea turtle is often sampled in the channel, while the very rare Kemp's ridley rarely occurs there. The primary mitigative measures identified and implemented so far for dredging are use of the California-type draghead and timing of dredging during September through November. The Corps' most recent (1984-85) maintenance work was stopped in late January 1985, when the necessary minimum amount of dredging for the Navy Trident Base was completed. The main reasons for discontinuing dredging until fall 1985 were that the *McFarland* was committed to another project as well as a concern over sea turtle taking. Channel maintenance was completed in fall 1985, in the "window" of September through November.

The task force will remain intact indefinitely to review maintenance dredging and any emerging methods that may be effectively implemented to reduce sea turtle impacts. The task force will also continue to review information on sea turtle biology and distribution so that recommendations for dredging can be implemented to reduce the impacts of maintenance dredging on sea turtles.

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Seasonal Changes in the Serum Testosterone Titers of Loggerhead Sea Turtles Captured Along the Atlantic Coast of the United States

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ABSTRACT

Serum testosterone titers were recorded for loggerhead sea turtles, *Caretta caretta*, captured along the Atlantic coast of the United States. Immature females exhibited low testosterone titers throughout the year ($\lesssim$30.0 pg/mL). Immature males had significantly higher titers than females, ranging from 76.4 pg/mL to 557.5 pg/mL. The mean monthly titers of immature males fluctuated significantly during the year with the highest mean value recorded during August and the lowest during March. Adult males exhibited a wide range of titers (80.0 to 24,275.7 pg/mL). During certain months, adult males showed a distinct dichotomy in testosterone titers. These data suggest that some turtles were reproductively active and some were not. Our results suggest that reproductively active males appear to have high titers during February through April, followed by a significant decrease in titers during May. Adult female testosterone titers ranged from <41.4 pg/mL to 1209.1 pg/mL. Females sampled on the nesting beach had higher titers than adult females captured in the water during the same months. The mean monthly testosterone titers of adult females captured in the water changed significantly with time, increasing prior to the nesting season and then peaking during the middle of the nesting season. Our results are consistent with those recorded for captive green sea turtles. The possible roles of testosterone in specific reproductive events (i.e., migration, mating, and sperm and egg production) are discussed.

INTRODUCTION

Seasonal changes in the circulating levels of testosterone have been recorded for only one species of sea turtle, the green sea turtle, *Chelonia mydas*, at the Cayman Turtle Farm, Ltd. (Licht et al. 1979, 1985). These studies, which did not include immature turtles, indicated that both adult males and adult females exhibit significant changes in serum testosterone titers during the year.

Adult males exhibited significant increases in testosterone titers during the premating season followed by a drop in testosterone titer just prior to and during the start of the mating season. Licht et al. (1985) suggest that these data support the hypothesis that spermatogenesis is seasonally coupled to a "prenuptial" androgen cycle. Additionally, their data indicated that the magnitude of the prebreeding testosterone titers positively correlates to the subsequent number of females mounted and the duration of mounting by a given male. This suggests that testosterone also has a role in mating behavior.

Adult female green turtles exhibited a significant rise in serum testosterone titers during the month prior to mating. Their titers appear to peak during the mating season, then decrease slightly (but not significantly) through the nesting season. The role of testosterone in the reproductive physiology and behavior of the female green sea turtle (if one exists) is not known. However, several researchers have suggested that testosterone in reproductively active freshwater turtles could act as a precursor for the estrogen needed in egg production (Callard et al. 1978; McPherson et al. 1982).

Studies of the captive green turtles at the Cayman Turtle Farm have provided insight into endocrine mechanisms involved in reproduction. However, endocrine cycles in captivity may not accurately reflect those of sea turtles in natural populations. Factors associated with captivity such as increased feeding, lack of migrations, and minimal thermal changes could alter normal endocrine cycles. This is evident when comparing intervals between nesting seasons for captive green sea turtles versus those in natural populations. The average interseasonal nesting interval for green sea turtles at the Cayman Turtle Farm is 1.4 years (Wood and Wood 1980), whereas green sea turtles nesting at Tortuguero and in Suriname average 2.33 and 3.14 years, respectively (Carr et al. 1978). Captivity also may affect the reproduction of male turtles. Licht et al. (1985) were able to correlate prebreeding testosterone titers to breeding behaviors for male turtles that were captured in the wild and taken to the Cayman Turtle Farm. However, these correlations were not detectable for farm-reared male turtles.

Considering the information above, endocrine studies of sea turtles from natural populations would be beneficial for several reasons. First, turtles from natural populations may provide a better model for examining hormones which may control certain reproductive events such as migration. Second, studies of turtles in natural populations would facilitate the evaluation of endocrine data from previous studies of captive turtles. Third, regardless of whether the hormone dynamics differ in turtles from natural populations as compared with those from captivity, studies on natural populations would provide a much needed increase in the baseline data on reproductive steroid dynamics in sea turtles. Lastly, the study of the reproductive hormone cycles of turtles in natural populations may provide information which will benefit present management programs for endangered populations. For these reasons, we have begun to analyze reproductive steroid levels of sea turtles captured in the wild. In the present study we provide data on seasonal changes in the testosterone titers of immature and adult loggerhead sea turtles, *Caretta caretta*, captured along the Atlantic coast of the United

States. We then discuss these data relative to observations and hypotheses on the general reproductive behavior and status of the turtles at the time they were captured.

METHODS AND MATERIALS

The methods of capture, measurement, blood sampling, and radioimmunoassay are described by Wibbels et al. (1987). The intraassay coefficient of variation for the testosterone assays was 5.9% and the interassay coefficient of variation was 19.0%. One additional sampling location was used. Turtles nesting at Melbourne Beach, FL, were sampled after they finished covering their eggs. These nesting turtles had a tendency to contract their neck musculature when the sampling needle was inserted, thus making sampling difficult. Therefore, a modified method for nesting loggerheads was developed in which one side of the turtle was lifted until the plastron formed an angle of approximately 70 degrees with the ground. This caused the turtles to extend their necks, thus exposing the correct area for insertion of the blood sampling needle.

Prediction of adult or immature status

Turtles were predicted to be adults or immatures based on their straight carapace lengths. The minimum length chosen for an adult was 80 cm and the maximum length chosen for an immature was 76 cm. These maximum and minimum values were selected after considering the carapace lengths of nesting females along the Atlantic coast of the United States (Hirth 1980) and those of immature loggerheads which we have laparoscopically examined (Wibbels et al. 1987). Turtles between 76 and 80 cm were excluded from the analysis due to our inability to accurately predict if they were adults or immatures. The possibility that some immature turtles may have had carapace lengths of 80 cm or greater is addressed in the Discussion.

Prediction of immature sex

The sex of immature loggerheads captured in this study was predicted by a serum testosterone titer sexing technique (Wibbels et al. 1987).

Prediction of adult sex

Adult sea turtles have traditionally been sexed according to their tail lengths (Pritchard, et al. 1983). Males have long tails extending well past the posterior margin of the carapace, and females have short tails which extend approximately to the posterior margin of the carapace. Unfortunately, no studies have critically analyzed specific tail lengths of adults relative to known sexes. We considered adults with tail lengths of 25 cm or less to be females and those with tail lengths of 40 cm or greater to be males. Turtles with tail lengths between 25 cm and 40 cm were excluded from analysis.

RESULTS

Immature Turtles

The sex of 256 immature loggerheads was predicted using a testosterone sexing technique (Wibbels et al. 1987). Males exhibited significantly greater testosterone titers than females (*t*-test, $P<0.001$). Male titers ranged from 76.4 to 545.0 pg/mL, and female titers ranged from below the sensitivity of the assay ($\lesssim$15.0 pg/mL when extracting 1.0 mL of serum) to 31.0 pg/mL. The mean serum testosterone titers of males and females, grouped by month, are shown on Figures 1 and 2, respectively. Comparisons of the females' monthly mean testosterone titers were not performed, since the majority of female titers were below the sensitivity of the assay. The monthly mean testosterone titers of the males (Fig. 1) exhibited significant changes (ANOVA, $P<0.001$). Multiple comparisons of mean monthly values indicated that the testosterone titers of males captured during August and January were significantly higher than those of males captured during March ($P<0.05$, Student-Newman-Kuels test). No other significant differences were detected among the monthly mean testosterone titers.

Adult turtles

Adult male testosterone titers ranged from 80.0 to 24,475.7 pg/mL. During several of the months, there appeared to be a distinct dichotomy in the titers. For example, during February 1982 two turtles captured had titers of 14,784.0 and 17,234.4 pg/mL, while the three other turtles captured that month had titers ranging from 181.9 to 256.5 pg/mL. Males captured during March 1983 exhibited a similar dichotomy. For this reason, males with relatively low titers (<500 pg/mL) were grouped separately during our analysis. Figure 3 shows the mean testosterone titers of males captured at various times of the year. Males (with titers above 500 pg/mL) exhibited high titers during February and March. Titers then decreased significantly during May (ANOVA, $P<0.001$). Males exhibiting relatively low testosterone titers (<500 pg/mL) were captured during various months of the year.

Adult female loggerheads exhibited testosterone titers ranging from below the sensitivity of the assay ($\sim$40.0 pg/mL when extracting 0.5 mL of serum) to 1209.1 pg/mL. The monthly mean testosterone titers of the adult females are shown in Figure 4. Nesting female titers were significantly greater than those of females captured in the water during the same time period (*t*-test, $P<0.001$). The monthly mean titers of females captured in the water exhibited significant changes (ANOVA, $P<0.05$). Mean titers increased from May through June and then began to decrease through July and August. Significant changes were not detectable in the monthly mean testosterone titers of the nesting females ($P>0.05$).

DISCUSSION

Immature loggerheads

The results indicate that immature female loggerheads have low testosterone titers throughout the year ($\lesssim$30.0 pg/mL). Immature male loggerheads have significantly higher titers than immature females. The male testosterone titers exhibited significant seasonal fluctuations. However, the variability of titers during certain months combined with small sample sizes for several months prevents meaningful interpretation of these data relative to time of year.

Adult loggerhead sampling locations

The adult turtles used in this study were captured along the Atlantic coast of central Florida near natural nesting areas. All but one of the adult males and the majority of females captured in the water were netted in the Cape Canaveral Ship Channel. The adjacent

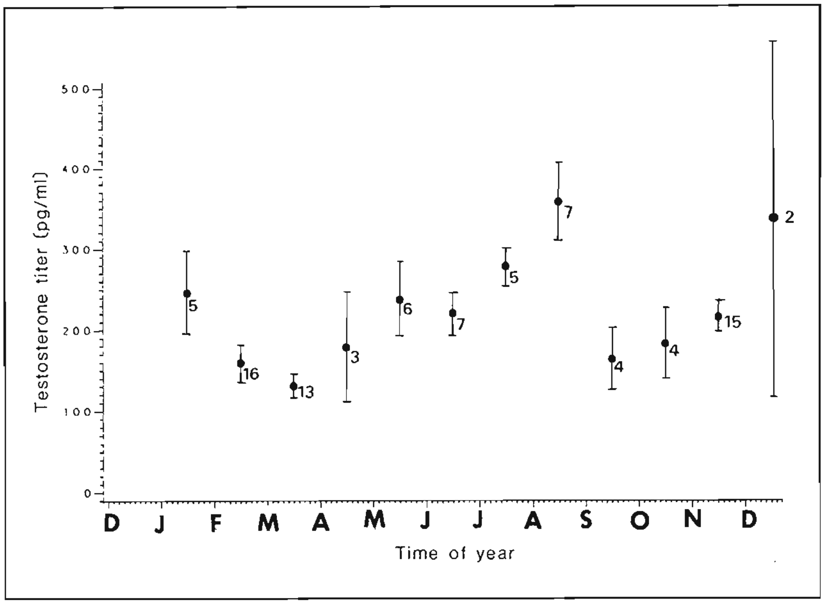

Figure 1—Mean monthly serum testosterone titers of immature male loggerheads captured along the Atlantic coast of the United States. Points represent maximum mean values since the majority of the titers were under the sensitivity of the radioimmunoassay. The number adjacent to each point indicates sample size. Standard errors of the means are represented by vertical lines.

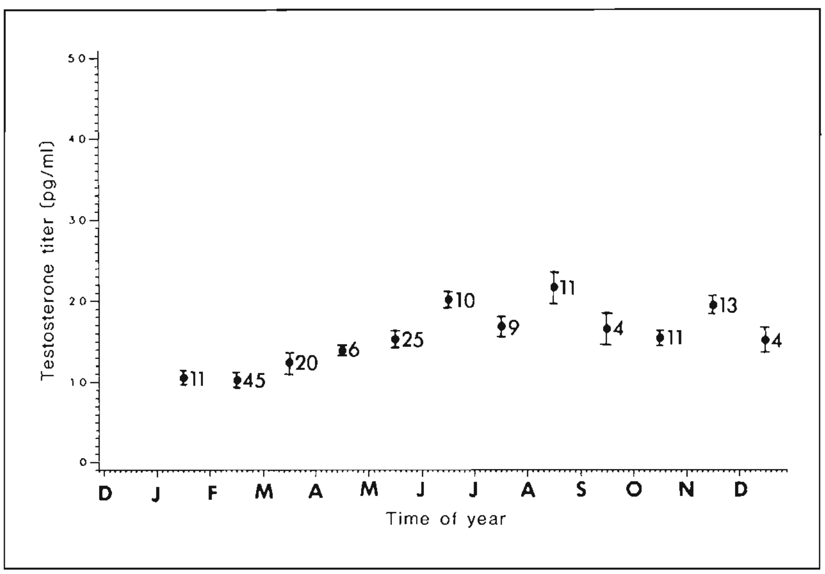

Figure 2—Mean monthly serum testosterone titers of immature female loggerheads captured along the Atlantic coast of the United States. The number adjacent to each point indicates sample size. Standard errors of the means are represented by vertical lines.

beaches on Cape Canaveral and Kennedy Space Center are major nesting areas for loggerheads (Ehrhart 1979; Hopkins and Richardson 1984). Scattered nesting occurs to the south of the channel for approximately 30 km (Hopkins and Richardson 1984). The densest nesting of loggerheads in the United States occurs 40 km south of the Cape Canaveral Ship Channel at Melbourne Beach (Hopkins and Richardson 1984), our sampling site for nesting females. Adult females tagged in the channel have primarily been recorded nesting on beaches of Cape Canaveral, Kennedy Space Center, and Melbourne Beach (Henwood 1987a). The data collected by Henwood (1987b) indicate that adult males and adult females, as well as immatures, show movements into and out of the channel that correlate with time of year. Therefore, although this channel is anomalous in its large aggregation of loggerheads, turtles in the channel appear to be normal members of a population(s). The ten adult turtles not captured in the Canaveral ship channel or on the beach at Melbourne Beach were captured in the Indian River or at the power plant on Hutchinson Island. Both of these locations are also in close proximity to major loggerhead nesting beaches (Hopkins and Richardson 1984).

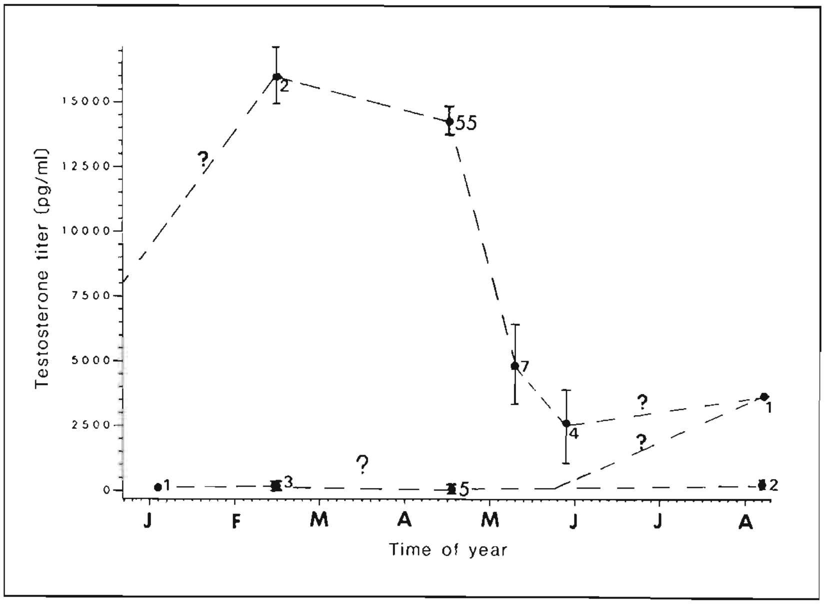

Figure 3—Mean monthly or semimonthly testosterone titers of adult male loggerheads captured along the Atlantic coast of central Florida. Males with titers <500 pg/mL were grouped separately. The number adjacent to each point indicates sample size. Standard errors of the means are represented by vertical lines.

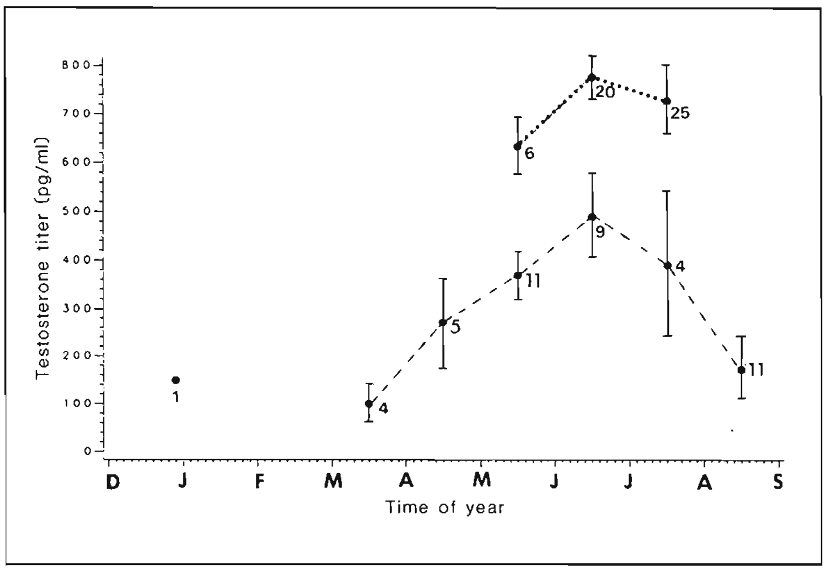

Figure 4—Mean monthly testosterone titers of adult female loggerheads captured along the Atlantic coast of central Florida. Dotted line connects means of nesting turtles, and dashed line connects means of turtles captured in the water. The number adjacent to each point indicates sample size. The means for March, April, and May each include one titer that was under the sensitivity of the assay; the mean for August includes three titers that were under the sensitivity of the assay. Standard errors of the means are represented by vertical lines.

Adult male loggerheads

Adult males exhibited a dichotomy in testosterone titers. It is possible that some of these males were immature. However, some of the turtles with low titers were well over the minimum size criteria we chose. For example, a turtle with a low titer during March had a straight carapace length of 97.0 cm and a tail length of 50.8 cm. Therefore, this suggests that at least some of the males sampled in this study may have multiannual reproductive intervals. While it is well documented that adult female sea turtles possess multiannual reproductive intervals, this subject is difficult to address in adult males. To substantiate that a male is reproductively active during a given year, it will be necessary to determine an accurate indicator for reproductive status. Observations of mating behavior could verify reproductive status; unfortunately, the time and location of mating have not been well documented in any sea turtle population. Our results indicate that, at least during certain months of the year, testosterone titer might indicate whether a male is reproductively active. Thus, testosterone titer could prove to be a useful tool in studying the reproductive ecology of male sea turtles.

Adult males which appeared reproductively active exhibited high levels of testosterone during February and April, followed by a significant decrease during May (Fig. 3). Licht et al. (1985) recorded a similar monthly pattern for captive green turtles, but mean monthly values were higher (as high as ~38,000 pg/mL). Additionally, titers of male loggerheads in this study decrease significantly over a shorter time period (one month) compared with captive green turtles (two months). However, these differences may be attributed to factors such as temperature, effects of captivity, or interspecific disparities. Nevertheless, our adult male data appear strikingly similar to those recorded for captive green turtles. Unfortunately, our data set contain only a few adult males captured during the months of June through January, and therefore do not permit the determination of when testosterone titers begin to increase in a reproductively active male. Licht et al. (1985) found that titers in captive green sea turtles began increasing in January.

Henwood (1987b) found that adult male loggerheads begin migrating into the Cape Canaveral Ship Channel during February. By April, the number of adult males in the channel reaches a maximum. Then, during May, it drops precipitously, resulting in only a few males being present in June. Comparison of our data with that of Henwood suggests that many of the males migrating into the channel between February and April have high testosterone titers. Although we have no data on gonadal weights, we speculate that these high titers may play a role in spermatogenesis, as suggested by Licht et al. (1985) for the green sea turtle. The influx of adult males with high testosterone titers into the channel also suggests the possibility that testosterone may be important for inducing migration. This subject has not been studied in turtles but has received some attention in fish, where a variety of studies suggest that testosterone may have a role in regulating migratory behavior (reviewed by Woodhead 1975).

The time and location of the mating of adult loggerheads along the Atlantic coast of the United States has not been documented. Henwood et. al. (1987b) indicates that during March, when large numbers of adult males are present in the Canaveral Channel, there are few adult females. However, the number of adult females increased significantly during May, the month when males begin to leave the channel. This indicates that mating could occur, at least in the Cape Canaveral Ship Channel, during the month of May. Captive green sea turtles, which have mated for more than 100 minutes, nest an average of 28.4 ($\pm$11.4) days after mating (Wood and Wood 1980). If loggerheads behave in a similar fashion (and other aspects of their reproductive ecology do appear similar), then one would expect mating to occur in late April and May, since nesting begins in mid-May and becomes heavy during June. This predicted mating period would coincide with the arrival of females in the Cape Canaveral Ship Channel and with the decrease in male testosterone titers. Licht et al. (1985) recorded similar drops in the testosterone titers of male green sea turtles prior to and during the start of the mating season. Mating male green turtles captured off the west coast of Mexico had higher testosterone titers than did mating males at the Cayman Turtle Farm (Licht et al. 1980). Therefore, it is possible that these wild green turtles were mating earlier (relative to the expected decline in testosterone) than captive turtles. Therefore, our testosterone data, together with data on captive green turtles (Wood and Wood 1980; Licht et al. 1979, 1985), data on mating male green turtles in the wild (Licht et. al. 1980), and the data on adult loggerhead movement patterns (Henwood 1987b) strongly suggest that the most probable time for the mating of these loggerheads would be late April through May. The significant drop in the testosterone of adult males during this time period suggests that this hormone is not directly regulating mating behavior. However, Licht et al. (1985) found that the premating peak in the testosterone titers of green sea turtles positively correlated to the number of females mounted and the total mounting time of a given male. Furthermore, Owens (1976) showed that injections of testosterone could induce mating behavior in immature male green sea turtles.

Adult female loggerheads

Henwood (1987b) found that the number of adult females in the Cape Canaveral Ship Channel increases sharply during May, remains high during June, and then decreases through July and August. Additionally, his tag recovery data verify that many of these turtles nest on nearby beaches. Comparing our results with his data suggests that testosterone titers are increasing as the adult females move into the channel during May (Fig. 4). Titers appear to remain high through June and July, and then decrease toward the end of the nesting season. Figure 4 indicates that nesting females have higher titers than those captured in the water. We speculate that this may result, at least partially, from capturing turtles which are at various reproductive stages. For example, the group of females captured in the water during July could be composed of turtles that are between nestings and turtles that have already nested for the last time. Additionally, it is possible that some of the females were still immature or were adults which were not reproductively active during the year they were captured. Regardless, the results indicate that testosterone titers increase prior to the nesting season and then remain elevated through the nesting season. Licht et al. (1979) recorded similar data for captive green sea turtles except that their titers were highest during mating, then decreased slightly, but not significantly, during nesting. However, with wild green sea turtles, Licht et al. (1980) recorded higher testosterone titers for nesting turtles than for mating turtles.

During May, when large numbers of females begin moving into the Cape Canaveral Ship Channel, testosterone titers appear to be increasing. Therefore, as with adult males, it is possible that testosterone may have a role in migratory behavior. Licht et al. (1979) suggest that increased testosterone could also facilitate mating behavior in female green sea turtles. If loggerheads mate prior to the nesting season (as do captive green sea turtles) then our data indicate that testosterone titer is increasing during the time of mating. The affects of androgens on female mating behavior have not been studied in turtles, but androgens have been shown to stimulate receptivity in some lizards (Nobel and Greenberg 1940).

The female loggerheads' elevation in testosterone titer prior to the nesting season is similar to that recorded for two other multiclutched turtles, the green sea turtle (Licht et al. 1979) and the stinkpot turtle, *Sternotherus odoratus* (McPherson et al. 1982). Callard et al. (1978) suggest that increases in testosterone in the painted turtle, *Chrysemys picta*, could be related to its ability to act as a precursor for the synthesis of estrogen, which is important in the mobilization of vitellogenin from the liver and subsequent egg production (Ho et al. 1982). McPherson et al. (1982) concurred with this hypothesis and speculated that multiclutched turtles may have an increased ability to aromatize testosterone to estrogen, allowing for a more compact interval between nestings. Additional studies correlating the female loggerheads' testosterone and estrogen titers could provide insight into the question of whether or not aromatization is an important adaptive mechanism in egg production.

Testosterone as an indicator of reproductive status

Results indicate that testosterone titer could be used, during certain months to determine if an adult male is reproductively active. Because adult females exhibited elevated titers prior to and during nesting season, their testosterone titers also have the potential of being used as an indicator of reproductive activity during this time period. However, further evaluation of female titers is necessary because the individuals captured in the water exhibited a wide but continual range of titers. This prevented the accurate prediction of reproductively active versus reproductively inactive individuals. In summary, the testosterone titers show strong potential as a tool for evaluating reproductive status. By collecting blood samples during tagging and netting projects, much new information could be generated which would provide a better understanding of the reproductive ecology of sea turtles and thus facilitate the enhancement of management stratagies for endangered populations.

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Sexing Techniques and Sex Ratios for Immature Loggerhead Sea Turtles Captured Along the Atlantic Coast of the United States

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ABSTRACT

Serum testosterone titer, tail length, and straight carapace width/length ratio were evaluated as possible indicators of the sex of immature loggerhead sea turtles. Serum testosterone titer proved to be an accurate indicator of sex. Tail length and straight carapace width/length ratio were not accurate indicators of sex. The testosterone sexing technique was used to sex immature loggerhead sea turtles captured at four locations along the Atlantic coast of the United States. The predicted sex ratios obtained at the four sampling locations were not significantly different from one another. The pooled sex ratio of the captured turtles (1.94F:1.00M, *n*=256) was significantly skewed toward female. Additionally, the results suggest that immature loggerhead sea turtles do not undergo sex-specific migrations.

INTRODUCTION

The sex of many turtle species is determined by the temperature at which the eggs are incubated (reviewed in Bull 1980). An initial step in evaluating the ecological and evolutionary significance of this type of sex determination is the estimation of the resulting population sex ratios. For this reason, researchers have recently begun studying sex ratios in various turtle populations (Vogt and Bull 1984; Mrosovsky et al. 1984a,b; Limpus and Reed 1985).

Sea turtle populations represent a useful model for sex ratio studies for several reasons. First, research indicates that at least five species of sea turtles possess environment-dependent sex determination (Yntema and Mrosovsky 1980; Morreale et al. 1982; McCoy 1983; Mrosovsky et al. 1984a; Wibbels et al. 1985). Second, many conspecific sea turtle nesting beaches are widely separated latitudinally, thus the sex ratios produced on such beaches are of comparative interest (i.e., do different nesting beaches produce different sex ratios or do pivotal temperatures in the sex determining mechanisms vary relative to nesting beach temperatures?). Lastly, sex ratios in sea turtle populations are of interest because of conservation considerations. Due to their endangered status in many parts of the world, sea turtle populations are being affected by management programs. These programs can include captive-rearing and artificial-incubation techniques which may potentially increase the turtles' probability of reaching sexual maturity. However, these same techniques could also significantly influence population sex ratios, thereby altering reproductive success. A knowledge of population sex ratios and their effects on reproductive success could facilitate optimal use of present management techniques.

A point to consider when studying sea turtle sex ratios is the possibility of a dynamic sex ratio within a population. If differential mortality relative to sex occurs within a sea turtle population, then different sex ratios could exist for different age classes of turtles. For example, adult females might experience higher mortality than adult males due to their nesting behavior, nesting energy expenditures, and increased exposure to exploitation. Hatchlings could also be subject to differential mortality relative to sex. Turtles hatching early in the nesting season might experience a different mortality rate than those hatching later, due to factors such as food availability and water conditions. Additionally, Mrosovsky et al. (1984b) indicated that turtles hatching earlier in the nesting season may be preponderantly the opposite sex of those hatching later. Therefore, a comprehensive study of a population's sex ratio should include sex ratios of different size classes of turtles.

Mrosovsky et al. (1984b) indicated that sex ratios of hatchling loggerheads, *Caretta caretta*, could vary from 10 to 80% female depending on the time of year when the eggs were laid. Limpus et al. (1983) found that hatchling sex ratios could vary from an average of 29.5 to 63.1% female, depending upon which beach a nesting green turtle, *Chelonia mydas*, chose on Heron Island. These observations exemplify the problems associated with accurately extrapolating hatchling sex ratios to the sea turtle populations. To sample hatchlings randomly from a population, complete beach profiles, including nest densities relative to location on the beach and time of year, would be necessary for all the nesting beaches used by a given population.

There are also many problems associated with estimating adult sex ratios in sea turtle populations. Ross (1984) found one area near Masirah Island (Northern Indian Ocean) that had more adult male green sea turtles than adult females, yet in nearby areas there were no significant differences between the numbers of adult males and females. Recent data collected by the National Marine Fisheries

Service (NMFS) indicate that in the Cape Canaveral Ship Channel the ratio of adult male loggerheads to adult females changes significantly relative to the time of year (Henwood 1987). Limpus and Reed (1985) indicated that complex relationships may exist between the number of mature females associated with a nesting beach and the actual number nesting each year. These studies indicate that variables such as sex-dependent variations in migration patterns (Booth and Peters 1972) and the multiannual reproductive intervals exhibited by females make interpretation of adult sex ratio data difficult.

We suggest that an effective initial step in the study of sea turtle population sex ratios is the examination of the sex ratio in the juvenile-through-subadult portion of the population. This portion represents a condensation of many years of hatchling production. Furthermore, a study of this portion of the population circumvents the logistical problems associated with the study of adult and hatchling sex ratios. However, it is presently not possible to sex immature sea turtles using external morphology. Although adult sea turtles have traditionally been sexed according to tail length (Pritchard et al. 1983), this method has never been evalutated for immature turtles. Geldiay et al. (1982) noted differences between immature male and female loggerhead carapace width/length ratios. Unfortunately, he did not evaluate whether these differences could be used to sex individual turtles. Owens et al. (1978) analyzed serum testosterone titer via radioimmunoassay (RIA) to determine the sex of immature green sea turtles, but this technique has not been evaluated for other sea turtle species. Laparoscopy has been used to sex immature green turtles at the Cayman Turtle Farm (Wood et al. 1983) and near Heron Island (Limpus and Reed 1985). Although this is a definitive method for sexing turtles, it is logistically difficult in the field and requires surgical training. Development of a simpler sexing technique would facilitate larger scale sex ratio studies.

We report here on the evaluation of serum testosterone titer, tail length, and straight carapace width/length ratio as possible indicators of the sex of immature loggerhead sea turtles. We then use the testosterone titer sexing technique to estimate the sex ratios of loggerhead sea turtles captured at four different locations along the Atlantic coast of the United States.

METHODS AND MATERIALS

Methods of capture

Each turtle used in this study was captured at one of the following locations: (1) in the Cape Canaveral Ship Channel, FL; (2) in the cooling system intake channel of the St. Lucie nuclear power plant on Hutchinson Island, FL; (3) in the Indian River near Sebastian Inlet, FL; or (4) in the Chesapeake Bay.

A shrimp trawler, equipped with one or two shrimp or fish trawls with 18-m mouths, was used to capture turtles (n = 166) in the Cape Canaveral Ship Channel. Trawling was conducted intermittently from 3 September 1980 to 18 April 1983 between the hours of 0800 and 1600 EST. Trawls were limited to approximately 30 minutes duration to prevent mortalities.

The primary location for capturing turtles (n = 24) in the Indian River was a cove 1 km south of the Sebastian Inlet. A number of other sites, ranging from 3 km south of the inlet to 5 km north of the inlet, were also sampled. However, these sites were less productive and were not resampled. Sampling was conducted 2-3 days a week from 25 May 1983 to 15 July 1983. Turtles were captured in a 365-m-long tangle net which was approximately 3.5 m in depth and consisted of 25-cm mesh. The net was suspended from floats placed at 18-m intervals. All areas sampled ranged from 1.5 to 3.0 m in depth, thus the net's leadline always contacted the bottom. A normal sampling day consisted of putting the net in the water at 0700 and removing it at 1800 EST. The net was continually tended from a 5-m boat to facilitate the immediate removal of turtles, thus preventing mortality.

Turtles captured in the cooling system intake channel of the St. Lucie power plant entered that channel via a submerged concrete conduit which connected to a water intake head located 400 m offshore. The turtles (n = 61) were captured with a 35×3-m tangle net with 16-cm mesh. The net did not have a leadline, so turtles were able to reach the surface for air. The net was checked twice daily for turtles. Turtles were captured from 1 September 1982 through 17 April 1984.

In the Chesapeake Bay, turtles (n = 21) were caught in pound nets. These nets were located in the York River, near Gwynn's Island, and at the mouth of the Potomac River. The pound nets were in water ranging from 2 to 10 m in depth. Turtles were captured from 11 May 1983 through November 1983.

Exclusion of adult turtles from analysis

To prevent the use of adult turtles in this study (for reasons indicated in the Introduction), individuals with straight carapace lengths greater than 76 cm were excluded from the results. This value was chosen after considering the minimum carapace lengths of nesting females along the U.S. Atlantic coast (Hirth 1980) and the carapace lengths of turtles which were laparoscopically examined (all of which were immature).

Measurement techniques

Straight carapace lengths and widths were measured with calipers. Carapace lengths consisted of the distance from the anteriormost margin of the nuchal scute to the posteriormost margin of the longest postcentral scute. Carapace width consisted of the distance between the lateralmost margins of the right and left marginal scutes located at the widest portion of the carapace. Tail length was recorded with a tape measure and consisted of the distance from the posteriormost margin of the anal scutes to the tip of the tail.

Tail length and carapace width were not recorded for all turtles captured during this study. Therefore, the evaluation of tail length and carapace width/length ratio as sex indicators involved only a subset of the turtles captured (n = 164 and n = 153 respectively).

Blood sampling

Blood samples were obtained from the cervical sinuses of the turtles by the method described by Owens and Ruiz (1980). Turtles captured in the Cape Canaveral Ship Channel, the Indian River, and at the St. Lucie power plant were all sampled within 30 minutes after their removal from the nets. Turtles captured in the Chesapeake Bay were sampled within 6 hours after their removal from the pound nets. Blood samples were collected in sterile vacuum tubes and placed on ice (for up to 8 hours) until they were centrifuged with a desktop clinical centrifuge. The serum was pipetted off and frozen.

To investigate the affect of capture stress on testosterone titer, repeated sampling was performed on four turtles captured in the Cape Canaveral Ship Channel on 29 May 1982. From 0905 to 1455 EST, samples were obtained at intervals ranging from 20 to 80 minutes.

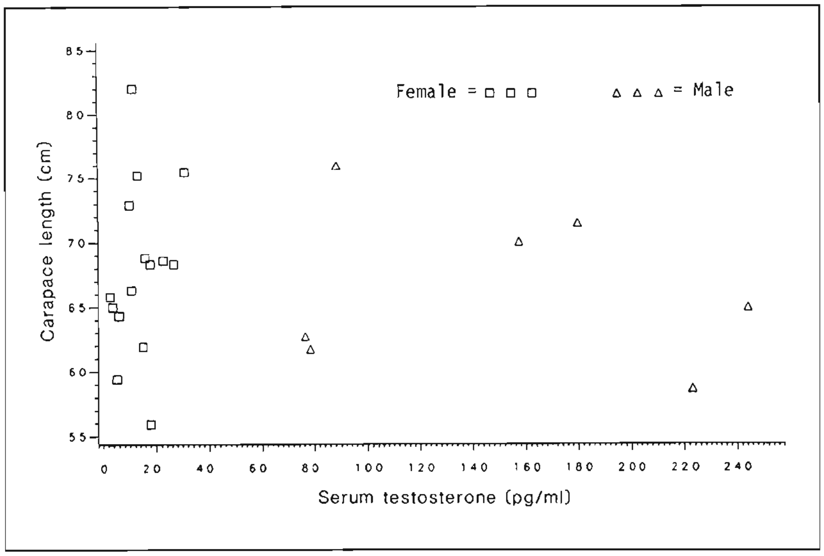

Figure 1—Serum testosterone titers of laparoscopically examined turtles.

Testosterone RIA

An RIA similar to that described by Coyotupa et al. (1972) was used to determine the testosterone titer in each serum sample. The antibody was obtained from Cambridge Medical Diagnostic (Lot No. R51226F) and was diluted 1:4500 with tris/gel buffer. Tritiated testosterone was obtained from New England Nuclear and was diluted so that 0.1 mL aliquot would yield 7500 cpm. Testosterone standards were obtained from Steraloids Inc.

One-mL aliquots of serum were extracted with 4 mL anhydrous ether. The ether phase was poured off, dried under a steady stream of nitrogen, and then reconstituted with 1 mL of acetone. Two 400-μL aliquots were pipetted from the 1 mL of acetone. These aliquots were then dried in air overnight. After drying, they were reconstituted with 100 μL of tris/gel buffer, vortexed, and then incubated in a water bath for 30 minutes at 4°C. Standard tubes with 100 μL of testosterone at known concentrations (ranging from 15.6 pg/mL to 200.0 pg/mL) were prepared. Tritiated testosterone (100 μL) and antibody (100 μL) were added to all standard and sample tubes. The tubes were then incubated overnight at 4°C. Following incubation, 1.0 mL of dextran-coated charcoal (0.313 g T 70 Dextran and 3.125 g Norit A charcoal per 500 mL tris/gel buffer) was added to each tube to absorb the unbound tritiated testosterone. All tubes were vortexed, incubated for 15 minutes at 4°C, and then centrifuged for 15 minutes at 1200 × g. The supernatant was poured into sealable bags with 5 mL of scintillation cocktail. All bags were counted for 5 minutes on a scintillation spectrometer. Testosterone titers in pg/mL were calculated from the counts using the standard curve generated in the assay. The intraassay coefficient of variation for the testosterone assays was 6.3% and the interassay coefficient of variation was 20.8%.

Corticosterone RIA

The dominant glucocorticoid produced in reptiles is corticosterone (Sandor 1969). We measured this hormone in the repeatedly sampled turtles to quantify stress-induced adrenal steroid production. These data are useful in determining if the production of other steroids affects serum testosterone titer.

The corticosterone RIA procedure is identical to that of the testosterone RIA except that only 250-μL aliquots of sera were extracted. Antibody (#377 anticorticosterone 3-bovine serum albumin) was obtained from Gordon Niswender and used at a dilution of 1:400. Tritiated corticosterone was obtained from New England Nuclear. Standards were obtained from Steraloids, Inc. Only one corticosterone assay was performed and its intraassay coefficient of variation was 2.1%.

Laparoscopy

The sex of 22 turtles was verified through laparoscopic examination. We initially used the laparoscopic technique described by Wood et al. (1983), including the general anesthetic doses recommended by Wood et al. (1982). However, use of this procedure on a shrimp boat with turtles that were captured in 30-minute trawls resulted in 2 of 6 turtles dying. We therefore substituted a local anesthetic (lidocaine) for the general anesthetic. This substitution decreased but did not prevent mortality (2 of 16 turtles died). We have since concluded that the stressed nature of these turtles (produced by capture in 30-minute trawls followed by prolonged exposure to direct sun on the deck of the shrimp boat) prevented mortality-free laparoscopy. However, we feel it is necessary to note that we have never experienced mortality with nonstressed captive turtles which we have laparoscopically examined in the laboratory (17 turtles).

RESULTS

Evaluation of testosterone titer

Serum testosterone titers of the turtles whose sexes were verified through laparoscopic examination are shown in Figure 1 (Female: $n=15$, $\bar{x}=13.9$, $s=\pm 8.1$; Male: $n=7$, $\bar{x}=149.7$, $s=\pm 70.1$). Male titers were significantly higher than female titers (t-test $P<0.05$) and the ranges did not overlap. The maximum titer recorded for a female was 31.0 pg/mL, and the minimum titer recorded for a male was 76.4 pg/mL.

The serum corticosterone and testosterone titers of the turtles which were repeatedly sampled are shown in Figures 2 and 3. Serum corticosterone titers increased significantly after capture (two-way ANOVA, $P<0.001$) indicating that the stress of capture induced adrenal steroid synthesis and release. Serum testosterone titer did not show a significant increase after capture (two-way ANOVA,

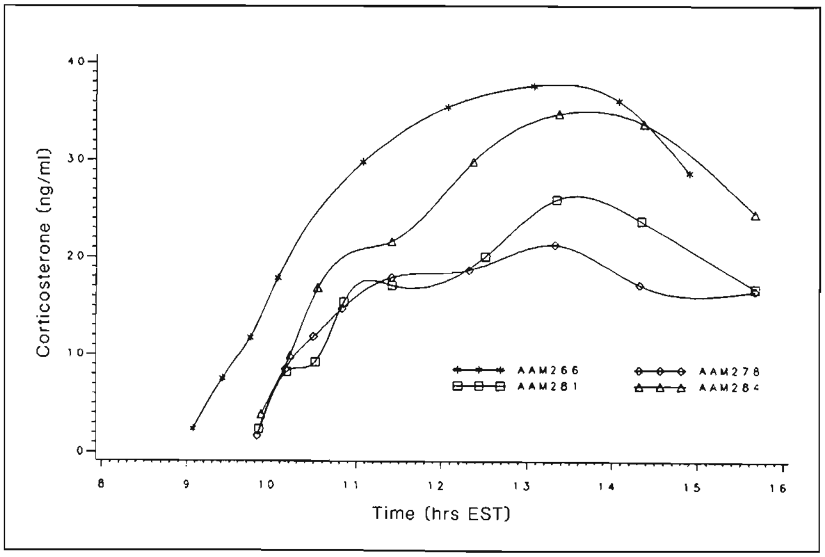

Figure 2—Serum corticosterone titers of loggerhead sea turtles which were sampled repeatedly.

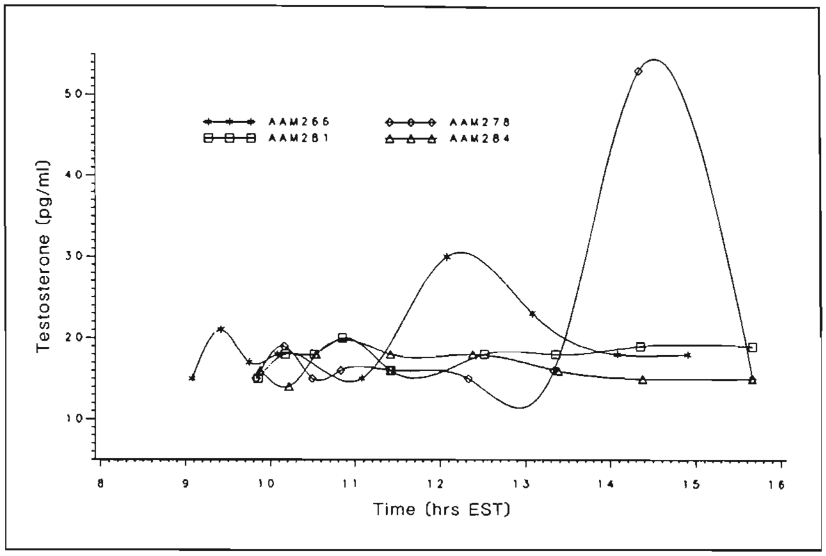

Figure 3—Serum testosterone titers of loggerhead sea turtles which were sampled repeatedly.

P>0.05), but two of the turtles did exhibit noteable variability (Fig. 3). However, the highest testosterone titer recorded for these turtles (53.0 pg/mL) was still below the minimum value recorded for the males that were laparoscopically verified (76.4 pg/mL). Furthermore, there were no noteable changes in testosterone titer during the initial 30 minutes following removal from the net (blood samples from 92% of the turtles used in the study were taken within 30 minutes after the turtles were removed from the nets). The testosterone titers of these four turtles indicate that they were all females. Although no males were used in this particular experiment, similar experiments with male stinkpot turtle, *Sternotherus odoratus*, indicate that testosterone titer decreases after capture, but this decrease occurs gradually over a long time period (50% decrease over a 2-week period; Mendonca and Licht 1985). This suggests that the titers of samples taken near the time of capture should not be influenced by the stress associated with capture.

The distinct difference between male and female serum testosterone indicates that this blood parameter can be used to accurately predict the sex of immature loggerheads. A conservative approach would be to predict that individuals with titers ⩾76.4 pg/mL (minimum titer of laparoscopically examined males) are males, and that 31.0 pg/mL (maximum titer of laparoscopically examined females) are females. However, we presently have no data to verify sex predictions for individuals with serum testosterone titers between 31.0 and 76.4 pg/mL. We have used the above method to predict the sexes of turtles captured in this study. The predicted sexes are used in the following evaluation of other possible sexing techniques and in the estimation of sex ratios.

The serum testosterone titers and the predicted sexes of the turtles captured at four sampling locations are shown in Figures 4-7. The sex of 16 of the 272 turtles captured was not predicted because of their intermediate testosterone titers (Table 3). The proportion of turtles exhibiting intermediate titers varied significantly between the four sampling locations (Replicated goodness of fit test, P<0.05). We speculate that variables such as temperature, time of year, and the time period between capture and blood sampling could affect the number of turtles with intermediate titers. The testosterone titers of the predicted males and females were consistent with those of the laparoscopically examined turtles (t-tests, P>0.05).

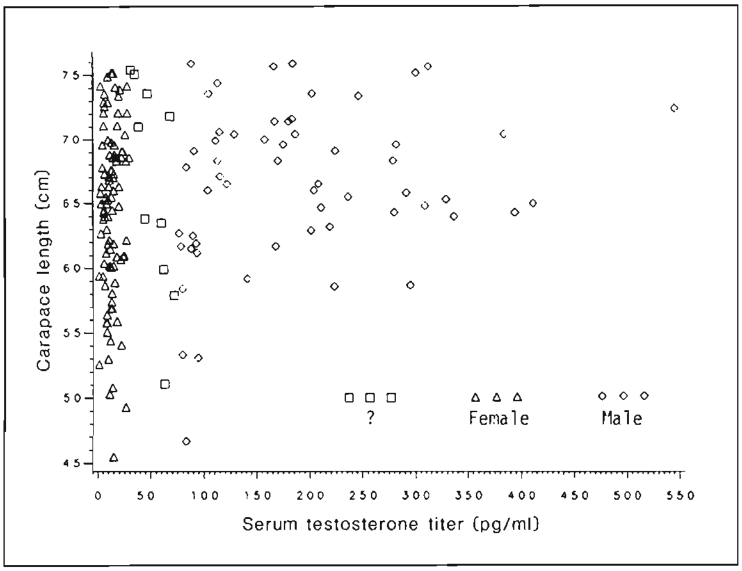

Figure 4—Serum testosterone titers of loggerhead sea turtles captured in the Cape Canaveral Ship Channel. Predicted sex is based on testosterone titer.

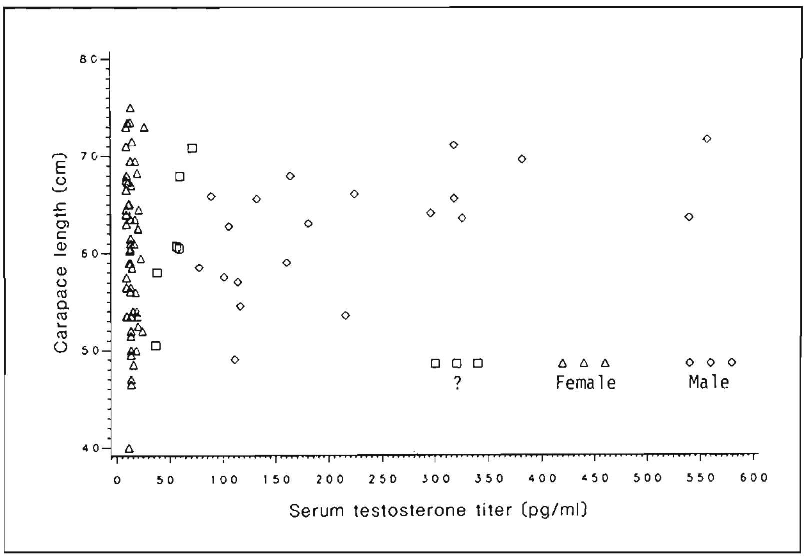

Figure 5—Serum testosterone titers of loggerhead sea turtles captured at the St. Lucie nuclear power plant on Hutchinson Island. Predicted sex is based on testosterone titer.

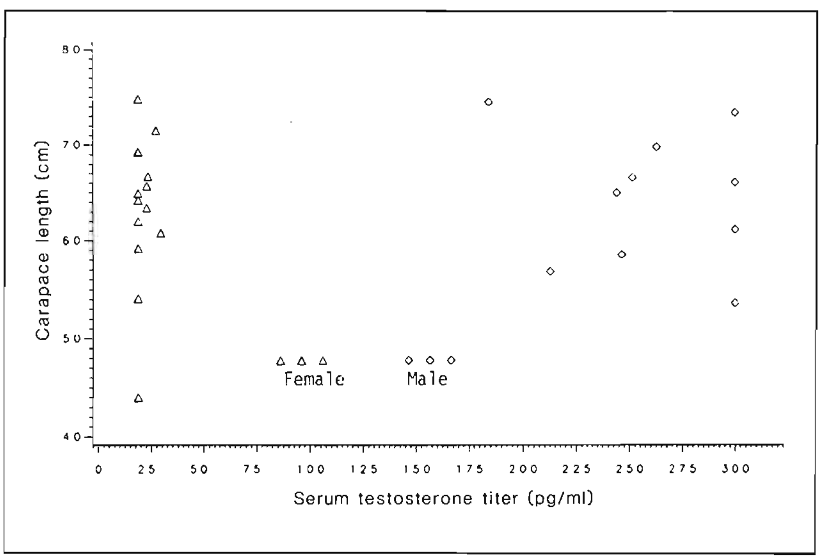

Figure 6—Serum testosterone titers of loggerhead sea turtles captured in the Indian River. Predicted sex is based on testosterone titer.

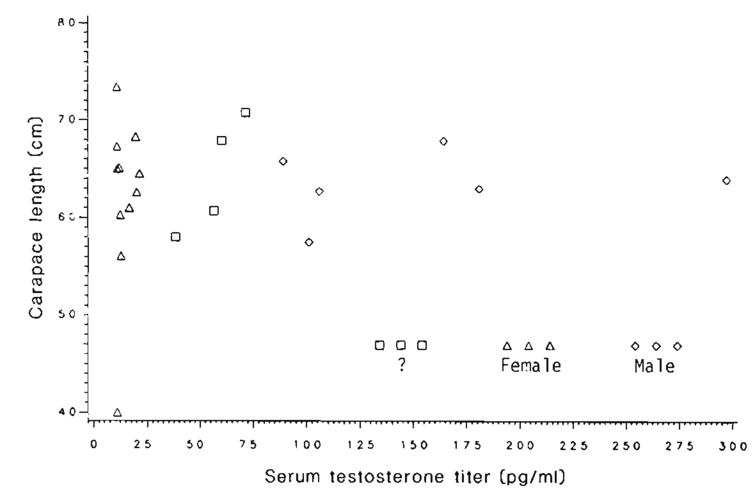

Figure 7—Serum testosterone titers of loggerhead sea turtles captured in Chesapeake Bay. Predicted sex is based on testosterone titer.

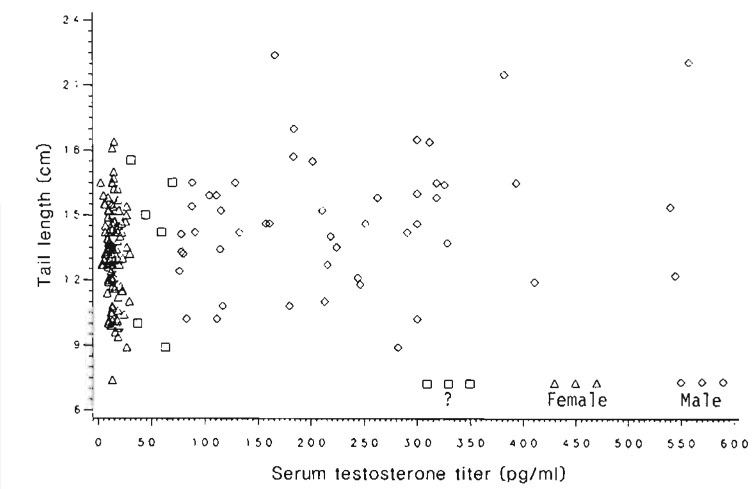

Figure 8—Comparison of immature male and female tail lengths of loggerhead sea turtles. Predicted sex is based on testosterone titer.

Evaluation of tail lengths

Male and female tail lengths are compared in Figure 8 (Female: $\bar{x}=13.6$ cm, $s=\pm2.1$ Although the ranges of male and female values overlapped to a great extent, male tail lengths were significantly longer than female (t-test, $P<0.05$). In an attempt to control for the effect of animal size on tail length, a tail length ratio (tail length/straight carapace length) was generated. Male and female tail length ratios are compared in Figure 9. As with tail length, the ranges of male and female tail length ratios overlapped to a large extent (Female: $\bar{x}=0.208$, $s=\pm0.023$; Male: $\bar{x}=0.224$, $s=\pm0.034$), but significant differences were detectable (t-test, $P<0.05$).

Evaluation of straight carapace width/length ratio

Male and female straight carapace width/length ratios are compared in Figure 10. No significant difference was detectable between male and female values (t-test, $P>0.05$).

Sex ratios

Table 1 lists the predicted sex ratios obtained during six different sampling periods in the Cape Canaveral Ship Channel. These sex ratios were not significantly different from one another (replicated goodness of fit test for homogeneity, $P>0.05$). The predicted sex ratios obtained during 4-month intervals at the Hutchinson Island sampling location are listed in Table 2. As with the sex ratios from the Canaveral channel, these also were not significantly different from one another (replicated goodness of fit test, $P>0.05$).

The pooled sex ratios predicted for each of the sampling locations are listed in Table 3, together with the chi-square values generated by comparing each sex ratio to a 1:1 ratio. These sex ratios were not significantly different from one another (replicated goodness of fit test for homogeneity, $P>0.05$). The pooled sex ratio from the four locations (1.94F:1.00M, $n=256$) was significantly different from a 1:1 (χ^2, $P<0.05$). Additionally, even if all of the turtles exhibiting intermediate values were males, the pooled sex ratio (1.64F:1.00M, $n=272$) would still be significantly different from a 1:1 ratio (χ^2, $P<0.05$).

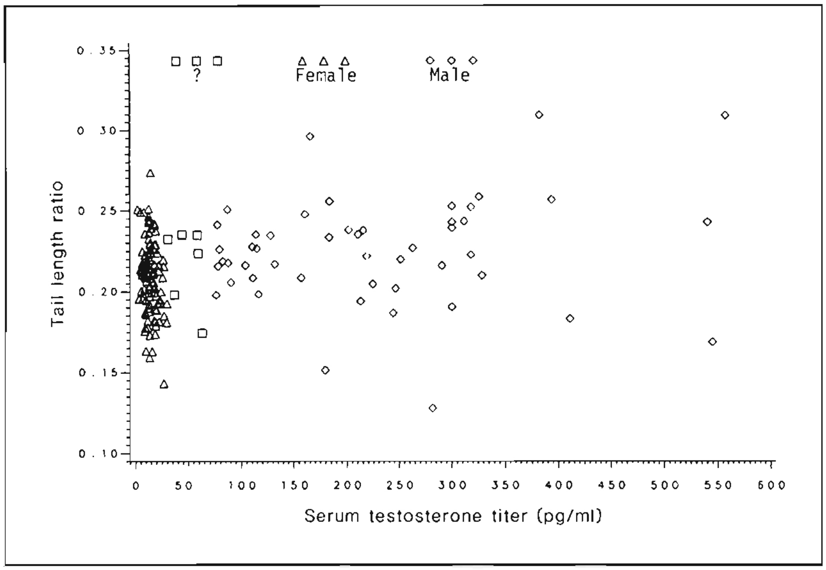

Figure 9—Comparison of immature male and female tail length ratios (tail length/straight carapace length) of loggerhead sea turtles. Predicted sex is based on testosterone titer.

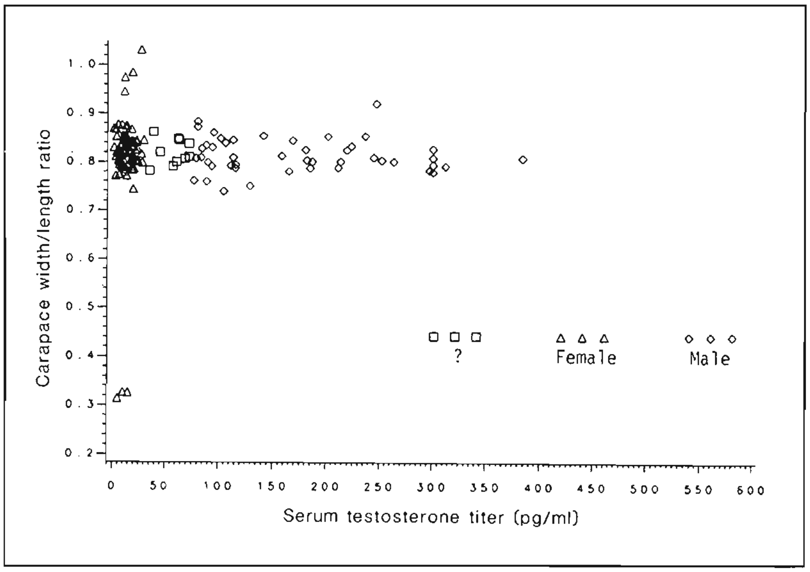

Figure 10—Comparison of immature male and female straight carapace width/length ratios of loggerhead sea turtles. Predicted sex is based on testosterone titer.

Table 1—Sex ratios of loggerhead sea turtles obtained during different sampling periods at the Cape Canaveral Ship Channel.

Date	No. females	No. males	Sex ratio	No. unknowns	Sample size
2/82	41	14	2.93F:1.00M	5	60
3/83	17	12	1.42F:1.00M	1	29
4/83	5	3	1.67F:1.00M	0	8
5/82	14	5	2.80F:1.00M	2	21
8/82	10	6	1.67F:1.00M	0	16
9/80-11/80	12	17	0.70F:1.00M	2	31

Table 2—Predicted sex ratios of loggerhead sea turtles obtained at Hutchinson Island during different sampling periods.

Date	No. females	No. males	Sex ratio	No. unknowns	Sample size
9/82-12/82	5	3	1.67F:1.00M	0	8
1/83-4/83	12	4	3.00F:1.00M	1	17
5/83-8/83	8	1	8.00F:1.00M	0	9
9/83-12/83	13	2	6.50F:1.00M	0	15
1/84-4/84	7	4	1.75F:1.00M	1	12

Table 3—Predicted sex ratios of loggerhead sea turtles captured at four sampling locations. * = $P<0.05$.

Location	No. females	No. males	No. unknowns	Sample size	Sex ratio	χ^2
Cape Canaveral	99	57	10	166	1.74F:1.00M	12.24*
Hutchinson Island	45	14	2	61	3.21F:1.00M	16.28*
Indian River	14	10	0	24	1.40F:1.00M	0.66
Chesapeake Bay	11	6	4	21	1.96F:1.00M	1.46
Pooled	169	87	16	272	1.94F:1.00M	25.72*

DISCUSSION

Sexing techniques

The results of this study indicate that the testosterone sexing technique is an accurate method for sexing immature loggerhead sea turtles. However, further laparoscopic examinations will be necessary to sex turtles which exhibit intermediate serum testosterone titers (30.1 to 76.3 pg/mL, equal to 6% of our sample of 272 turtles).

The results also indicate that as a group, immature male loggerheads have longer tails than immature females. Unfortunately, the ranges of male and female tail lengths overlap to a great extent (Fig. 8) and the mean difference in tail length is slight. Therefore, large sample sizes are necessary to note a significant difference. As a result, tail length and tail length ratio are not good indicators of the sex of individual turtles.

No significant differences were detectable between male and female straight carapace width/length ratios (Fig. 10). These data contradict Geldiay et al. (1982); however, insufficient information is given in their report to allow for careful examination of their methods and results. Our data indicate that straight carapace width/length ratio is not a good indicator of the sex of immature loggerheads.

Sex ratios

The predicted sex ratios of turtles captured at the Cape Canaveral and Hutchinson Island sampling sites did not exhibit significant changes relative to time of year (Tables 1, 2). This finding suggests that immature turtles (unlike adults) do not undergo differential movements relative to sex. Thus, this finding also supports the use of the juvenile-through-subadult portion of a population as an effective means of studying sex ratios within a population. Nevertheless, a comprehensive understanding of a population sex ratio would also require studies of hatchling and adult sex ratios.

The predicted sex ratios at all four sampling sites (Table 3) show a predominance of females. Statistical analysis indicates that these sex ratios are not significantly different from one another and that the pooled sex ratio from the four locations (1.94F:1.00M, $n=256$) is significantly skewed toward female. Thus, these data suggest that the sex ratio of immature loggerheads along the Atlantic coast of the United States is significantly skewed toward female.

Smith et al. (1977), utilizing electrophoresis of enzymes, could not distinguish separate populations of loggerheads along the Atlantic coast of the United States. If loggerheads along the Atlantic coast represent a single population, then one would expect the sex ratios from the four sampling locations to be similar. As stated earlier, sex ratios from the four sampling locations were not significantly different from one another. Thus, our data appear to support the single population hypothesis. On the other hand, if distinct populations were represented by each sampling location, then our results suggest that (1) the temperature regimes on the nesting beaches of different populations must be similar or (2) the pivotal temperature in the sex-determining mechanisms of the different populations must vary in accordance with the temperature regime of a given nesting beach.

Mrosovsky et al. (1984b) estimated the sex ratio of hatchling loggerheads from various beaches in Georgia and South Carolina to be 56.3% female based on data collected from 1977 through 1982. Our data indicate that the pooled sex ratio of immature loggerheads along the Atlantic coast of the United States is 66.3% female. This difference in sex ratios could arise if separate populations exist. However, if only a single population of loggerheads exists, then several hypotheses could account for the differences in these sex ratios. We offer the following as an example. If the pivotal temperature in the sex-determining mechanism of loggerheads does not vary among the Atlantic coast nesting beaches, then one might predict greater than 56.3% female hatchlings from Florida beaches (due to warmer incubation temperatures resulting from latitudinal differences). Considering the proportionally large number of loggerhead hatchlings originating from Florida beaches (Hopkins and Richardson 1984), one might also predict that the pooled sex ratio of hatchlings along the Atlantic Coast of the United States would be greater than 56.3% female.

Evolutionary theory indicates that the primary sex ratio in a population should be 1:1, assuming that the parental investment in producing male and female is equal (Fisher 1930; Charnov 1982). Thus, the skewing of a population's sex ratio is difficult, if not impossible, to explain based on standard evolutionary theory. However, Mrosovsky (1980) suggests that sea turtles may have a much greater scope in varying sex ratios than if they were restrained by a heteromorphic chromosome system. Unfortunately, the data collected to date are not sufficient to facilitate the generation of viable hypotheses regarding the evolutionary significance of sea turtle sex ratios. However, regardless of whether or not this female bias is a stable evolutionary phenomenon, its mere existence argues for further studies of sex ratios in sea turtle populations.

CONCLUSIONS

1) Serum testosterone titer is an accurate indicator of the sex of immature loggerheads.

2) Tail length and straight carapace width/length ratios are not good indicators of the sex of immature loggerheads.

3) Our data suggest that immature loggerheads (in contrast to adults) do not undergo sex-specific migrations.

4) Sex ratio of the turtles captured in this study (1.93F:1.00M) is significantly skewed toward female.

5) If loggerheads are to be artificially incubated or captively reared in the United States, production of the above sex ratio should be considered when choosing an incubation temperature.

6) Sex ratios from the four sampling locations are not significantly different from one another.

RECOMMENDATIONS

1) Continue to obtain immature loggerhead blood samples from as many locations as possible along the Atlantic coast of the United States. Samples obtained north and south of central Florida would be especially beneficial for comparative studies.

2) If laparoscopy of wild turtles is necessary in the future, we suggest implementing techniques which would decrease the stress associated with capture and holding of animals prior to the surgery.

3) Further biochemical genetic studies of loggerheads along the Atlantic coast could lead to a better understanding of population structure. A knowledge of population structure would be useful when analyzing sex ratios from different sampling locations.

4) Studies of hatchling loggerhead sex ratios from Florida beaches would be useful in understanding sex ratio dynamics for the entire region.

5) Continue present studies of adult loggerhead sex ratios from the Cape Canaveral Ship Channel. We feel it is imperative to continue and intensify the study of adult reproductive cycles. Our preliminary data indicate that reproductive hormone titers could be used to indicate the reproductive status of these turtles. Correlating reproductive status with tagging data could prove to be a powerful tool for understanding the reproductive ecology of these turtles. A knowledge of their reproductive ecology would facilitate the accurate estimation of adult sex ratios, which in turn would allow for the analysis of sex ratio dynamics within a population.

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Commercial Sea Turtle Landings, Cape Canaveral, Florida

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ABSTRACT

During the late winter and early spring months from 1970 through 1974, a sea turtle fishery developed at Cape Canaveral, Florida, with annual turtle landings ranging from 3,000 to 12,000 kg. The percentage of turtle landings was 31.4% green and 68.6% loggerhead. Reasons for the fishery development are discussed.

INTRODUCTION

Commercial landings of threatened or endangered species of sea turtles in U.S. waters need to be adequately analyzed. Descriptive analyses of U.S. sea turtle landings are limited, and only brief historical accounts of the Florida west coast and Key West turtle fisheries were presented by Caldwell and Carr (1957) and updated by Rebel (1974). Ehrhart (1983) reviewed the winter sea turtle gill net fishery that occurred at the turn of the century in the Indian River lagoon system, located behind Cape Canaveral, Florida. There is no account, however, of the Cape Canaveral sea turtle fishery that flourished offshore in the early 1970's. Cape Canaveral has one of the largest concentrations of non-breeding sea turtles in the world (Carr et al. 1980). Analysis of the commercial Canaveral sea turtle landings is necessary to help understand the ecology of this unique turtle aggregation, and to formulate conservation and management strategies mandated by the Endangered Species Act of 1973. In this paper, I summarize and discuss the reported commercial sea turtle landings for the Cape Canaveral area.

METHODS

The landings and values data in this paper were routinely collected and published by the Florida Department of Natural Resources in cooperation with the National Marine Fisheries Service, NOAA. These data were then summarized by species, month, and year, from 1952 through 1974, for Florida east coast counties. Monroe County, however, is omitted because the Key West turtle landings (located in Monroe County) consist of large numbers of green turtles captured from Caribbean and Central American waters, and not from U.S. east coast waters (Ingle 1971). The sea turtle, calico scallop, and shrimp landings from Brevard County are reported in detail because Cape Canaveral is the major port in the county, and the fishery resources landed at the Cape were likely caught in the productive waters of the Cape Canaveral Bight (Anderson and Gehringer 1965).

The sea turtle data were collected and reported by dockside seafood dealers, but it is probable that additional turtles were landed and directly consumed by vessel crews and not officially recorded. Therefore, these figures should be considered minimum harvest estimates, reflecting trends in the fishery.

All weights were converted from pounds to kilograms. It is not possible to estimate the accuracy of species identifications by fish dealers.

DISCUSSION

The reported commercial sea turtle landings from the Florida east coast changed dramatically from 1952 through 1974 (Fig. 1). From 1952 through 1969, the landings fluctuated from 0 to 2,250 kg, with no readily discernible pattern. However, from 1970 through 1974, Brevard County (Cape Canaveral) began reporting large turtle landings and virtually took over the entire east coast turtle fishery by doubling previous total landings.

There is no simple explanation for the sudden appearance of the Cape Canaveral turtle fishery. One possible explanation is that the Florida legislation, and the threat of the Endangered Species Act of 1973, raised the demand for turtle products, and seafood wholesalers stockpiled turtle products before a concerted enforcement program could be enacted. Ingle (1971) even suggested that there was

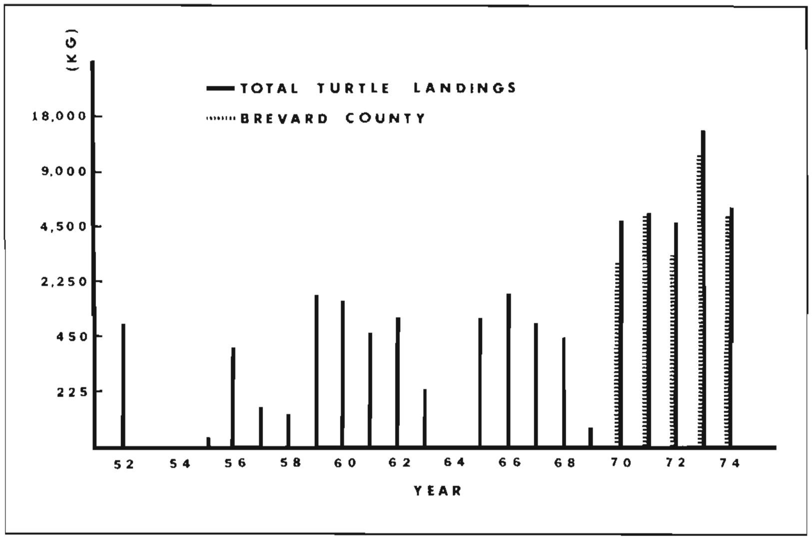

Figure 1—Annual commercial sea turtle landings from the Florida east coast, exclusive of Monroe County, 1952-74.

an increase of imported turtle products from Central America to Key West due to the restrictions placed on the Florida turtle fishery in 1971. The increased demand for turtles could easily be supplied by substituting domestically captured loggerheads (*Caretta caretta*) for the imported greens (*Chelonia mydas*). Cape Canaveral is the logical location in the United States to capture large quantities of turtles, close to consumer markets, to meet this rising demand. Unfortunately, the American public would be eating lesser quality loggerhead meat instead of the highly esteemed green turtle. The earlier aversion to loggerhead meat (True 1884) could have easily been overcome by producing highly spiced "turtleburgers" and "turtle stew."

The large increase of turtle landings at Cape Canaveral shown in Fig. 1 could be attributed to one or a combination of the following: (1) a directed fishery, (2) hypothermic stunned turtles, and (3) turtle bycatch by the trawl fisheries. However, there is no evidence of a direct turtle gill net fishery in the Cape Canaveral area during this period according to fishery reporting agents (J. E. Snell, Southeast Fish. Cent., Natl. Mar. Fish. Serv., NOAA, Miami, FL 33149, pers. commun. 1985), nor is there any record of a freeze during this period (Snelson and Bradley 1978) that would cold-stun the turtles residing in the Indian River lagoon system as recorded by Ehrhart (1983).

The bycatch of sea turtles by the penaeid shrimp trawl fishery is the most likely source of the Cape Canaveral turtle landings (Fig. 2). Shrimp nets capture many turtles incidentally (Hillestad et al. 1981), particularly in the Canaveral area (Carr et al. 1980). The landings plotted in Figure 2 show a possible correlation between annual landings of shrimp and turtles, but not between calico scallops and turtles. It is unknown what impact the calico scallop trawl fishery has on sea turtles, but it is unlikely to have as important an impact as the shrimp fishery. Turtle surveys conducted by the National Marine Fisheries Service, NOAA, in the Cape Canaveral area have shown that the turtles seem to be concentrated in the outer ship channel area (T. Henwood, Pascagoula Lab., Natl. Mar. Fish Serv., NOAA, Pascagoula, MS 39567, pers. commun. 1985). Large numbers of turtles could easily have been landed by shrimp vessel crews eager to increase their flagging revenues as shrimp prices and catch-per-unit-effort fluctuated. Using data derived from the Florida Summary of Commercial Marine Landings, the price-per-kilogram for turtles landed on the Florida east coast, 1952-74, averaged 0.42 for greens and 0.29 for loggerheads (Table 1). However, the price-per-kilogram for turtles landed in Brevard County, 1970-74, averaged 0.56 for greens and 0.38 for loggerheads. These price increases are modest, considering inflation, but the overall value of turtles landed at Cape Canaveral from 1970 through 1974 was reported as $12,012. This represents considerable "pocket change" for those crew members wishing to take the time to dress out turtles.

Although the species of sea turtle landed at Cape Canaveral were green and loggerhead, the species composition of the reported turtles varied annually from 1970 through 1974 (Table 2). The average species composition for these years was 31.4% green and 68.6% loggerhead. According to NMFS turtle survey data (T. Henwood, Pascagoula Lab., Natl. Mar. Fish. Serv., NOAA, Pascagoula, MS 39567, pers. commun. 1985), it is probable that the percentage of green turtles reported is too high if the turtles were captured in the ship channel itself and not on offshore shrimp grounds. Dockside seafood dealers and boat captains would not only be inaccurate in their identifications, but would probably lean more towards the more highly esteemed green turtle for more expedient sales.

The turtle fishery at Cape Canaveral was seasonal, the peak season occurring in the late winter to early spring when adult turtles congregated to mate (Fig. 3). Shrimping was poor duing these months, and it is likely that the shrimp vessel crews would probably have landed a marketable turtle bycatch during this period to increase revenues. Interestingly, no turtles were reported during the summer nesting months. It is possible that the breeding turtles were inshore and not available for capture.

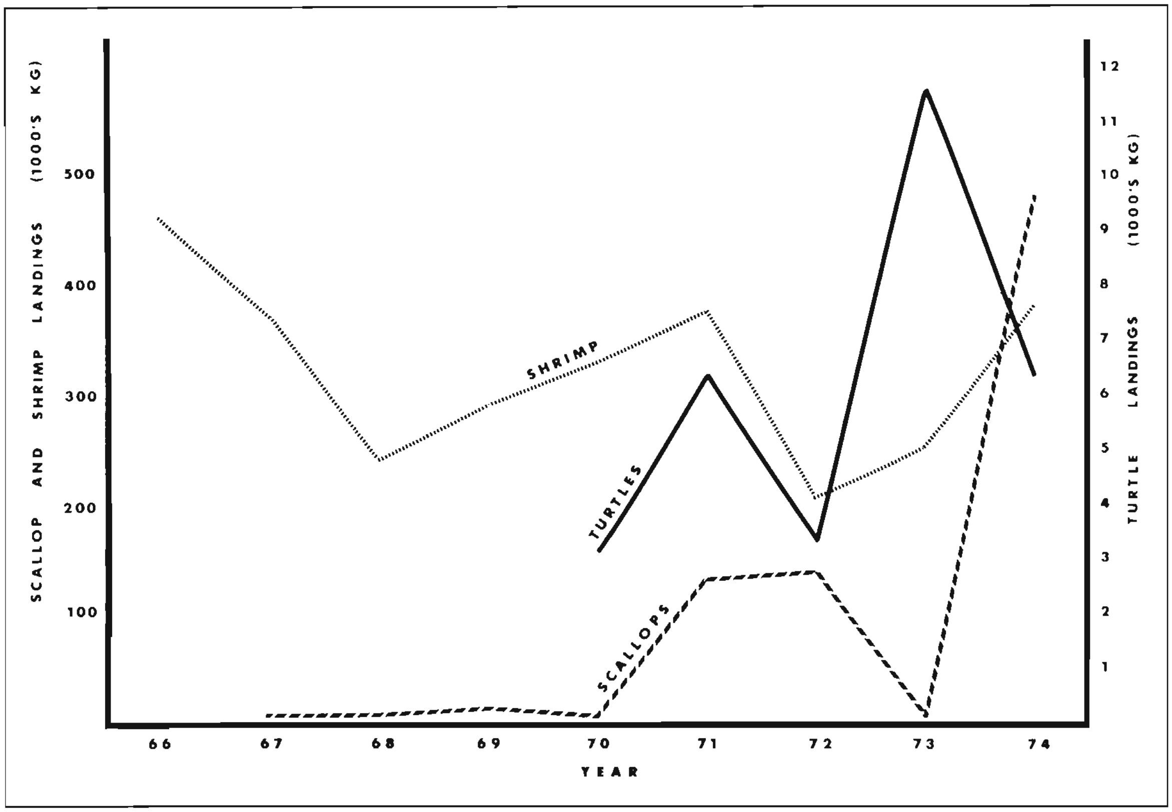

Figure 2—Annual commercial sea turtle, calico scallop, and penaeid shrimp landings from Brevard County, Fla., 1966-74.

Table 1—Mean price per kilogram of commercial sea turtle landings. Values were derived from Summary of Commercial Marine Landings (Florida 1952-74). *N* represents the number of years of data used in calculating the mean values.

Species	$\bar{X}$	SD	Range	*N*
Florida East Coast 1952-74				
Chelonia mydas	0.42	0.15	0.22-0.78	17
Caretta caretta	0.29	0.09	0.18-0.41	15
Brevard County 1970-74				
Chelonia mydas	0.56	0.18	0.36-0.78	5
Caretta caretta	0.38	0.13	0.22-0.56	5

Table 2—Sea turtle landings (kilograms) by species, in Brevard County, Florida, 1970-74.

Species	1970	1971	1972	1973	1974	Total	%
Chelonia mydas	1,613	2,323	1,021	1,321	3,451	9,729	31.4
Caretta caretta	1,464	4,033	2,332	10,303	3,081	21,213	68.6
Total	3,077	6,356	3,353	11,624	6,532	30,942	100.0

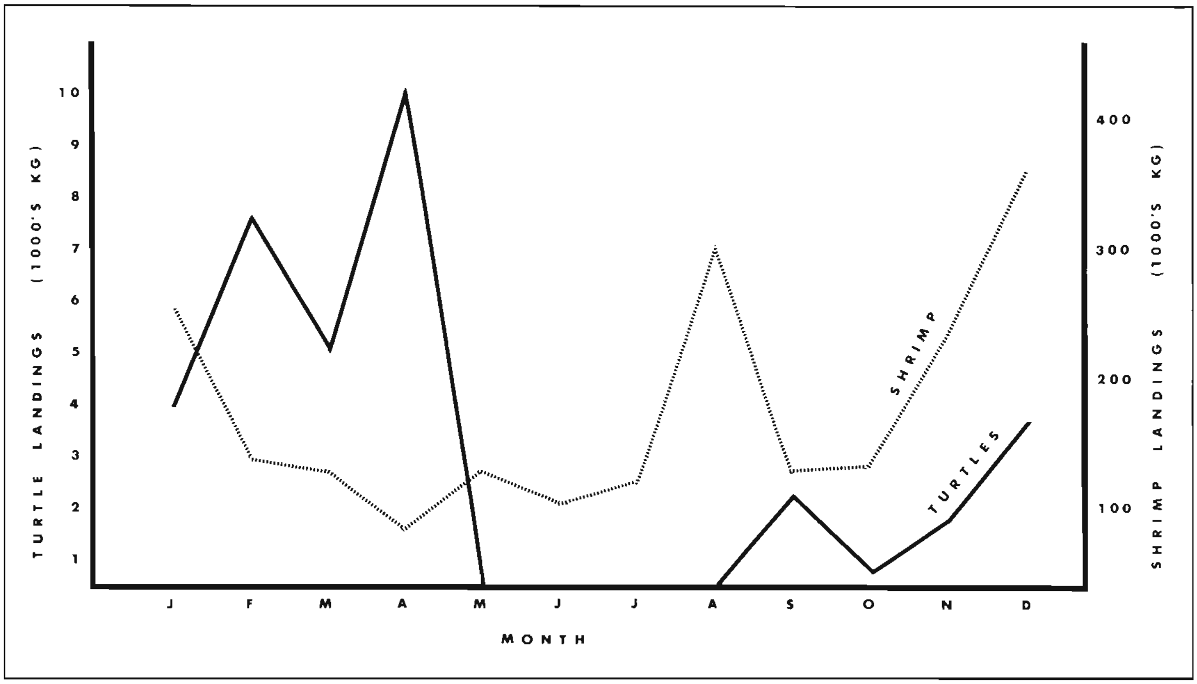

Figure 3—Monthly commercial sea turtle and penaeid shrimp landings from Brevard County, Fla., 1970-74.

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