NOAA Technical Memorandum NMFS-SEFSC-413

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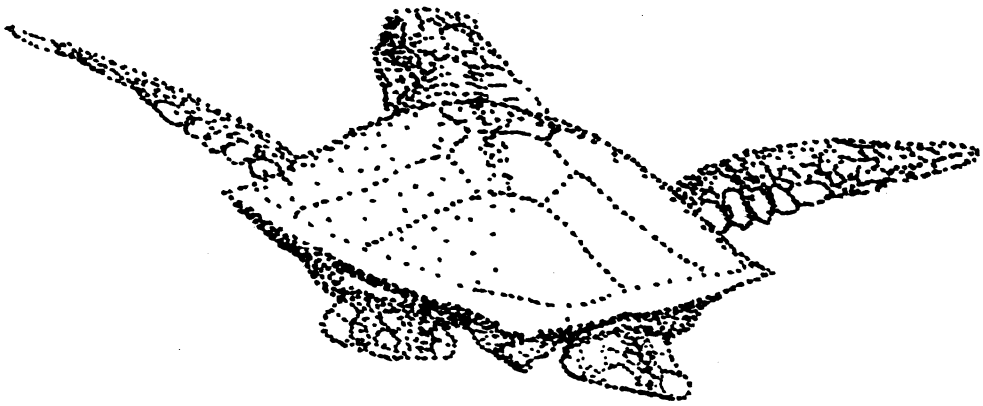

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National Oceanic and Atmospheric Administration
National Marine Fisheries Service
Southeast Fisheries Science Center
75 Virginia Beach Drive
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# INTRODUCTION

Most of the efforts to conserve sea turtles have centered primarily upon nesting areas and surrounding waters. In the western Atlantic the nesting ranges of sea turtles extend from the southern U.S. to South America, with most nesting occurring in tropical and subtropical regions. Because this terrestrial phase is highly visible and provides ready access to marine animals which are otherwise difficult to observe, there is a wealth of information on the nesting ecology of sea turtles. Placing such focus on nesting is perhaps inordinate given that the processes associated with nesting comprise such a small and select portion of the life cycles of sea turtles. With minor exceptions (Balazs, 1976), sea turtles only emerge from the water to nest, after which they return to the sea. It is possible that this abundance of information on nesting has had a disproportionate effect on our perception of the ecology of sea turtles. Further, this skewed outlook may unduly have influenced conservation and management strategies for these threatened and endangered animals.

The traditional outlook that sea turtles are tropical animals dates at least as far back as the middle of the 19th century (Dekay, 1842) and is pervasive throughout historical and current literature (for review, see Morreale et al., 1992). The customary view has been that sea turtles live their entire life cycles in warmer waters within the regions where nesting occurs. In reality, however, virtually nothing is known about the biology of adult males, a lot is known about nesting females and developing eggs, and little is known about the intervening years between the time hatchlings enter the water and the time when females return as adults to nest.

The generally accepted scenario for early life stages is that, as hatchlings, sea turtles swim away from their natal beaches and head out to the open sea (Carr, 1986*a*; 1986*b*; Carr and Meylan, 1980; Collard and Ogren, 1990; Witherington and Salmon, 1992). There is convincing evidence that these young juveniles remain in a pelagic environment, feeding in surface waters until they reach a certain size (Carr, 1967; Carr and Meylan, 1980; Carr, 1986*a*). After this pelagic stage, which presumably culminates at lengths of 20 to 30 cm for the Kemp's ridley (*Lepidochelys kempii*) and the green turtle (*Chelonia mydas*) and at 40 to 50 cm for the loggerhead (*Caretta caretta*), juveniles of these species undergo a behavioral shift and move into inshore waters. Age estimates based on skeletochronological analyses of specimens along the east coast suggest that Kemp's ridleys (Zug and Kalb, 1989) and loggerheads (Zug et al., 1986) of these size classes are approximately two to five years old.

It is postulated that, upon moving into inshore waters, young loggerheads and Kemp's ridleys take up residence in developmental habitats in the Gulf of Mexico (Carr and Caldwell, 1956; Ogren, 1989) and in coastal waters of Florida and Georgia (Mendonca and Ehrhart, 1982; Henwood, 1987; Henwood and Ogren, 1987), and are presumed to be seasonal migrants as far north as Chesapeake Bay (Lutcavage and Musick, 1985; Keinath et al., 1987). Although similarly small-sized juvenile sea turtles have been reported in northeastern waters repeatedly throughout the past century, they mostly were considered extralimital with such occurrences not representing the true geographical distribution of the species. Within the past three decades it has been documented that both leatherbacks (*Dermochelys coriacea*) and loggerheads occur in northeastern waters during the warmer months (Bleakney, 1965; Brongersma, 1972; Lazell, 1980;

Shoop, 1980). The contention by these researchers that such occurrences represented evidence of seasonal migration to these northern latitudes was most recently reinforced by a thorough assessment of occurrence and distribution of these two species based primarily upon extensive aerial survey data (Shoop and Kenney, 1992). Presumably because of the limitations of aerial surveys, however, smaller turtles rarely were seen. Thus, in recent years there are only few and scattered published records of Kemp's ridleys, green turtles, and small loggerheads in northeastern waters (Bleakney, 1965; Brongersma, 1972; Lazell, 1980, Shoop, 1980). Moreover, all of these were reports of relatively small numbers of individuals.

The interpretations of these scant data have varied greatly among conjectural accounts of sea turtle life cycles. Hendrickson (1980) believed that loggerheads could tolerate low temperatures but that the eastern seaboard was a disadvantageous environment for Kemp's ridleys. He also suggested that all individuals of this species in the Atlantic may be waifs that are lost to the reproductive population. The contention that northern sea turtles were extralimital was perhaps more compelling given that many of the turtles in both recent and historical accounts had been found cold-stunned or frozen. There has been a continuum of hypotheses ranging from the proposed 'lost waif' postulate, to the more moderate positions in which hypothetical alternatives also were presented (Carr, 1980; Pritchard 1989; Meylan 1986), to the other extreme offered by Lazell (1980) that New England waters should be considered a critical habitat to Kemp's ridleys and possibly loggerheads.

Although scientists' views differ on the fate of young sea turtles that venture into northeastern waters, there is a common and persistent belief that small turtles originally are swept into inshore waters of the Northeast by current anomalies such as eddies and meanders of the Gulf Stream (Carr, 1980: 1986*a*; Meylan, 1986; Ogren, 1989; Collard and Ogren, 1990). In this scenario young turtles are likened to larval fish, which have been known to be transported to shore in a similar manner. It is possible that the original biases that have shaped traditional thoughts on sea turtle ecology also have contributed to this view of juvenile sea turtles as powerless plankton whose dispersal often results from sporadic events and irregular current patterns.

As a result of a large number of juvenile sea turtles in New York that had washed ashore cold-stunned during the winter of 1985 and again in 1986 (Meylan and Sadove, 1986; Morreale et al., 1992), a long-term study was initiated, that provided us the opportunity to study the biology of juvenile sea turtles in northern waters. Because of the paucity of such information prior to our studies, we also were able, for the first time, to examine the relative merits of the diverse scenarios proposed in the literature concerning the role of northeastern waters in early life stages of sea turtles.

Our objective in this study was to determine the importance of New York waters in the life cycles of sea turtles. Among our specific goals for this research were to determine: 1) Which turtles occur in inshore waters of New York? 2) When and how frequently do these turtles occur? 3) What happens to them while they remain in inshore waters? 4) Do they succumb to the harsh winter environment? 5) Do these turtles represent a group of animals that is disjunct from the main reproductive populations in southern waters?

## MATERIALS AND METHODS

### Study Site

The geographic focus of the study was along the coastline and throughout the waters of New York State. Most of New York's shoreline is contained within Long Island, which extends nearly 200 km NNE from the mainland. The more than 400 km of this shoreline includes the southern barrier lagoons, the shallow eastern bays, and the deeper waters of Long Island Sound, all of which traditionally support high densities of biota.

### Mark-Recapture Study

A crucial factor in this research was obtaining access to sea turtles, which presumably were sparse within inshore waters. Therefore, it was necessary to elicit the support and cooperation of the local commercial fishermen who encountered sea turtles during normal operations. Over 200 fishermen were contacted individually, interviewed for information, and their assistance was requested. As a group, the fixed pound net fishermen received more attention because they reportedly captured the most sea turtles. Contact with fishermen was maintained on a frequent basis before and throughout each season.

Fishermen were requested to hold any sea turtles, live or dead, that they encountered. When they returned to port, they telephoned the 24 hr stranding number and were met as soon as possible by a member of the research team. All turtles captured were immediately weighed and measured. Standard inconel flipper tags were placed on the front flipper of every turtle and, with only few exceptions, turtles were released close to their points of capture. If a turtle was recaptured at an interval of more than 14 days, all of the previous steps were repeated, with the exception of tagging. Most of the loggerheads and green turtles were released within a few hours after capture. Select individuals of all three species were held temporarily in 2100 l tanks of circulating seawater for dietary studies before release (Burke, 1990; Morreale and Standora, 1992*b*). Many Kemp's ridleys and some loggerheads were outfitted with transmitters for use in the telemetry studies.

All data from tagged turtles also were provided to the National Marine Fisheries Service. Participation in this comprehensive sea turtle tagging network greatly enhanced the probability of receiving reports of long-distance recoveries of New York turtles.

*Cold-stunning and winter recovery--*

Major emphasis was placed on encouraging the involvement of the general public by reporting their observations or volunteering assistance in the search and collection of cold-stunned turtles during winter months. Winter collections began in 1985 and a volunteer network was established thereafter (Meylan and Sadove, 1986; Morreale et al., 1992). In 1988 the volunteer force exceeded 100 people and by 1989 more than 200 individuals were participating. Each volunteer was assigned a segment of beach to patrol at least once weekly between November and February of each year, the time of occurrence of cold-stunned turtles (Burke et al., 1991; Morreale et al., 1992). Cold-stunned turtles were collected on shore and in the surf during this period each year. Although beach patrol effort was not quantitatively equivalent

among years, it was nevertheless intensive in all of the study years. Each year beach patrols began at least two weeks prior to the occurrence of the first cold-stunned turtle on shore and continued until long after the number of turtle carcasses on shore had dwindled to nothing. These sampling efforts were considered to be both comprehensive and sufficiently extensive to make inferences about timing and distribution of cold-stunned turtles in New York.

## Radio and Sonic Telemetry

Beginning with preliminary research in 1987, radio and sonic transmitters were used extensively to study the behavior of numerous individual turtles over the next six years. The primary target species for this intensive monitoring was the Kemp's ridley. Turtles were outfitted with radio and sonic transmitters so that their movements and behavior could be monitored from a tracking boat, an airplane, on land, and underwater.

The radio transmitters used were of the same design as described by Standora and Morreale (1991). The lightweight radio transmitter, with a mass of 42 g, was attached to the trailing edge of the turtle's carapace by a flexible lanyard. A hydrodynamically shaped float attached to the antenna insured an upright posture, delivering the antenna out of the water when the turtle rose to the surface to breathe. The radio signal could then be received from a range of up to 15 km; a directional antenna mounted on the tracking vessel enabled monitoring of surfacing activity and direction of movement of the turtle.

In addition, many individuals were equipped with sonic transmitters that were mounted directly on the carapace. This 145 g transmitter emitted a signal that could be detected underwater from a maximum range of 3 km. Unlike the radio transmissions, the ultrasonic signal could be detected when the turtle is at or below the surface. This underwater signal also could be located with enough precision to recapture turtles underwater. During the 1988 season, a new type of depth-sensing sonic transmitter was tested and successfully used to monitor vertical movements of turtles within the water column. This type of sonic transmitter was used to monitor diving behavior of turtles in all subsequent years.

Turtles that were captured by fishermen were released near the point of capture and tracked from that point in the research vessel. Some of the turtles used in this study were turtles that had been cold-stunned the previous winter and held in captivity until their release the following summer. Release positions of these turtles were generally near the original capture site. Turtles, once released, were allowed unimpaired travel for a period of at least 14 days. After this interval, individuals were recaptured by scooping them up with a dipnet or by locating and capturing them underwater. Upon recapture, turtles were measured and weighed.

The telemetry studies began with the first turtle releases, generally in July, and continued into November until no turtles could be located from the tracking vessel, from land or from aerial surveys. Turtles were monitored 24 hr per day, except for stops for supplies and boat repairs. Turtle location was recorded continuously and surfacing behavior was recorded for one hour in each 4 hr time period of the day and night (i.e. 1200-0400, 0400-0800, etc..). Diving patterns also were recorded for many individuals. While following one turtle closely, the nearby waters frequently were scanned for other telemetered turtles. If another turtle was encountered, it was monitored and sometimes recaptured for measurement. Because at times there were several turtles being monitored simultaneously, it was necessary to prioritize on an individual basis.

## Resource Availability and Utilization

In several separate dietary studies, fecal samples from wild-caught turtles were collected and analyzed for food content (Burke, 1990; Morreale and Standora, 1992*b*; Burke et al., 1993). Gut contents from dead turtles that had been cold-stunned or washed ashore in the warmer months also were analyzed for food items (Burke et al., 1994). In addition, a study was undertaken to assess the food resources that were available in the habitats most frequented by sea turtles. This was deemed to be especially important after it became evident that turtles were foraging in inshore waters. After characterizing the habitats in which the turtles were active, it was necessary to determine which of the available resources the turtles were using.

The techniques used to characterize habitats and to assess resource availability involved the analysis of benthic biota, as quantified by systematic bottom trawling in specific habitats (Morreale and Standora, 1992*b*). At eight sampling sites in eastern Long Island where turtles consistently had been observed in previous years, benthic trawl surveys were conducted once a month from July through October 1990. Simultaneous fecal sample analyses of turtles from both mark-recapture and telemetry studies provided a method for determining which resources the turtles were using within these habitats.

Comparisons of benthic species composition and relative abundance were made among sample sites and among the sampling periods to determine spatial and temporal patterns in distributions of food resource availability. During the same period, fecal samples from Kemp's ridleys were analyzed to assess the food resources consumed by the turtles within the sampling areas. Fecal samples were retrieved from 13 of 15 individual turtles; 12 samples were retrieved from turtles upon their initial capture and four additional samples were retrieved from turtles that were recaptured in the telemetry study.

In this study, a summary of the relative abundances of different food items found in the feces of all the turtles was compared with the actual availability of these same food resources at the sampling sites throughout the season. In addition, food consumption by four individual turtles that were being monitored was compared with food availability in the specific habitats where the turtles were residing (for details, see Morreale and Standora, 1991).

## Growth

Growth measurements were determined from recaptured tagged turtles and on the telemetered individuals upon recovery. All measurements of carapace and plastron lengths of turtles were taken along a straight line with forester's calipers. Carapace measurements included SCL (nuchal notch to pygal tip), nuchal notch to posterior notch, and maximum width. Plastron length was measured along the midline. Turtles were weighed on a hanging scale or a top-loading scale, both accurate within 100 g.

Each year, several trials were conducted in which repeated measurements were compared for individual researchers and between researchers. In 1988 and 1989, measurements were taken and recorded by only two individuals (one of them SJM). From 1990 through 1992, measurements again were taken only by SJM and one other researcher. By using the same techniques each year, and minimizing variability among individuals, we were confident that measures of SCL are reliable to ± 0.1 cm; other shell measurements were much less reliably reproduced. Weights of animals also varied greatly over relatively short periods of time. Although there was not a

problem with precision in measurement, actual animal weights varied greatly with fluid gain or loss through evaporation and expulsion. Defecation of solids also largely effected the measured weight. Since most individuals in the study were small, changes by a few hundred grams could cause significant differences in total weight.

Because of the inherent variability associated with the other measuring techniques, growth was analyzed solely by using SCL values. Although most turtles were not measured when recapture intervals were less than 14 days, some values were recorded; these were included along with all other values, both positive and negative, in calculating growth regressions and mean growth rates. To compare these growth data with those presented in other studies growth values had to be converted to monthly or yearly rates.

**Satellite Telemetry**

The objective for this segment of the project was to develop a successful method of employing satellite telemetry to determine the migration patterns for turtles from northeastern waters. The purpose of using satellite telemetry, which distinguished it from the radio and sonic telemetry, was to determine the specific routes of travel for emigrating turtles once they entered the ocean. Until later in our research, the small sizes of the study animals and the large sizes of the transmitters precluded the use of this type of telemetry.

In 1990 the prototype satellite transmitters were available that were suitable for use on turtles of the size of Kemp's ridleys in New York waters. Given the experimental nature of these transmitters, the research efforts at first focused on: 1) development of application techniques appropriate for the turtles (Standora and Morreale, 1991); 2) evaluation of satellite transmission data relative to actual turtle behavior; and 3) preliminary documentation of late season migratory movements (Standora et al., 1992).

The telemetry study design in 1991 and 1992 incorporated programming changes based on our earlier evaluation of daily transmission cycle, dive duration, number of dives, average dive duration, and water temperature. In addition, after the preliminary research in 1990, the transmitters underwent design changes which made them smaller and lighter. Along with these modifications, all later transmitters were placed in custom-made, towable buoyant housings. Transmitters were attached with breakaway links to prevent entanglement or long-term encumbrance of the turtle. During 1991 and 1992 monitoring was conducted on Kemp's ridleys that presumably were beginning their fall movements out of the area. In 1992 the only late-season turtles available for telemetry were loggerheads.

Satellite transmitter duty cycles were programmed to 8 hr of activity with 16 hr of down time each day. The 8 hr period in which the transmitters were activated coincided with the hours of highest surface activity by the turtles (between 0800 to 1600 EST), as was determined in the previous years of this study. The choice of this duty cycle was selected as the best trade-off between maximizing the potential for collecting data and extending overall battery life. The predicted life of these transmitters was from 50 to 65 days, depending on the surfacing activity of the turtle.

Transmissions were monitored via satellite on a daily basis and all of the location data were plotted. Because the signals vary greatly in level of reliability (Standora and Morreale, 1991), actual turtle position was selected based upon quality of the transmitted signal and the

distance away from the previous and subsequent positions. Only those signals with higher reliability were used in determining movement patterns of the turtles.

## RESULTS

### Mark-Recapture Study

The long-term maintenance of the mark-recapture study, combined with the consistent effort with which it was conducted, ensured the continuity of turtle distribution data collected in New York waters from 1988 through 1992. Although less complete, additional data were also collected in 1987. This extensive data base was used as the primary means to analyze demographic characteristics of New York's sea turtle populations in addition to distribution patterns and seasonal and yearly activity cycles.

In all, there were 337 captures and subsequent recoveries of sea turtles from 1987 through 1992 (Table 1). Among the 228 individuals that were caught at least once, four species were represented: the loggerhead, *Caretta caretta*; the Kemp's ridley, *Lepidochelys kempii*; the green turtle, *Chelonia mydas*; and the leatherback, *Dermochelys coriacea*. The loggerhead was the most often captured, representing 56% of all individuals, followed by the Kemp's ridley, which comprised 27% of the total. Two turtles had been tagged elsewhere prior to capture in New York waters: a loggerhead tagged in New Jersey 376 days before its capture in Long Island, and a leatherback that was caught in nearshore waters by a trawler 762 days after being tagged while nesting on Yalimapo Beach in French Guiana.

All 228 individuals were released with flipper tags. There were 109 subsequent recoveries of tagged turtles, 97 of which were recaptured alive (Table 1). The recapture numbers for Kemp's ridleys were boosted by numerous recaptures in the telemetry studies. Among the recaptures of tagged turtles were 11 individuals reported from out-of-state waters, representing a long-distance recovery rate of nearly 5% of all turtles tagged. Only one turtle ever was recaptured in New York waters in two separate years. A 38 cm green turtle originally caught, tagged, and released in Gardiners Bay in September 1990 was recaptured nearly one year later 13 km from its previous capture site.

Commercial fishermen accounted for 84% of the 317 original captures and recaptures of live sea turtles in New York waters over the six years. By far the most frequent method of capture by fishermen (93%) was by pound net (Fig. 1). Trawlers reported a total of 16 captures, 5 were entangled in lobster pot lines, and 4 were entangled in gill nets. Other methods of obtaining live turtles included miscellaneous captures from boats, retrieval of those that were cold-stunned on shore or hit by boats, and the recapture of numerous Kemp's ridleys and a loggerhead as part of the telemetry study.

Live turtles were captured along the entire length of Long Island Sound, throughout the eastern and southern bays, and along the south shore of Long Island (Fig. 2). Because most of the live turtles were captured in pound nets, however, the distribution of turtles strongly reflects the locations of the nets, which mainly are concentrated in eastern waters.

The total number of captures per year ranged from 30 to 86 over the span of six years (Fig. 3). Judging by these live captures, sea turtles occur with great regularity in New York each

Table 1. Total numbers of sea turtles captured and tagged in New York waters from 1987 through 1992 as part of the mark-recapture study. Recoveries include both recaptures of live turtles and retrieval of dead turtles that previously had been tagged. Parentheses represent the numbers of turtles that were dead upon recovery.

| Species | Original Captures | Recoveries | |
|---|---|---|---|
| | | Total | Out-of-state |
| *Caretta caretta* | 129 | 47 (6) | 6 (4) |
| *Lepidochelys kempii* | 61 | 43 (4) | 2 |
| *Chelonia mydas* | 30 | 19 (1) | 3 (2) |
| *Dermochelys coriacea* | 8 | 0 | 0 |
| Total | 228 | 109 (12) | 11 (6) |

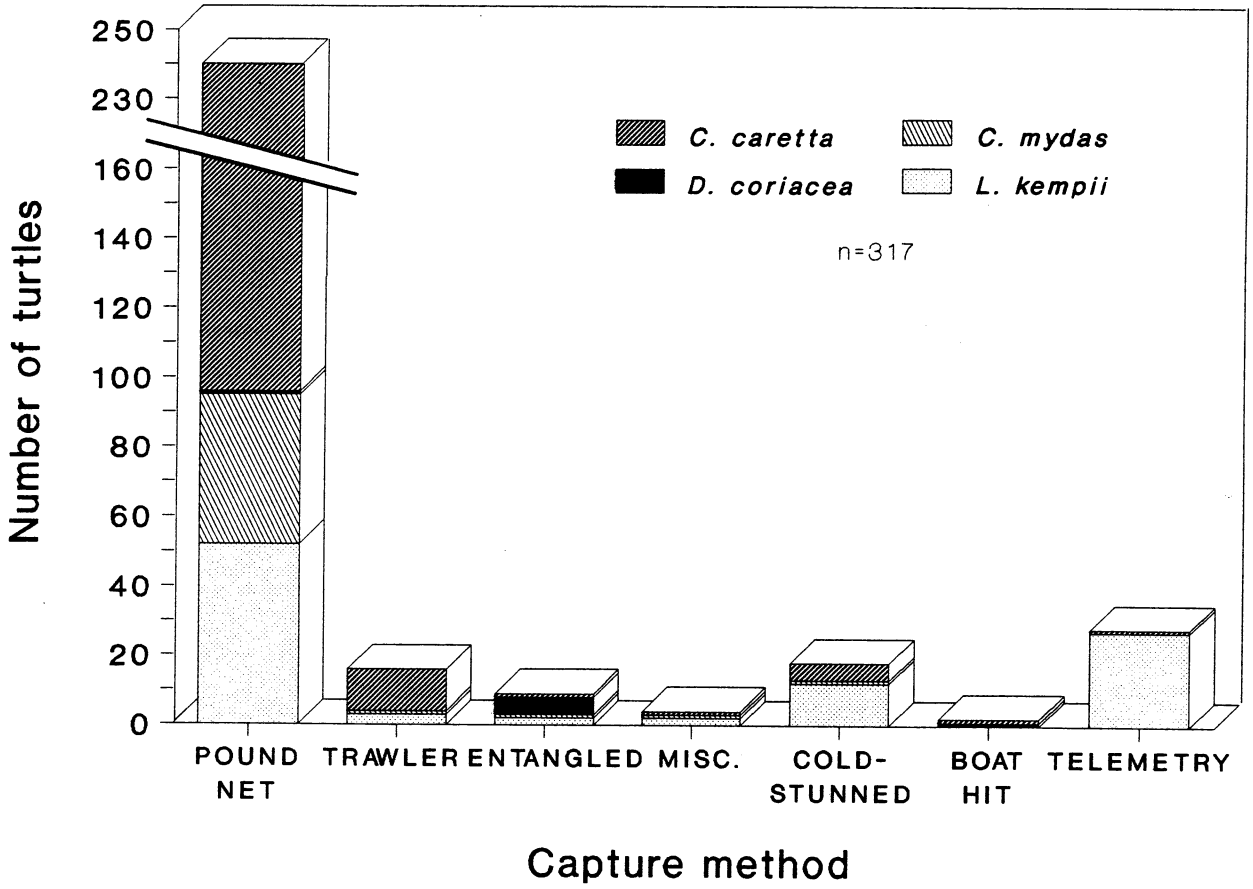



Fig. 1 Methods of obtaining live sea turtles in New York waters from 1987 through 1992. The total includes 226 original captures and 91 recaptures. Of the 257 captures by fishermen, 93% were by pound net.

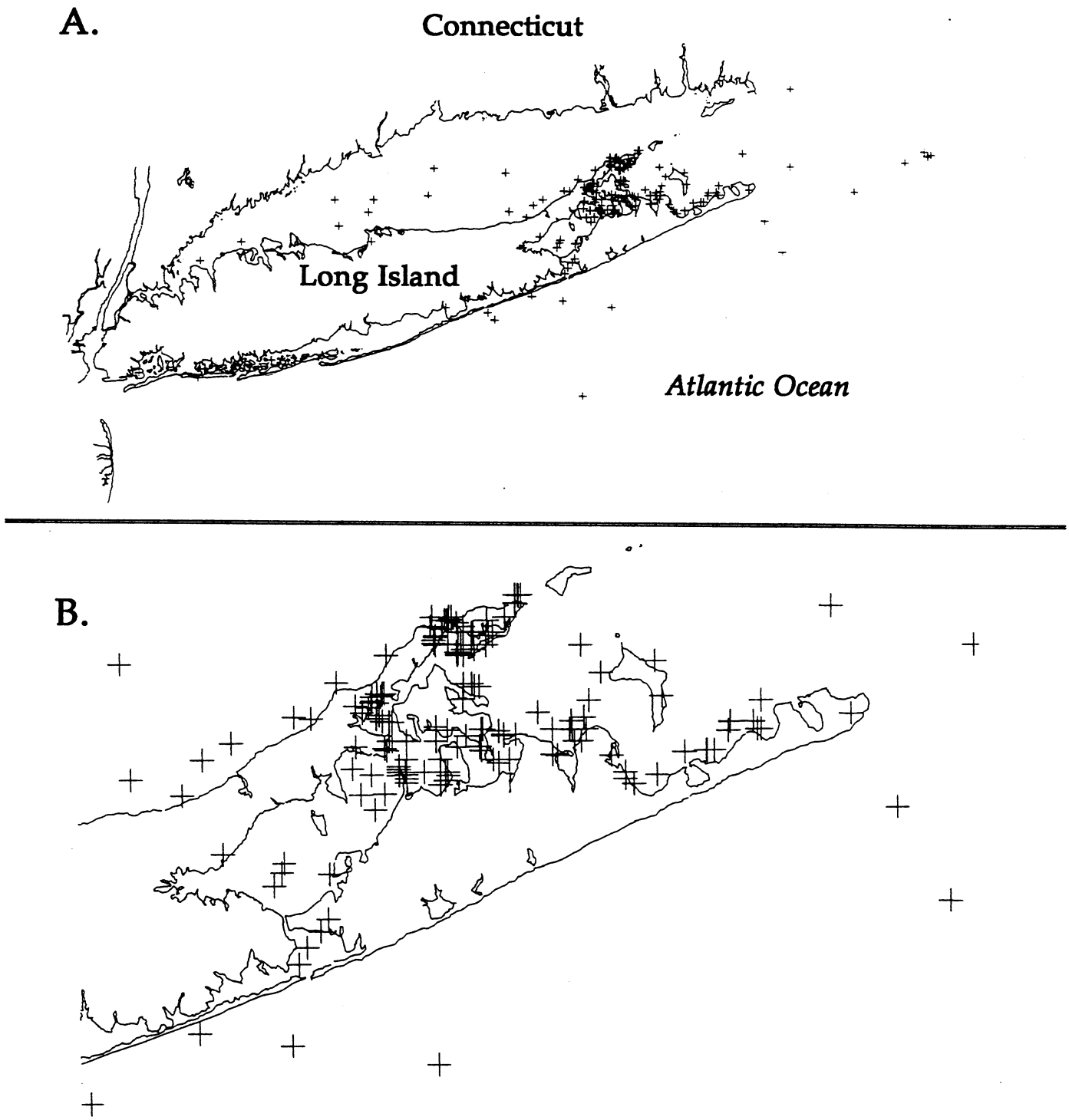



Fig. 2. A) The geographic distribution of live sea turtles captured in New York waters from 1987 through 1992. Crosses represent individual captures at that location. B) A close-up view of the high concentration of captures in eastern Long Island reflecting, for the most part, the locations of pound nets.

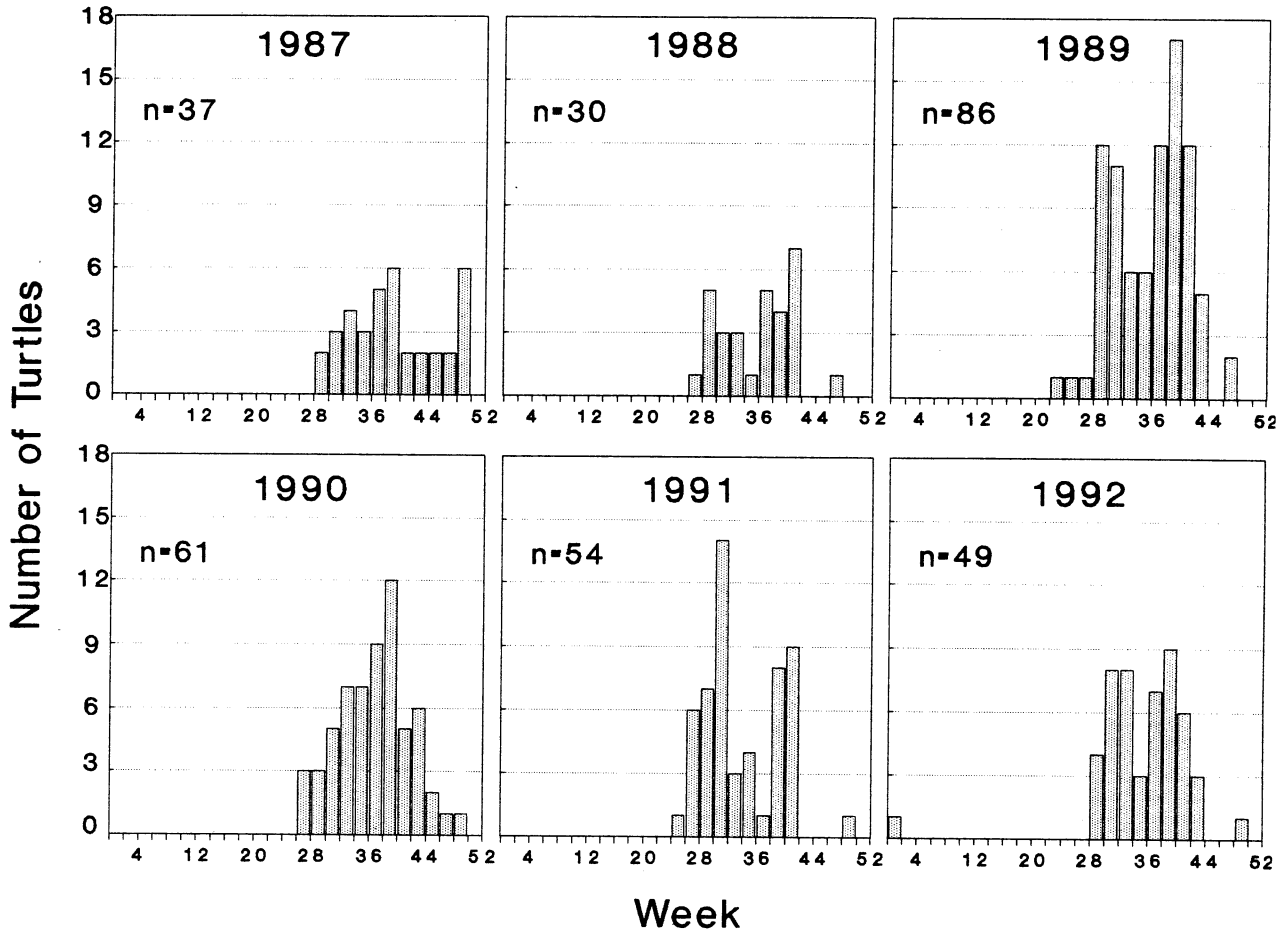



Fig. 3. Timing of occurrence of all original captures and recaptures of live sea turtles during each of six consecutive years. Bars represent the number of captures during the indicated two-week period.

year. They are not observed in inshore waters during the first 22 weeks of the year (except for a loggerhead that washed ashore cold-stunned on an ocean beach on 4 January 1992). In general, the season in which live turtles are encountered begins in June each year and extends for 22 to 26 weeks after that date. The turtle season can further be divided into an activity season and a period in which turtles become cold-stunned (Fig. 4). As determined by the timing of 300 captures of healthy and active turtles, the activity season ranges from 12 June to the first week of November, a period of 21 weeks. The relatively few live turtles encountered after 8 November in any year were cold-stunned.

Among the six years of the mark-recapture study, only three tagged turtles were found later cold-stunned. Moreover, only one of these turtles, a loggerhead recovered in the winter of 1991, ever was captured in the summer, released under normal conditions, and found cold-stunned the following winter. The remaining two winter recaptures were Kemp's ridleys that had been found cold-stunned during the previous winter and had been rehabilitated and released, only to become cold-stunned for the second consecutive year. Thus, it appears that most turtles tagged during the activity season are not present in inshore waters when cold-stunning begins. The pattern of captures further indicated that turtles are leaving between late September and mid-October. Because pound nets capture animals that are moving, the observed increase in captures during this period likely reflects the movement of animals out of the bays.

In general, first-time captures of turtles also are good indicators of their timing of arrival from which comparisons can be made among years (Fig. 5). The total number of live original captures each year ranged from 16 to 55 ($\bar{x}$ = 34.7). Both species composition and pattern of influx of new turtles were similar among years. The general pattern in the timing of captures over all six years was a steady capture of new turtles from late June continuing through October. Except for the cold-stunned animals, all first-time captures of turtles occurred between 12 June and 17 October. Thus, there was a gap of at least several weeks each year between original captures of turtles during the activity season and the retrieval of newcomers that were cold-stunned; this interruption further demarcated the activity season from the period of cold-stunning.

Although there were many potential influences upon the number of individual turtles captured in inshore waters, regional water temperatures were considered the most likely to result in such a regular annual influx and departure of sea turtles. The high similarity between surface water temperatures at a monitoring station in Long Island Sound and monthly mean water temperatures from satellite data enabled us to compare temperatures among the study years from 1987 through 1992 (Fig. 6). Water temperatures ranged from less than 5°C each winter to greater than 20°C in the summer. With only minor differences, the same pattern was repeated in each of the six years. Temperatures remained above 15°C from June through mid-October, after which time they declined rapidly. This time period was remarkably similar to the observed activity season of turtles in New York.

## Radio and Sonic Telemetry

Despite the abundance of data from the mark-recapture studies, in many cases only inferences on specific behaviors of individuals could be made. The use of radio and sonic telemetry techniques enabled us to monitor the activities of individual sea turtles while they resided within inshore areas of New York. Turtles were monitored in each of the six years of

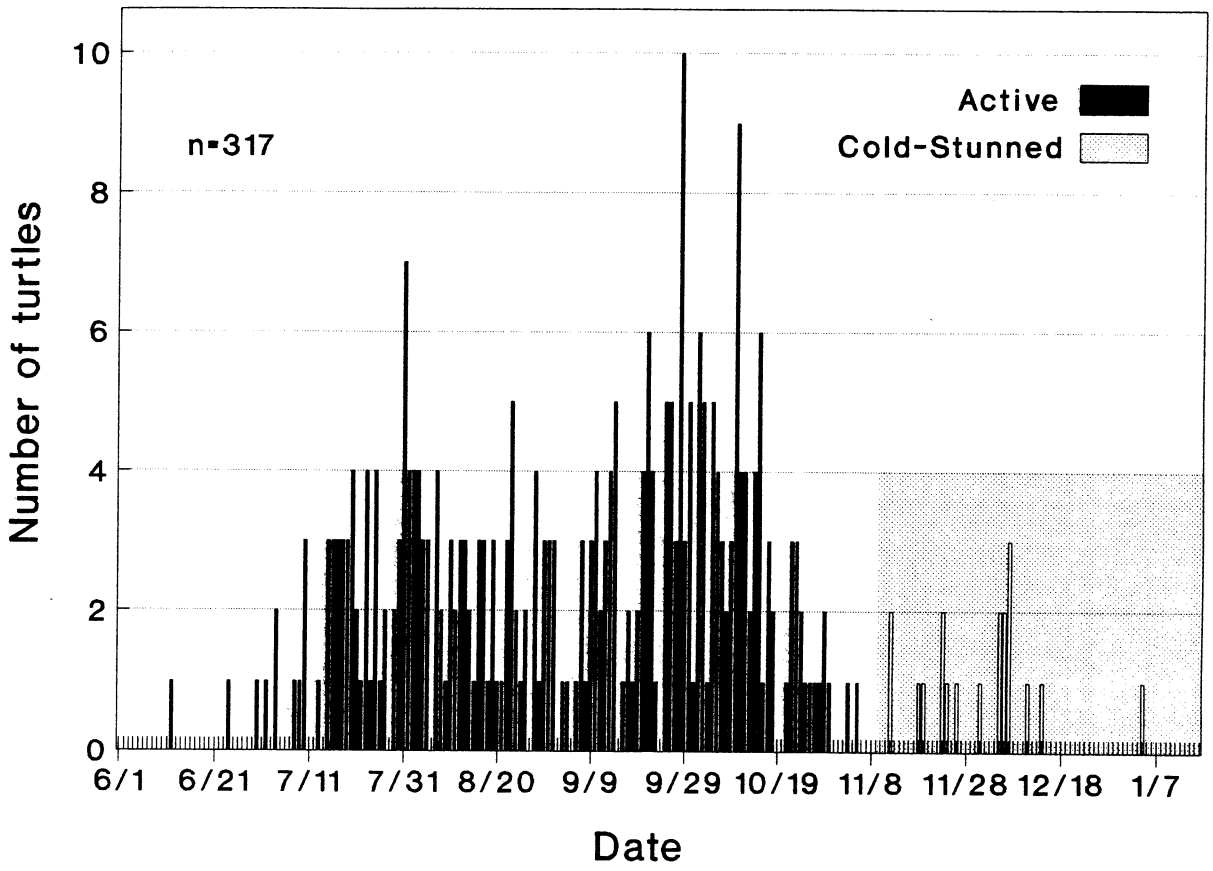



Fig. 4. A composite of the dates of capture of live sea turtles over the 6 yr period, 1987-1992. The capture season, which extends from mid-June until early January, is further divided into a 21 week activity season followed by a period in which all live turtles are cold-stunned.

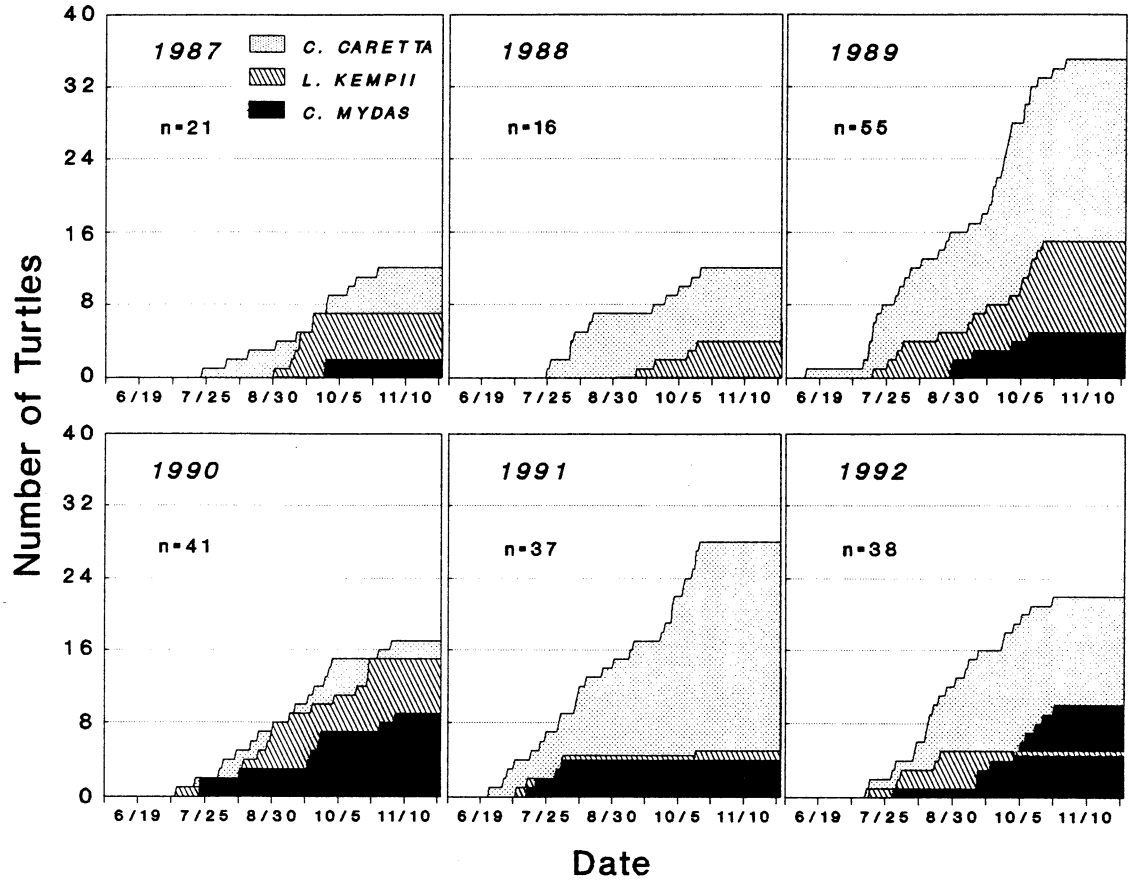



Fig. 5. Timing of original captures of the three species of cheloniid sea turtles in New York waters and species composition for each of the years from 1987 through 1992. Shaded areas represent cumulative totals of individuals through each season.

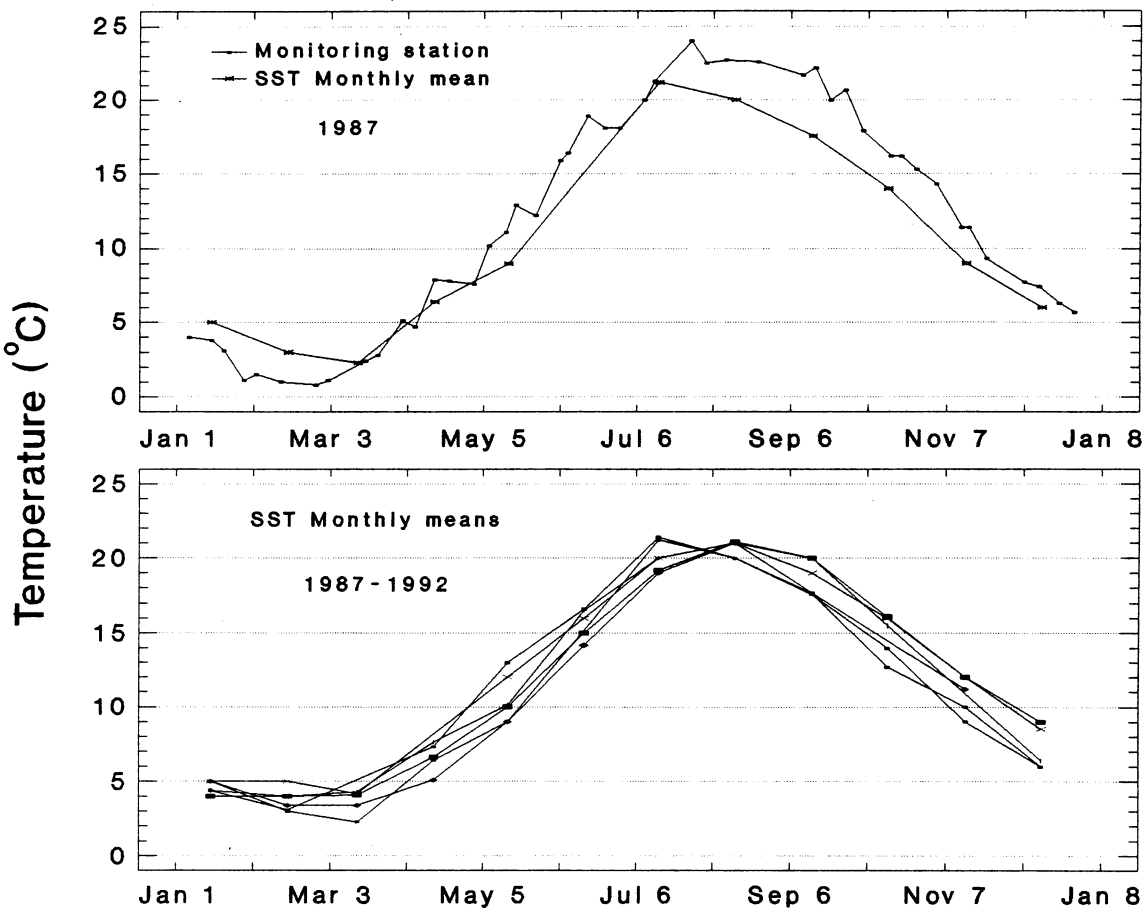



Fig. 6. Annual fluctuations in sea surface temperatures (SST) in eastern Long Island Sound. The upper graph verifies the close relationship between weekly measurements and NOAA monthly means from AVHRR satellite data in a single year. The lower graph demonstrates the highly similar patterns from year to year.

study; in all, 27 Kemp's ridleys and 1 loggerhead were monitored (Table 2). All told, tracking spanned the activity season in each of the first four years. As many as 10 turtles were tracked in a single year (Morreale and Standora, 1990) and individuals were tracked for periods ranging from 1 to 121 days. The typical movement patterns of turtles during the activity season are exemplified in Figures 7, 8, and 9. During the summer months of July through September, turtles entered inshore waters and took up residence in specific and relatively confined areas for up to many weeks (Fig. 7). As water temperatures began to decline in late September, turtles altered their activity patterns and began to make directed movements out of these habitats. Through a continuation of such movements turtles almost invariably moved eastward, into more open bodies of water (Fig. 8). By October these directed movements ultimately conveyed the turtles into the open ocean (Fig. 9). Of the 17 Kemp's ridleys that were being monitored after mid-September, 12 were directly observed heading eastward toward open water upon last contact: six were tracked to Gardiners Bay, one to Napeague Bay, three to Block Island Sound, and two were followed into the ocean. Only one of 28 telemetered turtles (a cold-stunned individual from the previous year) ever was retrieved cold-stunned in the winter.

Despite the high degree of similarity in general movement patterns among individuals both within the same year and among years, diving behavior of individuals within activity seasons varied considerably. Among 16 Kemp's ridleys for which there were sufficient data on submergence and surfacing activities, mean durations at the surface ranged widely from 4.9% to 98.3% during daylight hours (Table 3). The data on surface durations have extremely important implications to other aspects of the turtle's biology such as feeding and activity levels. One turtle spent more than 95% of its time at the surface while another spent more than 95% below the surface. Among all turtles the overall mean percentage of time spent at the surface was 37.5% (Fig. 10). Eleven of the 16 turtles spent more than one half of their time beneath the surface and five of these individuals stayed underwater more than 90% of the time during the day. The overall mean duration of dives among individuals was 14.7 min.

For the most part, turtles were observed to be sub-surface animals that frequently swam to the bottom during dives (Fig. 11). Based on 50 records of complete dives by six turtles, a generalized dive profile was constructed in which a turtle spends 56% of its time in the upper third of the water column, 12% in the middle, and 32% in the bottom third. This generalized dive pattern was influenced by two distinctly different diving behaviors which we considered typical among turtles (Fig. 12). In water deeper than 15 m turtles frequently dived to a depth of 6 to 10 m where they appeared to be swimming in a more directed manner. In such a dive pattern a turtle would spend much of its time in the upper portions of the water column. When turtles submerged in shallower water, they frequently dived to the bottom, where they spent more than 50% of the entire dive. The remainder of the dive was spent shuttling to and from the bottom. Both types of dives frequently culminated at similar depths.

## Resource Availability and Utilization

Benthic communities at the sampling sites where turtles were frequently observed consisted of a broad diversity of biotic groups, including 8 crab species, 12 mollusks, 15 fish, and more than 10 different algae (Morreale and Standora, 1991). Among the turtle fecal samples, however, there was a much lower diversity of species. In the 16 fecal samples from Kemp's ridleys

Table 2. Summary of 27 Kemp's ridleys and a loggerhead monitored by radio and sonic telemetry in the New York bight from 1987 through 1992.

| Tag number | Release date | Tracking duration | Number of recaptures | Transmitter type |
|---|---|---|---|---|
| | | *L. kempii* | | |
| | | **1987** | | |
| PPJ801 | 07/16/87 | 121 days | 1 | radio and sonic |
| PPJ802 | 07/29/87 | 18 days | 2 | radio and sonic |
| PPJ809 | 09/05/87 | 21 days | 1 | radio and sonic |
| PPJ810 | 09/22/87 | 6 days | 1 | radio and sonic |
| | | **1988** | | |
| PPJ831 | 07/13/88 | 89 days | 5 | radio and sonic |
| PPJ834 | 07/25/88 | 1 day | 0 | radio and sonic |
| PPJ839 | 08/26/88 | 91 days | 2 | radio and sonic |
| PPJ838 | 09/18/88 | 26 days | 1 | radio and sonic |
| PPJ874 | 09/18/88 | 27 days | 2 | radio and sonic |
| PPJ853 | 09/29/88 | 1 day | 0 | radio |
| PPJ856 | 10/23/88 | 1 day | 1 | radio |
| | | **1989** | | |
| PPY005 | 07/24/89 | 1 day | 1 | radio and sonic |
| PPY008 | 07/26/89 | 28 days | 3 | radio and sonic |
| PPY010 | 08/16/89 | 45 days | 1 | radio |
| PPJ839 | 08/24/89 | 28 days | 0 | radio |
| PPY015 | 08/24/89 | 33 days | 1 | radio and sonic |
| PPY021 | 09/10/89 | 27 days | 2 | radio and sonic |
| PPY023 | 09/16/89 | 1 day | 0 | radio and sonic |
| PPY026 | 09/25/89 | 16 days | 2 | radio and sonic |
| PPY039 | 10/08/89 | 17 days | 2 | radio and sonic |
| PPY046 | 10/14/89 | 4 days | 0 | radio and sonic |
| | | **1990** | | |
| QQE006 | 08/08/90 | 6 days | 2 | radio and sonic |
| QQE010 | 08/21/90 | 14 days | 1 | radio and sonic |
| QQE017* | 09/06/90 | 14 days | 1 | radio and sonic |
| QQE025 | 10/02/90 | 9 days | 1 | radio and sonic |
| QQE034* | 10/15/90 | 9 days | 1 | radio and sonic |
| | | **1991** | | |
| QQM806* | 08/27/91 | 3 days | 1 | sonic |
| | | *C. caretta* | | |
| | | **1992** | | |
| QQY616 | 09/13/92 | 2 days | 1 | radio and sonic |

* Turtles also tracked later with satellite transmitters.

Fig. 7. Movements of a Kemp's ridley, PPY010, in New York waters based upon data from radio and sonic telemetry over a period of 45 days. 1=release 16 Aug. 1989. 6=recapture 3 Sept. 12=last contact 30 Sept.

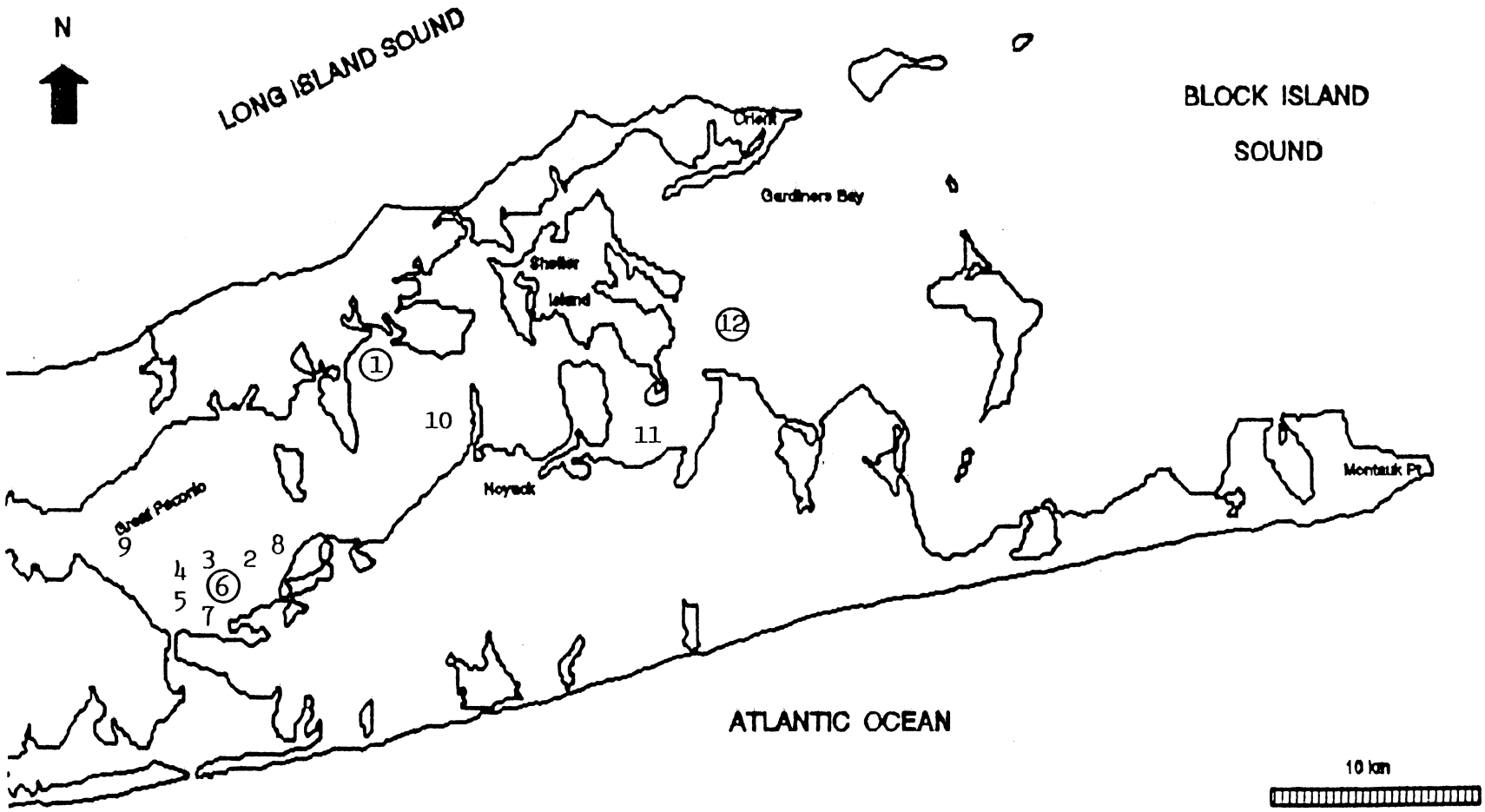


Fig. 8. Movements of a Kemp's ridley, PPY021, in New York waters based upon data from radio and sonic telemetry over a period of 27 days. 1=release 10 Sept. 1989. 2=recapture 14 Sept. 6=recapture 25 Sept. 18=last contact 7 Oct.

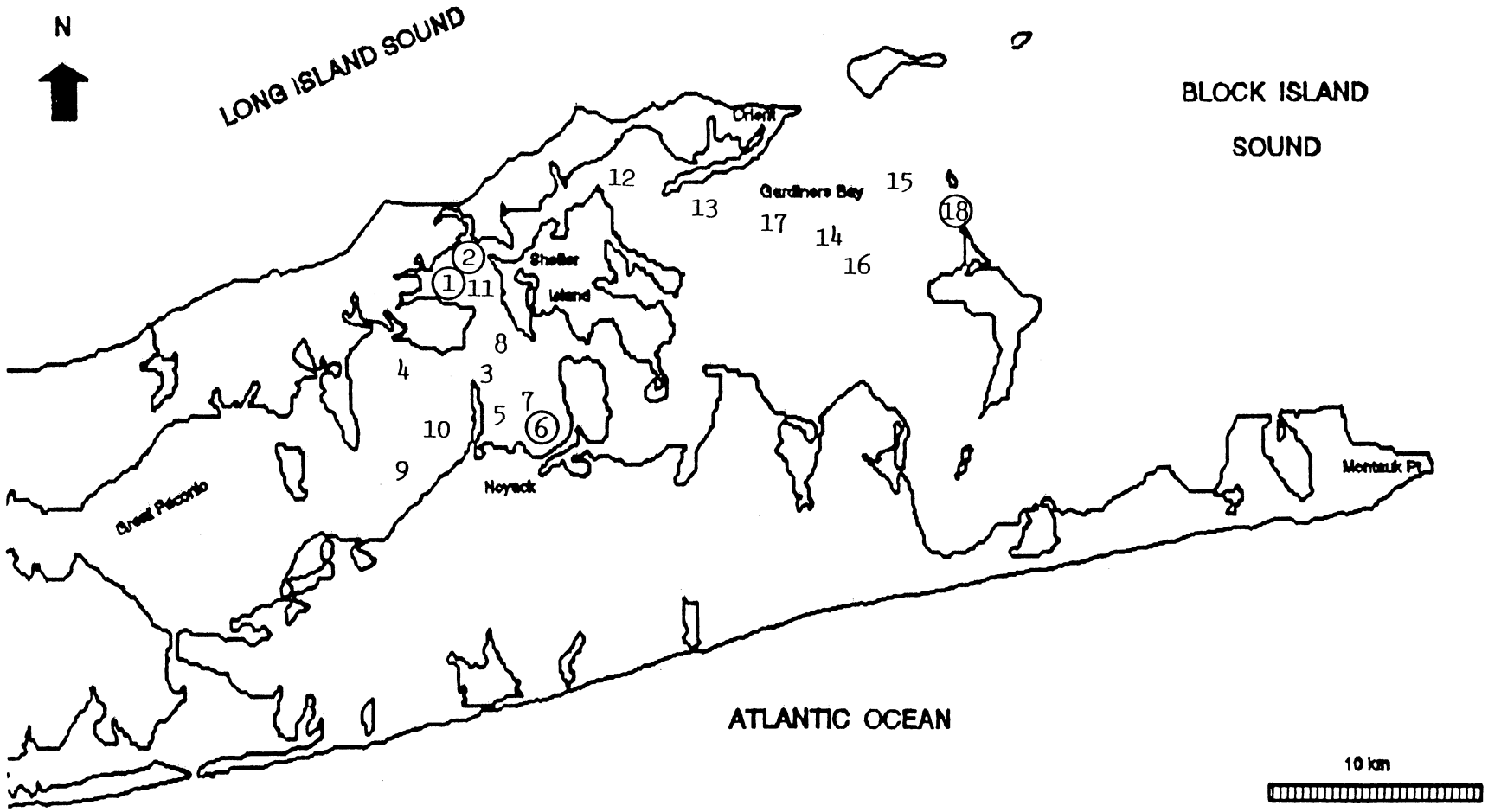


Fig. 9. Movements of a Kemp's ridley, PPY039, in New York waters based upon data from radio and sonic telemetry over a period of 17 days. 1=release 8 Oct. 1989. 9=recapture 23 Oct. 12=last recapture 23 km south of Montauk Pt. 25 Oct.

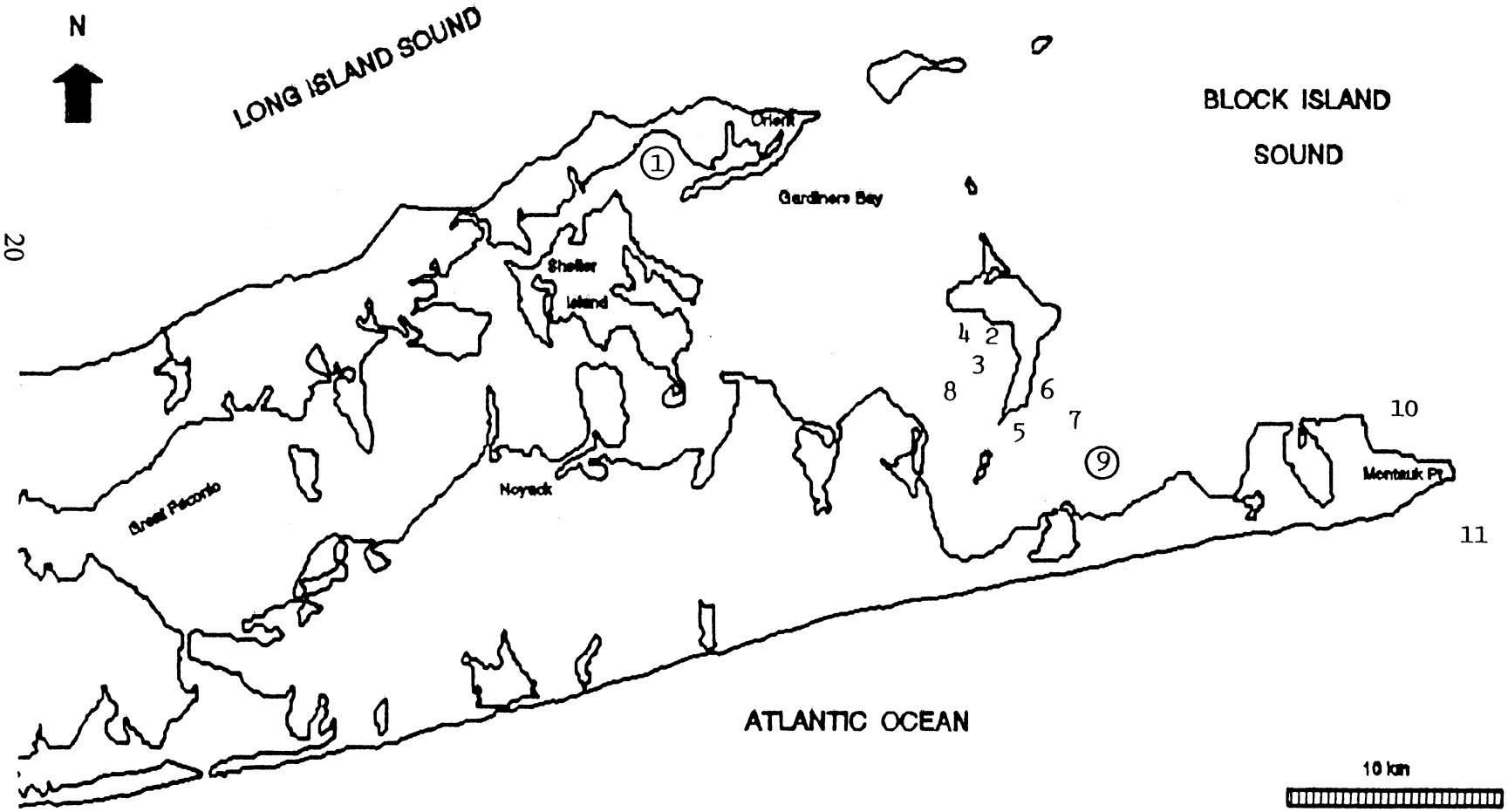


Table 3. Average amount of time spent at the surface between the daytime hours of 0600 and 2000 for 16 individual Kemp's ridleys that were monitored by radio and sonic telemetry from 1988 through 1990. Individuals were monitored in 1 hr sampling periods; there was never more than one sample per 4 hr segment.

| Tag number | Release date | # 1 hr samples | Duration at surface per hour (s) | SD ± | Range | Mean % |
|---|---|---|---|---|---|---|
| **1988** | | | | | | |
| PPJ831* | 07/13/88 | 55 | 1312 | 1379 | 1-3600 | 36.4 |
| PPJ839* | 08/26/88 | 13 | 2831 | 848 | 1397-3600 | 78.6 |
| PPJ874 | 09/18/88 | 55 | 867 | 1172 | 0-3600 | 24.1 |
| **1989** | | | | | | |
| PPY008 | 07/26/89 | 43 | 3139 | 723 | 310-3600 | 87.2 |
| PPY010 | 08/16/89 | 12 | 248 | 185 | 0- 527 | 6.8 |
| PPY015 | 08/24/89 | 24 | 178 | 98 | 62- 512 | 4.9 |
| PPY839* | 08/24/89 | 9 | 235 | 233 | 48- 810 | 6.5 |
| PPY021 | 09/10/89 | 19 | 833 | 1005 | 48-3600 | 23.1 |
| PPY026 | 09/25/89 | 8 | 2095 | 1403 | 225-3600 | 58.1 |
| PPY039 | 10/08/89 | 20 | 1086 | 1281 | 0-3600 | 30.2 |
| PPY046 | 10/14/89 | 5 | 2547 | 1236 | 436-3600 | 70.8 |
| **1990** | | | | | | |
| QQE006 | 08/08/90 | 8 | 3539 | 171 | 3115-3600 | 98.3 |
| QQE010 | 08/21/90 | 41 | 307 | 269 | 90-1509 | 8.5 |
| QQE017 | 09/06/90 | 49 | 371 | 541 | 65-3600 | 10.3 |
| QQE025 | 10/02/90 | 22 | 1709 | 1113 | 137-3600 | 47.4 |
| QQE034 | 10/15/90 | 16 | 287 | 362 | 0-1555 | 8.0 |

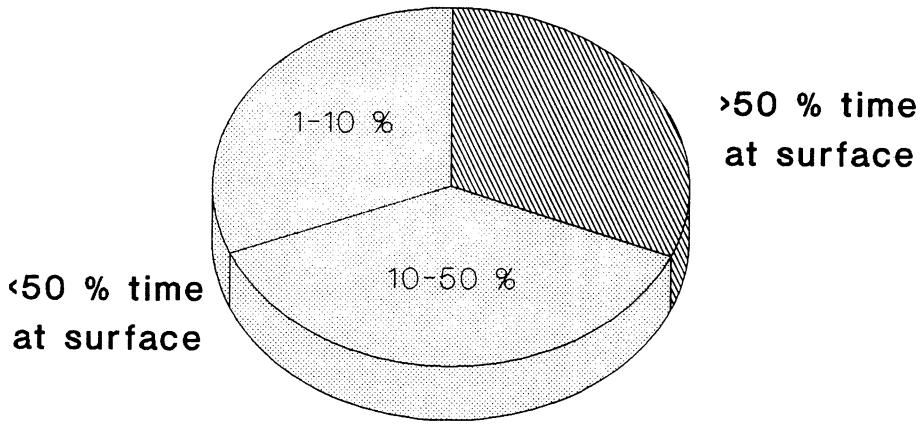
* Turtles were cold-stunned the previous winter, rehabilitated, and released.

Daylight hours 0600-2000

*L. kempii n = 16*

No. of obs. = 399

Overall mean percentage of time at surface = 37.5 %




Overall mean submergence time per dive = 14.7 min

Fig. 10. Surfacing and submergence patterns of 16 Kemp's ridleys during daylight hours. The stippled sections represent the proportions of individuals that were observed at the surface less than 10% (n=5) and between 10% and 50% of the time (n=6); Crosshatches represent the proportion that remained at the surface more than 50% of the time (n=5).

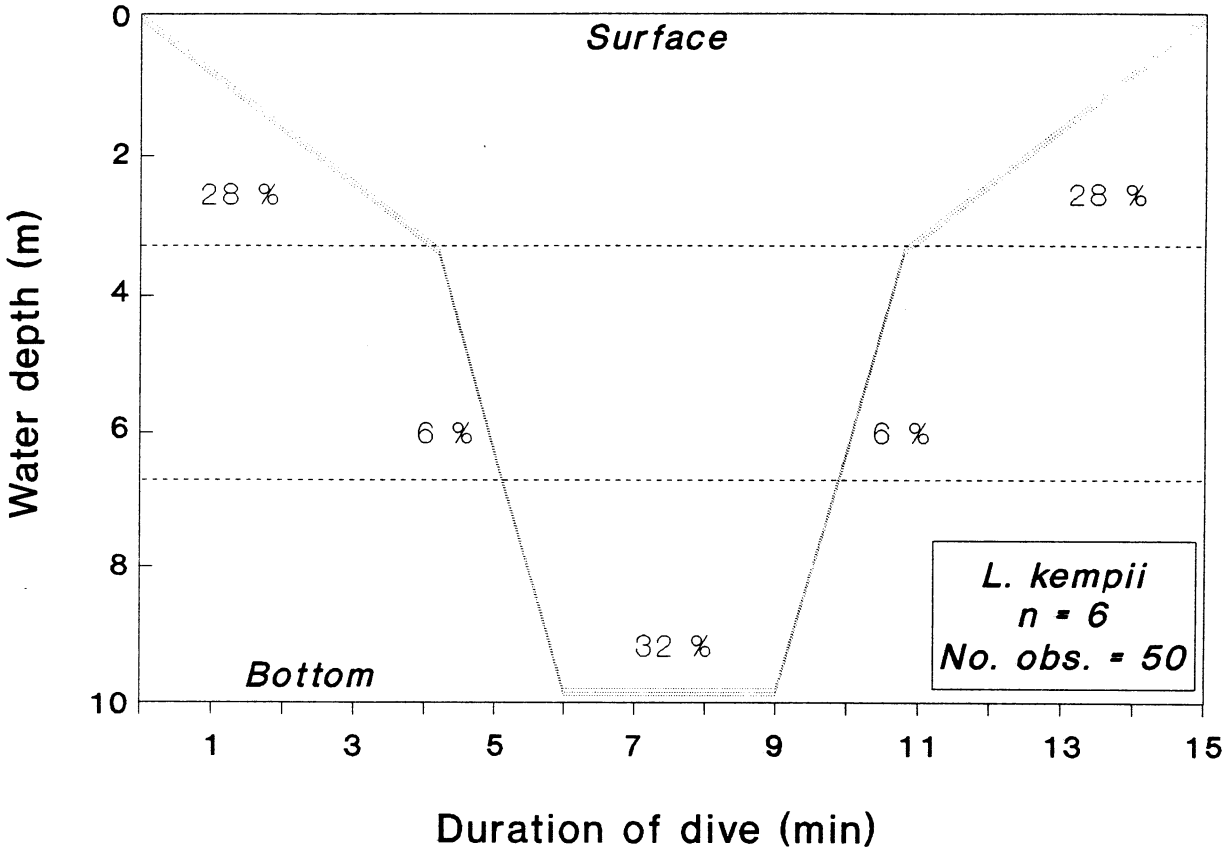



Fig. 11. A generalized dive pattern for Kemp's ridleys constructed from records of 50 complete dives from 6 individuals. The water column was divided into thirds and standardized to a depth of 10 m.

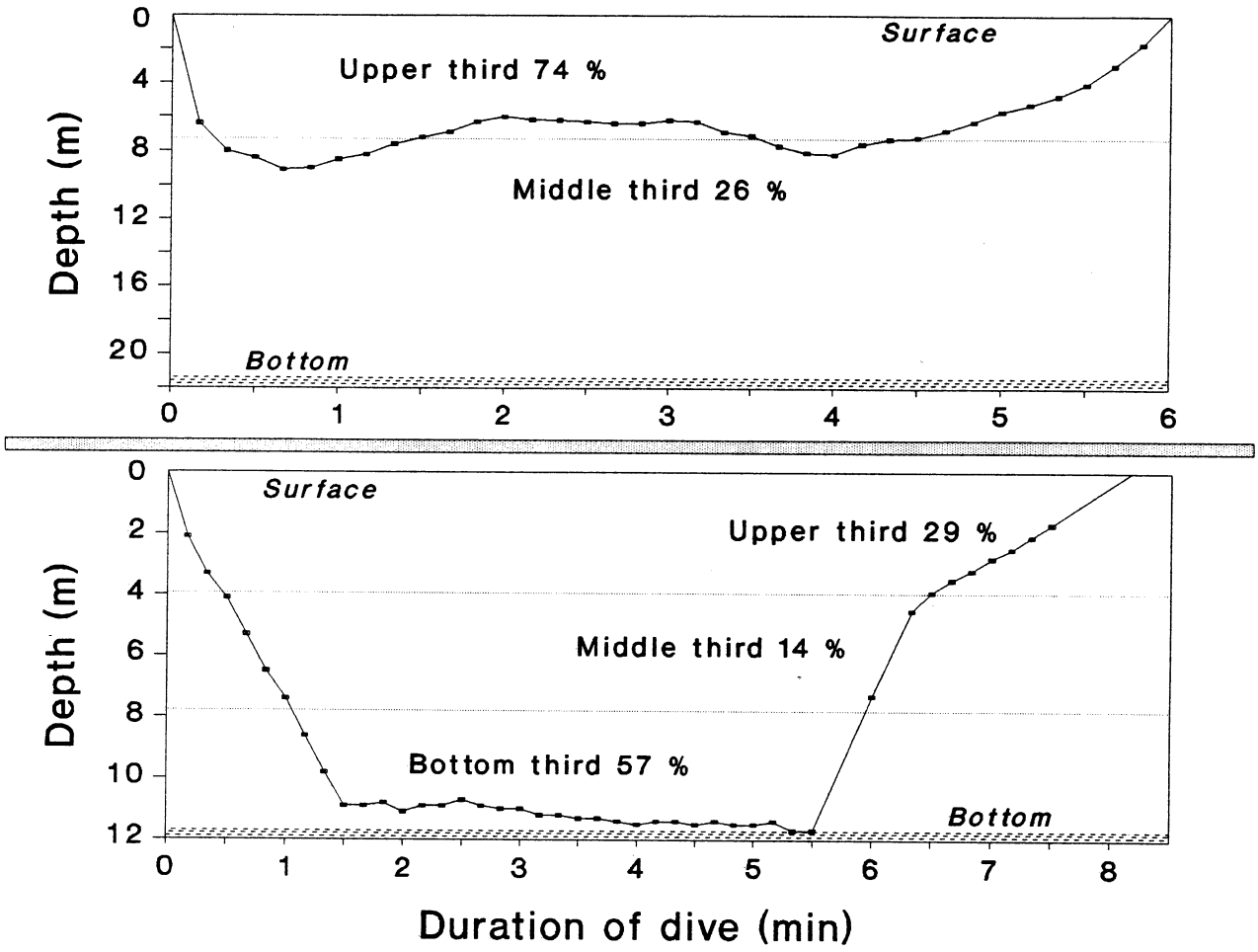



Fig. 12. Two distinct dive patterns with respect to relative position in the water column were typically observed depending upon water depth. In both deep water (above) and shallow water (below), however, dives frequently culminated at similar depths.

during the 1990 activity season the dietary components could be grouped into four major categories (Fig. 13). Among these, however, crabs were by far the most important component in the feces. They were present in 15 samples and constituted the greatest proportion of these samples. This was comparable to our previous studies in which crabs comprised greater than 80% of the weight of the diets of both Kemp's ridleys and loggerheads (Burke, 1990; Burke et al., 1993; 1994).

To make quantitative comparisons of the food in turtles' diets to the resources that were available in the habitats, only crabs were considered. Four species of crabs that occurred at the sampling sites were large enough to be reliably sampled by the trawl. Among these were two species of swimming crabs, the lady crab (*Ovalipes ocellatus*) and the blue crab (*Callinectes sapidus*) and two species of walking crabs, the spider crab (*Libinia emarginata*) and the rock crab (*Cancer irroratus*). The lady crab was the most abundant species, occurring at all eight sampling sites and predominating at seven of these sites. The spider crab was second in abundance, but was concentrated in four of eastern sites. The other two crab species were only present at three or fewer sites and always in very low densities.

Overall, relative abundance of crab species in the fecal samples differed considerably from their availability at the eight sites (Fig. 14). Spider crabs represented more than 53% of the fecal components. This was more than twice their overall relative abundance at the sampling sites. Lady crabs were the second most abundant fecal component despite their much greater availability relative to spider crabs. The comparatively sparse blue crabs did not occur in any feces, but the similarly rare rock crabs comprised 17% of the diet.

The spider crab was the genus of crab that was most often predominant in the feces and guts of loggerheads and Kemp's ridleys in all of our previous and subsequent studies (Burke, 1990; Burke et al., 1993; 1994; Morreale and Standora, 1992*a*). In one study of the diets of green turtles, the main dietary components were various algae (Burke et al., 1992).

## Growth

Presumably as a result of their diets in New York waters, turtles of all three cheloniid species have exhibited measurable and, in some instances, substantial growth within an activity season (Fig. 15). Although growth rates were highly variable among the 38 individuals, regressions of growth rates for all three species were significantly positive ($p<.01$) and increases in SCL versus time exhibited reasonably strong linear relationships with coefficients of determination of 0.61 (n=14) for *Caretta caretta*, 0.85 (n=17) for *Lepidochelys kempii*, and 0.80 (n=7) for *Chelonia mydas*. The slope of the regression for Kemp's ridley growth was slightly greater than that for green turtles; the slope for loggerheads was nearly twice as high.

When making comparisons of growth rates of sea turtles from New York to those of other regions, numerous difficulties arose, not the least of which were the limited data from other studies. Ignoring the complications, the slopes of regressions of growth rates, which were converted to monthly rates (daily rates x 30), were compared to those reported for turtles in Florida (Mendonca, 1981). For loggerheads, the slope of 1.21 in New York was greater than the value of 0.48 reported for Florida. Green turtles in New York also exhibited a greater value of 0.65 compared to 0.26 for Florida turtles. Perhaps the largest factor that detracted from the validity of such comparisons, however, was the difference in size distributions of turtles between

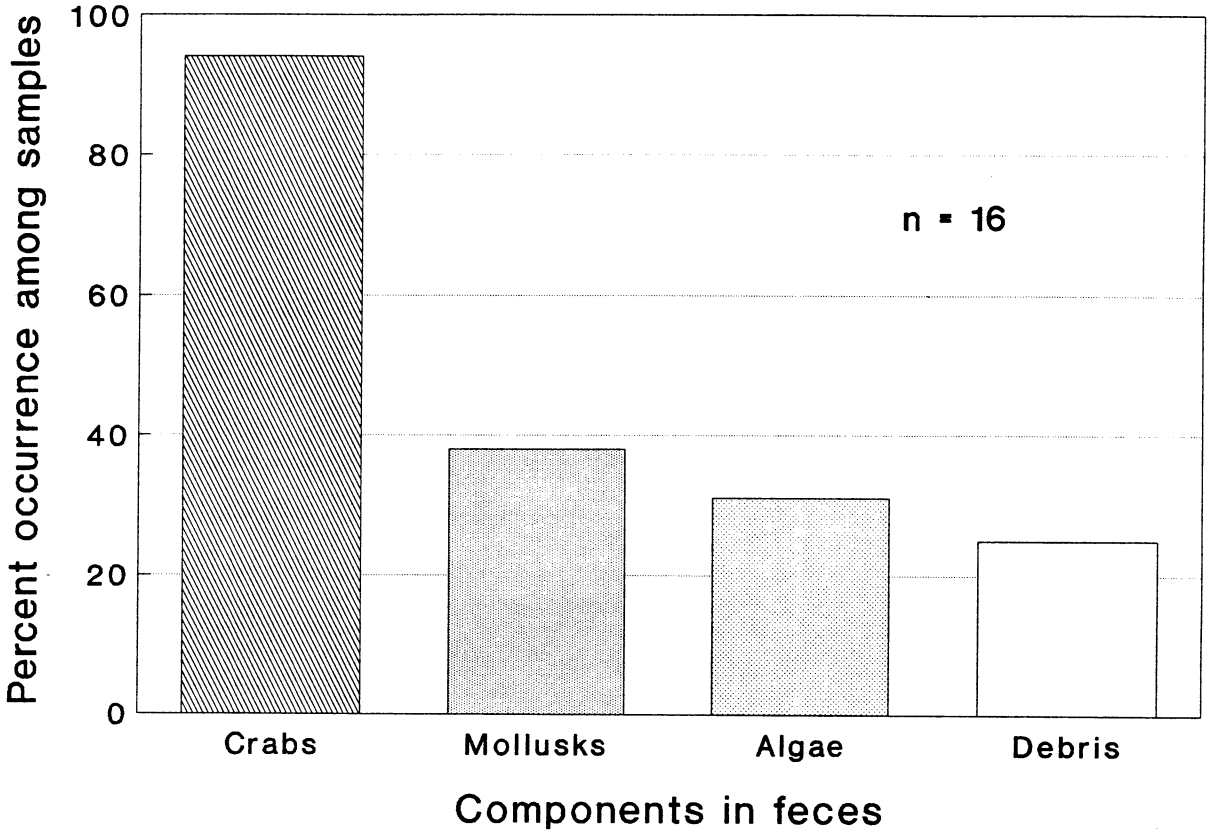



Fig. 13. The four major categories of dietary components, both biotic and synthetic, occurring in 16 fecal samples from free-swimming Kemp's ridleys.

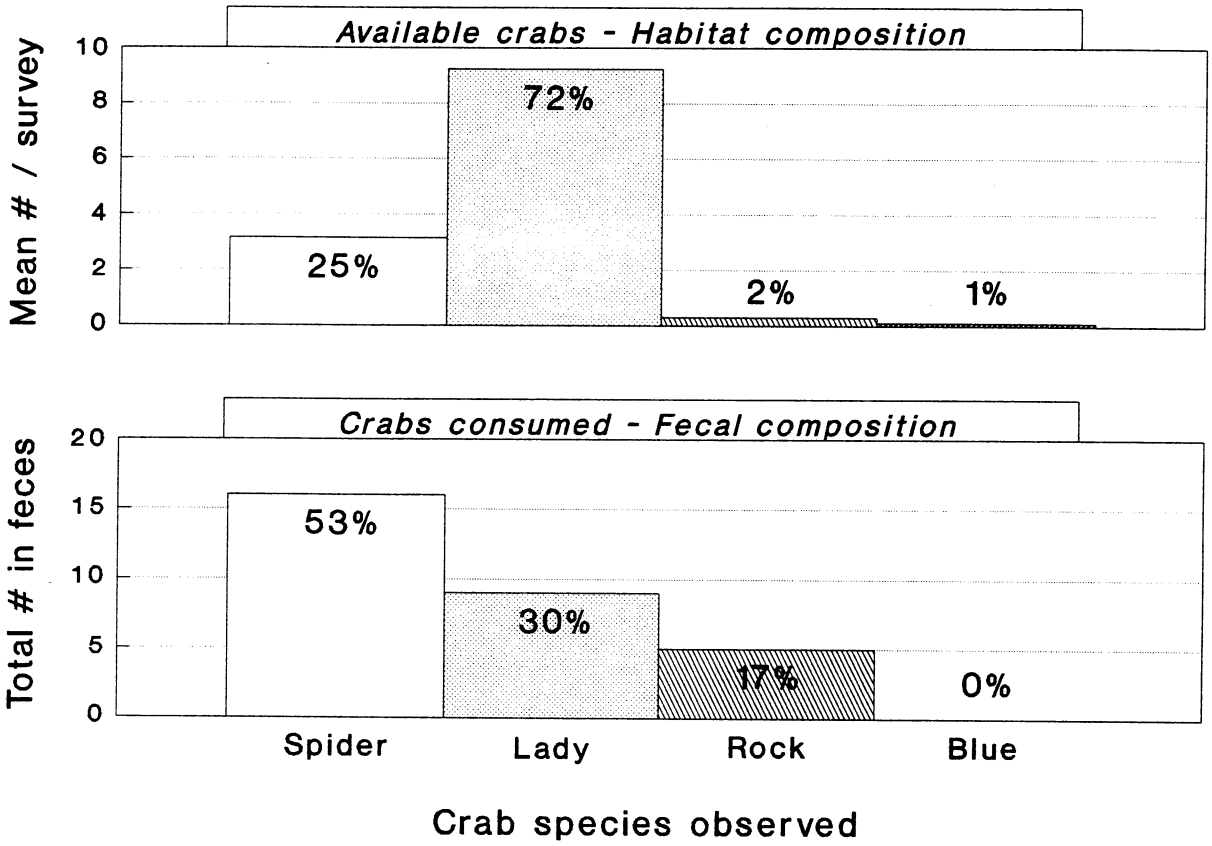



Fig. 14. Mean overall percentages of crab species at eight sampling sites in Long Island compared with the crabs found in the feces of Kemp's ridleys during the same season.

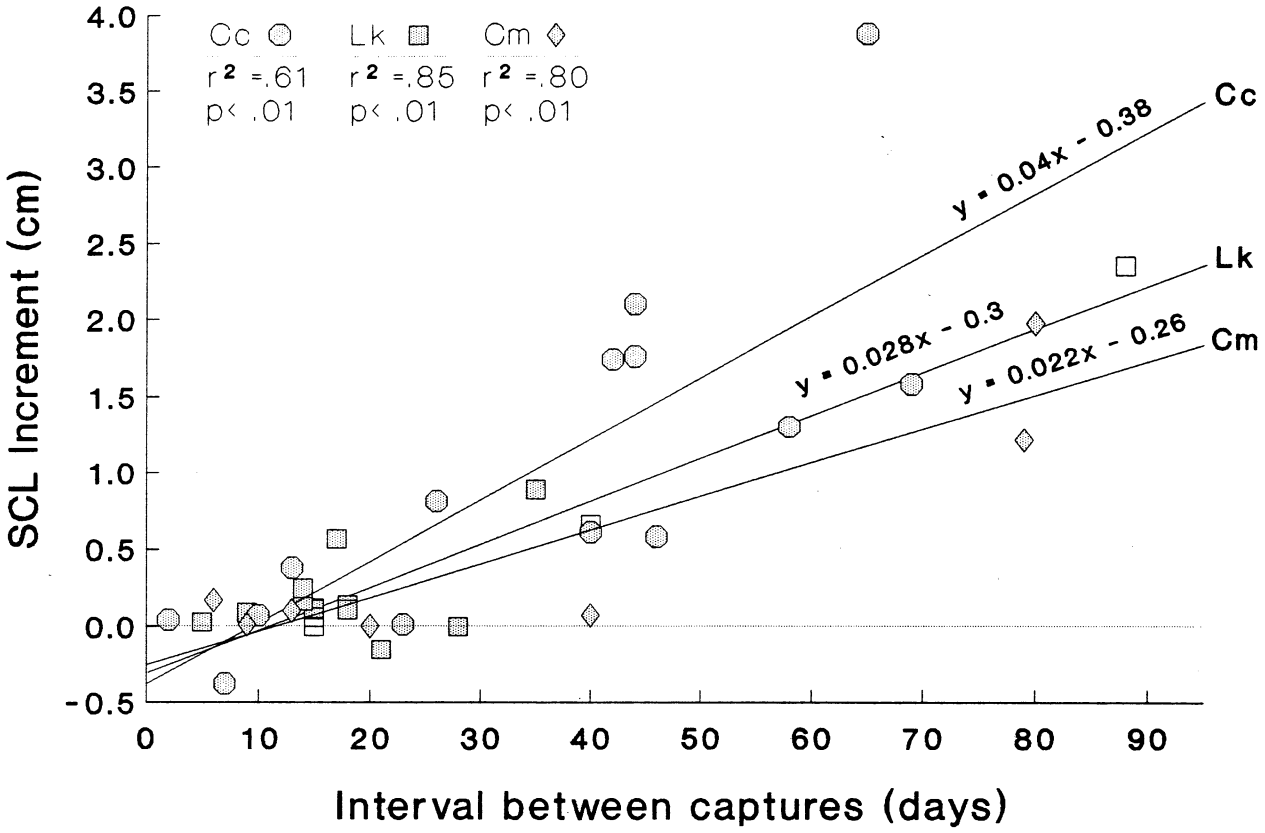



Fig. 15. Linear regressions of increases in straight-line carapace length (SCL) after recapture intervals ranging from 2 to 90 days for *Caretta caretta* (*Cc*; n=14), *Lepidochelys kempii* (*Lk*; n=17), and *Chelonia mydas* (*Cm*; n=7). All turtles were free-ranging. Open squares represent three Kemp's ridleys that were cold-stunned and rehabilitated prior to release.

the two studies. To compare growth among turtles of comparable size classes, growth had to be extrapolated to a yearly rate (Table 4). Extracting what little information there was, 30 to 40 cm green turtles in New York exhibited higher growth rates than those in Florida (Mendonca, 1981) and Hawaii (Bjorndal and Bolten, 1988*a*) but lower rates than reported for the Bahamas (Bjorndal and Bolten, 1988*a*). Growth rates of loggerheads in the 50 to 60 cm size class were lower in New York than in Florida (Mendonca, 1981) and in the 40 to 50 cm size class were lower than those in the Bahamas (Bjorndal and Bolten, 1988*b*).

## Long-Distance Movements

It was not until our first data on a long-distance tag return from South Carolina that a sea turtle ever had been documented to have travelled from the Northeast to southern waters (Morreale and Standora, 1989). Subsequent to this initial evidence of migration, we have recorded many such long-distance movements of turtles from New York. Included among these were loggerheads, Kemp's ridleys, and green turtles. With the exception of a single loggerhead that moved from Rhode Island to Georgia (Shoop and Ruckdeschel, 1989), these are the only records ever of sea turtles emigrating from the North to the South.

Although tagging studies only provide information on net movements of individuals, six of the long-distance movements that we recorded included turtles that were tagged and recaptured within the same season (i.e. before the following spring). Thus, despite the absence of precise movement data, inferences about the travel routes of turtles could be made when their capture histories were plotted (Fig. 16). Because the intervals between release and recovery were relatively short (range = 37 to 178 days), the turtles that made these long-distance movements from New York probably followed direct pathways to their southern recovery locations. In addition, these data further demonstrated that loggerheads, Kemp's ridleys, and green turtles all were capable of leaving northeastern inshore waters prior to winter. Five of these turtles were found in coastal waters of North Carolina, more than 700 km from their original capture sites.

It was more difficult to determine the paths of travel of turtles recovered after longer intervals (i.e. in a subsequent season). In all, there have been seven such long-term recoveries of New York turtles, five of which were recovered in southern waters (Fig. 17). Intervals between these recoveries ranged from 236 to 454 days. There also was a wide geographic distribution among recovery locations along the entire eastern seaboard. Two individuals were recaptured as far north as New York in the summer of the following year (this includes a loggerhead originally tagged in New Jersey). One of the loggerheads was recaptured more than 1600 km to the south in inshore waters of Florida the following spring. Regardless of the inherent difficulties in determining precise routes of travel, such long-term records provided further evidence of migratory movements between northern and southern waters.

## Satellite Telemetry

In our ground-truth verification studies of satellite signals we calculated that turtle locations predicted by satellite differ from the actual turtle locations by an average of approximately 13 km (Standora and Morreale, 1991). Such inaccuracy is inappropriate for evaluating fine-scale turtle movements or locations in inshore waters. Discrepancies of this magnitude become insignificant, however, when assessing broad-scale turtle movements. Thus,

Table 4. Comparisons of growth rate values for juvenile sea turtles from different geographic regions. Growth values are presented as increases in straight-line carapace length per year; rates from New York are extrapolations of measurements over intervals of less than three months.

| Species | Size CL (cm) | New York | | | Florida* | | | Bahamas** | | | Hawaii*** | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | $\bar{x}$ | SD | n | $\bar{x}$ | SD | n | $\bar{x}$ | SD | n | $\bar{x}$ | SD | n |
| *L. kempii* | | | | | | | | | | | | | |
| | 20-30 | 2.2 | 1.6 | 4 | --- | --- | - | --- | --- | - | --- | --- | - |
| | 30-40 | 4.5 | 4.2 | 13 | --- | --- | - | --- | --- | - | --- | --- | - |
| | Overall | 4.0 | 3.8 | 17 | | | | | | | | | |
| *C. mydas* | | | | | | | | | | | | | |
| | 20-30 | 2.8 | 5.0 | 4 | --- | --- | - | --- | --- | - | --- | --- | - |
| | 30-40 | 5.8 | 3.1 | 3 | 5.3 | 2.8 | 4 | 8.8 | 0.6 | 5 | 1.1 | 0.4 | 4 |
| | Overall | 4.1 | 4.3 | 7 | | | | | | | | | |
| *C. Caretta* | | | | | | | | | | | | | |
| | 30-40 | 5.6 | --- | 1 | --- | --- | - | ---- | --- | - | --- | --- | - |
| | 40-50 | 10.9 | 6.6 | 8 | --- | --- | - | 15.7 | 1.3 | 3 | --- | --- | - |
| | 50-60 | 3.0 | 14.0 | 5 | 7.4 | 1.4 | 2 | ---- | --- | - | --- | --- | - |
| | Overall | 7.7 | 9.9 | 14 | | | | | | | | | |

* Data from Mendonca, 1981.
** Data from Bjorndal and Bolten, 1988.
*** Unpublished data from Balazs (Bjorndal and Bolten, 1988).

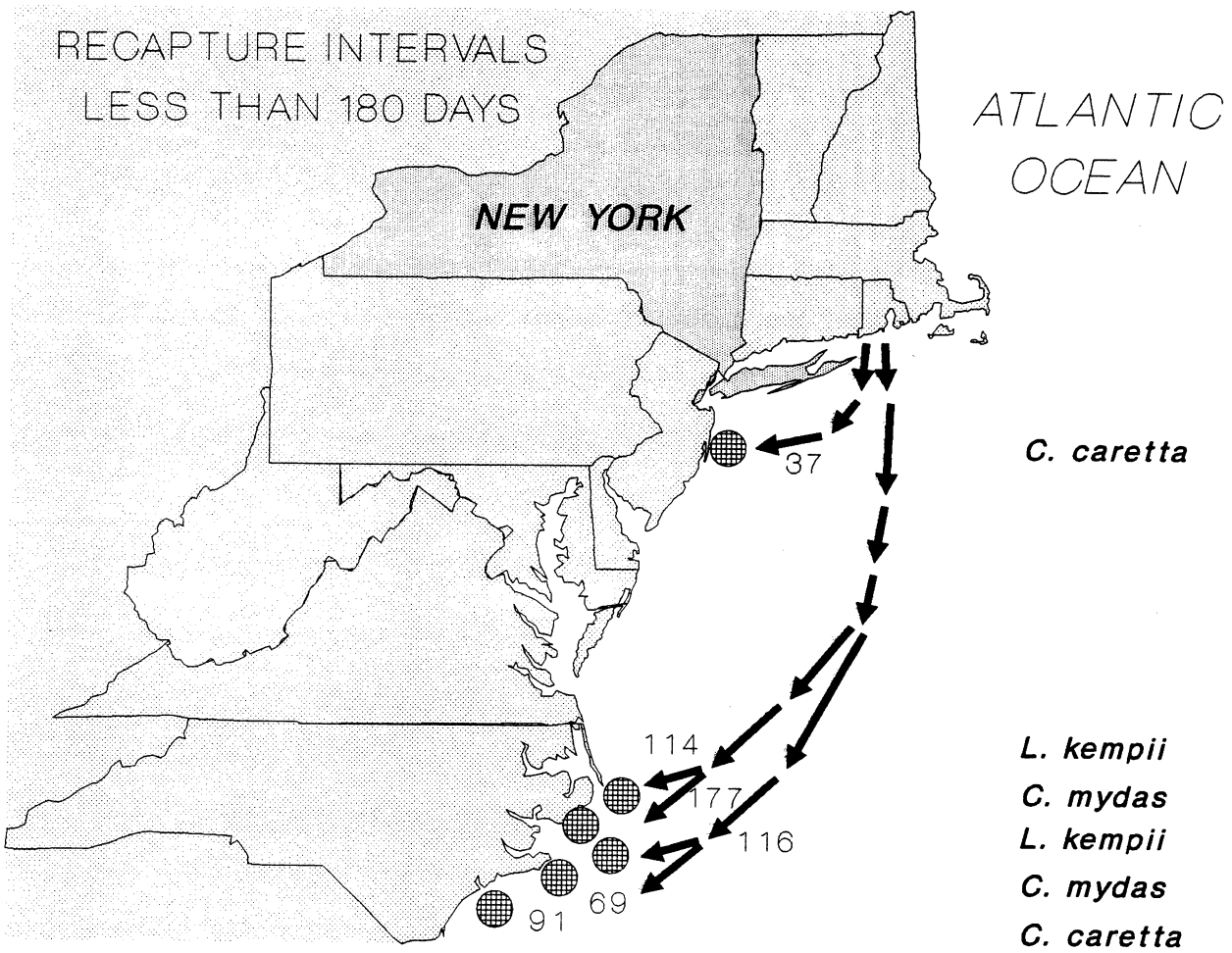



Fig. 16. Out-of-state recovery locations of six turtles that had been captured and released in New York waters earlier in the same activity season. The number of days between release and recovery are indicated for each turtle. Arrows represent net movements rather than actual routes of travel.

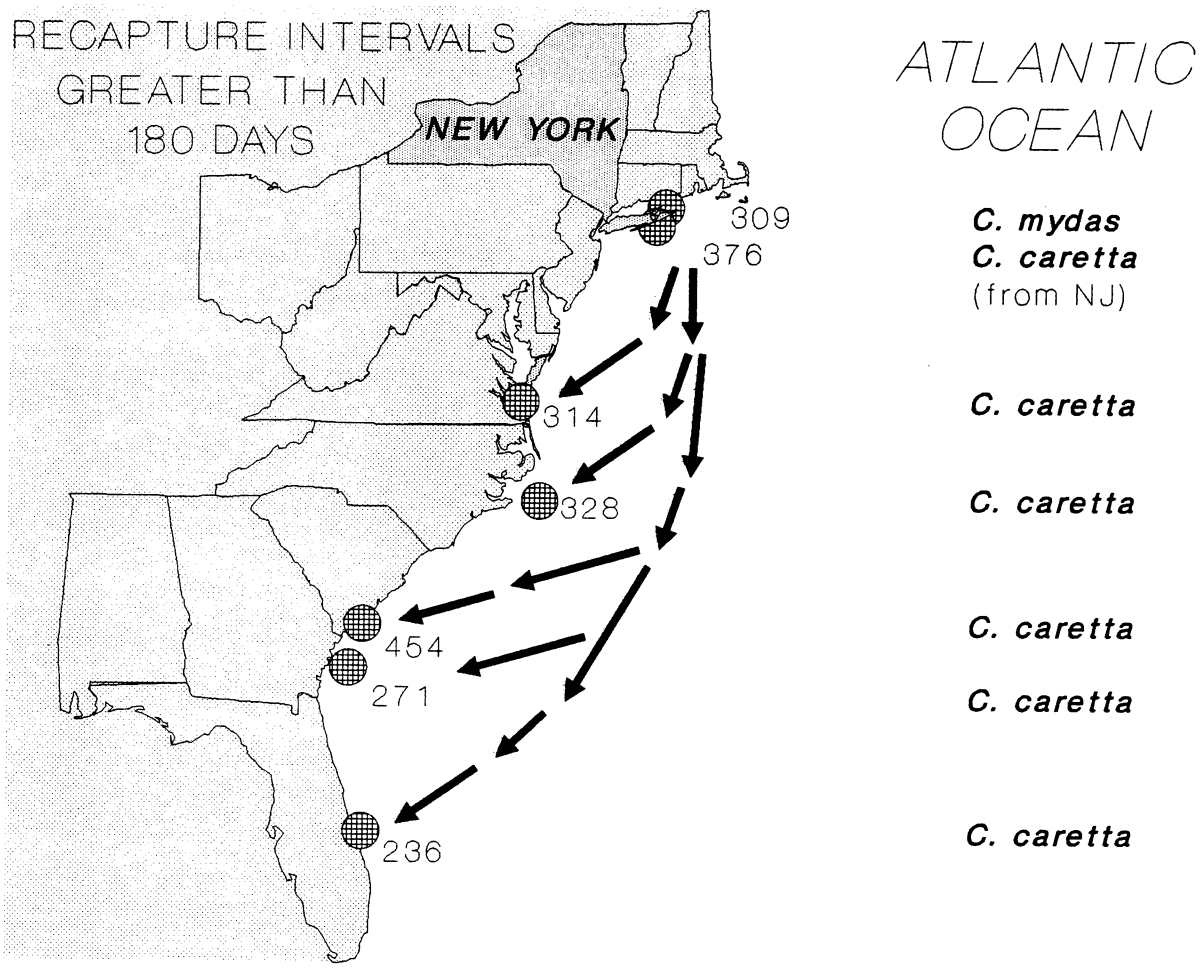



Fig. 17. Long-term recovery locations of seven turtles that had been captured and released in the New York area in a previous season. Five turtles were recovered in southern states after intervals between 236 and 454 days; two individuals reappeared in New York in the following year. Arrows represent net movements.

with the exclusion of poorer quality and the most extreme location data, it was possible to reliably determine with relative precision the movements for several individual Kemp's ridleys and loggerheads as they emigrated from New York waters.

Each year, monitoring of turtles via satellite began during the latter portions of the activity season (Table 5). The first satellite transmitter experiment, with a Kemp's ridley in 1990, confirmed earlier observations that resident sea turtles move out of inshore waters and into the ocean during the fall (Fig. 18). This turtle was tracked by radio and sonic transmitters and later via satellite throughout the month of September as it remained within the eastern bays of Long Island. Subsequently, during the first week of October, it headed directly out to sea, then along the Long Island shoreline for the next 17 days before transmitter signals became erratic and stopped.

In a separate track, a Kemp's ridley that was resident in 1991 showed similar patterns of behavior (Fig. 19). Prior to the initiation of tracking on 18 September, this turtle had been captured three times in the eastern bays over the preceding two months and had increased in weight by more than 27%. In the second week of October, however, the turtle took up a direct course, heading into the ocean, along the south shore of Long Island, and continuing southwestward toward the New Jersey coast. From October 24 through 31 the turtle travelled steadily southward along the east coast until it reached North Carolina waters, where its movement slowed. Throughout the entire track from Montauk Point to Cape Hatteras, this individual never ventured farther than 60 km from shore and remained consistently within the 40 m depth contour. This oceanic route represented a total net distance of 709 km with a mean swimming speed of 22 km per day. The water temperature along this track remained steady between 14°C and 16°C until the turtle encountered Gulf Stream waters that were mixing with inshore waters off of Cape Hatteras on day 56. On day 58, while this individual was in water of nearly 19°C, temperature back at the initial release site in New York had dropped below 11°C; the first cold-stunned Kemp's ridley appeared only 12 days later.

When transmissions ceased on 15 November, it was assumed that the batteries were depleted. After a 13 day hiatus, however, transmissions resumed from more than 535 km ENE of the turtle's last position off Cape Hatteras. Since the transmitter also was constantly at the surface, we do not believe these represented the movements of a live turtle.

A third Kemp's ridley (QQE034) that originally was captured and released with a satellite transmitter in mid-October 1990 also was tracked within eastern Long Island waters and as it swam eastward out of inshore waters (Fig. 20). After entering the Atlantic on 7 November, the turtle swam steadily southward covering an average of 20 km per day over the next two weeks. This course quickly conveyed the turtle to the warmer, but very deep, slope waters of the continental shelf. Beginning on 22 November, the pace of movement decreased and became less directed, resulting in slow meandering circles over the next 17 days. There also were no dives recorded during this period, indicating that the breakaway link had released the transmitter from the turtle. Thus, conservatively, this turtle had travelled from New York to southern waters approximately 220 km offshore of Virginia over a period of 38 days.

Not only were long-distance movements of these satellite-monitored turtles in agreement with our observations from the inshore telemetry and mark-recapture studies, but the behavior of Kemp's ridleys appeared to be representative of the other species as well. Three loggerhead

Table 5. Summary of three Kemp's ridleys and four loggerheads released in New York waters and monitored by satellite telemetry from 1990 through 1992.

| Tag number | Release date | Initial Measurements SCL (cm) | Initial Measurements Mass (g) | Tracking duration | Net movement |
|---|---|---|---|---|---|
| | | | *L. kempii* | | |
| **1990** | | | | | |
| QQE017 | 09/22/90 | 34.60 | 5909 | 27 days | 71 km |
| QQE034 | 10/15/90 | 38.80 | 8977 | 38 days* | 318 km* |
| **1991** | | | | | |
| QQM806 | 09/18/91 | 36.06 | 6136 | 58 days** | 709 km |
| | | | *C. caretta* | | |
| **1992** | | | | | |
| QQY609 | 10/03/92 | 48.25 | 19,290 | 9 days | 150 km |
| QQY626 | 10/13/92 | 55.89 | 27,500 | 29 days | 878 km |
| QQY631 | 10/24/92 | 50.22 | 20,659 | 14 days | 330 km |
| QQY625 | 11/06/92 | 46.72 | 15,090 | 118 days | 852 km |

* Transmitter probably detached after this time.
** Later transmissions probably not from a live turtle.

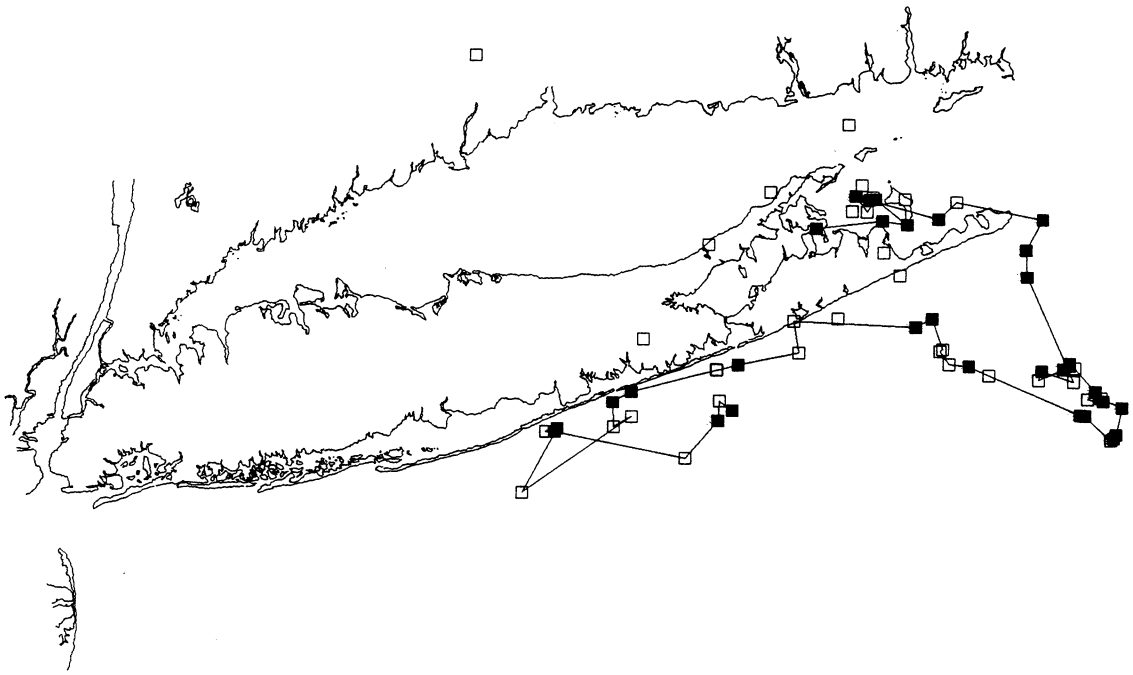


Fig. 18. Track of Kemp's ridley QQE017 monitored via satellite. Tracking began in eastern Long Island, New York on 22 Sept. 1990. The turtle entered the ocean on 2 Oct. and was monitored as it swam southward then westward along the coast. Open symbols represent lower quality signal locations; closed symbols represent high quality signal locations; the line illustrates the turtle's probable path of travel.

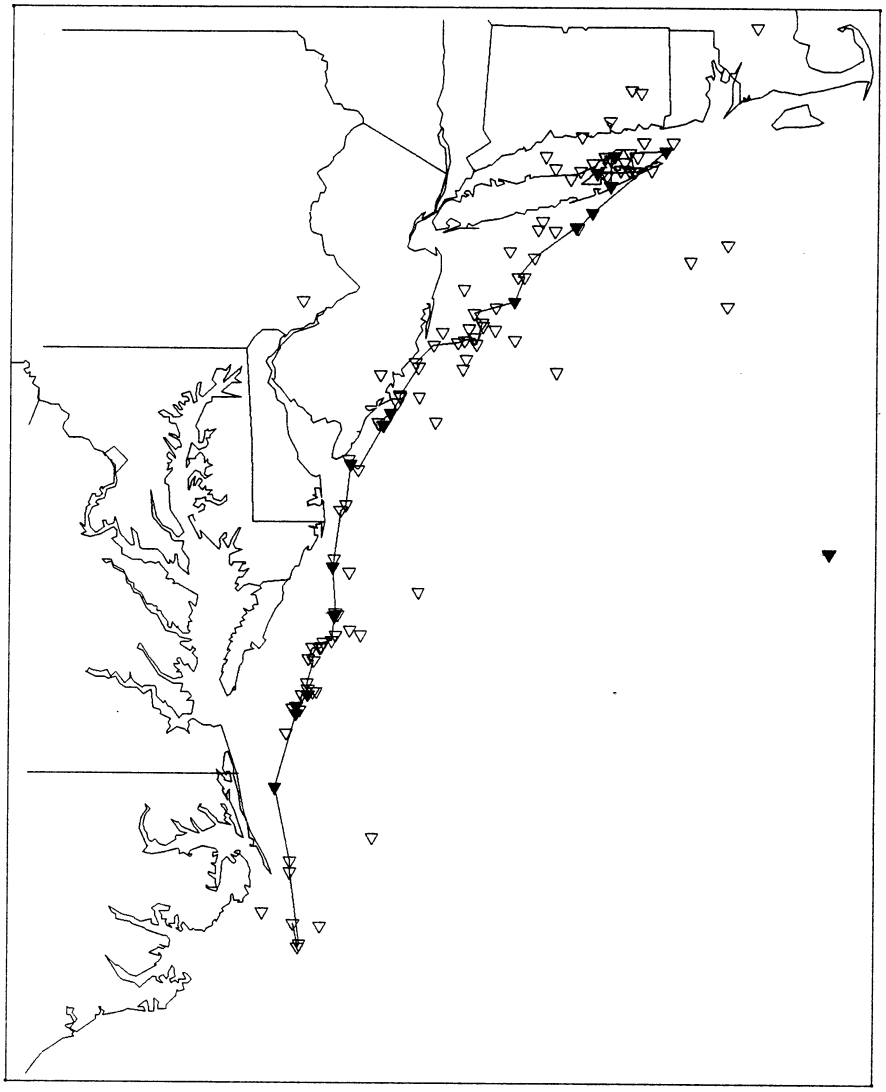


Fig. 19. Track of Kemp's ridley QQM806 monitored via satellite. Tracking began in eastern Long Island, New York on 18 Sept. 1991. Upon entering the ocean on 14 Oct. the turtle swam southwestward, then southward, reaching Cape Hatteras by 15 Nov. The floating transmitter resurfaced 13 days later, 535 km to the northeast. Symbols are the same as in Fig. 18.

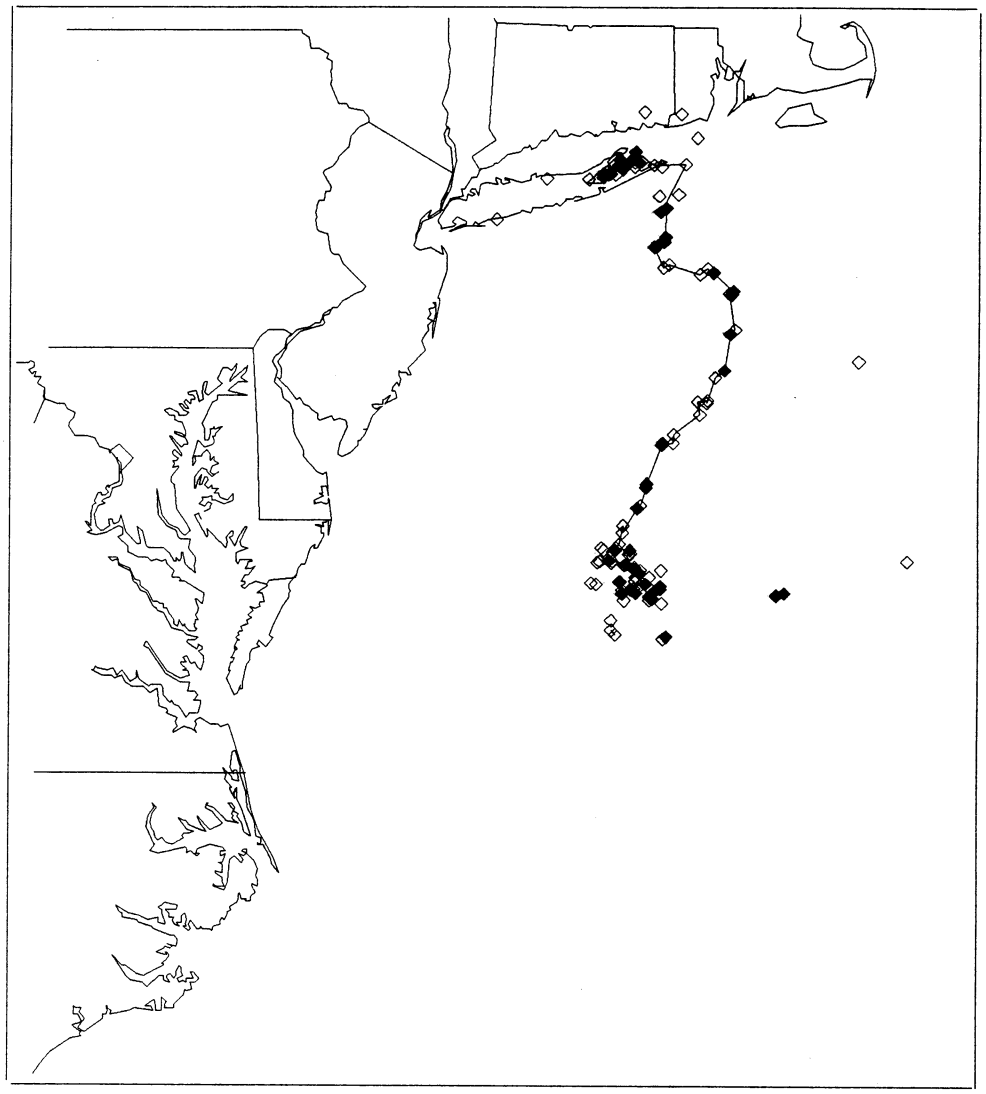


Fig. 20. Track of Kemp's ridley QQE034 monitored via satellite. Tracking began in eastern Long Island, New York on 15 Oct. 1990. After entering the ocean on 7 Nov., the turtle headed almost directly southward, encountering the deeper slope waters east of Virginia by 22 Nov. Subsequent transmissions probably were from a detached transmitter. Symbols are same as in Fig. 18.

turtles released with satellite transmitters in October 1992 displayed almost identical patterns of movement as the Kemp's ridleys of preceding years (Fig. 21). One of these turtles left New York's inshore waters and travelled steadily southward along the coastline to at least as far as Cape Lookout, North Carolina. Upon last contact with the transmitter, this turtle had travelled more than 870 km in 29 days, remaining in shallower nearshore waters the entire journey. The other two loggerheads that left in October headed directly southward and continued on this course for 150 km and 330 km over periods of 9 days and 14 days respectively. Although these tracks were somewhat truncated, the transmitter of the first of these animals was found 25 days after last contact on shore at Cape Hatteras. Thus, despite this turtle's southward movements into offshore waters, it apparently later moved closer to shore as it approached North Carolina.

The anomalous behavior of a fourth loggerhead released in 1992 may have been a result of colder temperatures that prevailed after its early November release (Fig. 22). After moving westward along the Long Island shore this turtle slowed its progress, exhibiting only minimal movements for approximately three weeks. Following this relatively inactive period, it slowly swam southward within nearshore waters. By mid-December the turtle was in waters of approximately 20 m in depth off the coast of Maryland. As the turtle moved steadily offshore over the next 12 days and encountered the slope waters, temperatures increased from less than 10°C to nearly 13°C. By continuing this eastward heading, the turtle encountered Gulf Stream waters with temperatures greater than 20°C within a week. Over the next 50 days the turtle was tracked as it swam to within 300 km NNE of Bermuda, a position more than 1170 km from its release location. By early March the turtle had slowly returned to a position approximately 750 km east of North Carolina. Thus, the total distance this individual loggerhead was tracked was greater than 1800 km. Because of the longevity of this transmitter, it appears that we observed a turtle overwintering in warmer waters offshore, followed by the initiation of its return to coastal areas with the advent of the next spring.

## DISCUSSION

The long-term research goal of this project was to define the role of New York waters in the life history of sea turtles. Contrary to the historical perception of northeastern sea turtles as waifs, it has become apparent that the coastal waters of New York provide important developmental habitat for Kemp's ridleys (*Lepidochelys kempii*), loggerheads (*Caretta caretta*) and green turtles (*Chelonia mydas*) during their early life stages. The numbers of Kemp's ridleys reported here represent the largest concentrations of this species ever reported outside of the Gulf of Mexico and greatly exceed all previous records in northeastern waters. A common feature of the Kemp's ridleys found in New York was that all of them were juveniles, as were all of the green turtles and nearly all of the loggerheads. Additionally, most of these turtles were tightly grouped, falling within in the size ranges of 2 to 5 yr old animals (Zug et al., 1986; Zug and Kalb, 1989).

The data that were collected over the course of the 5 yr study indicate that New York waters support large numbers of these young cheloniid turtles, as well as some adult-sized leatherback turtles (*Dermochelys coriacea*), on a regular annual basis. After scrutinizing historical records we also have concluded that similar patterns of occurrence and distribution of turtles have

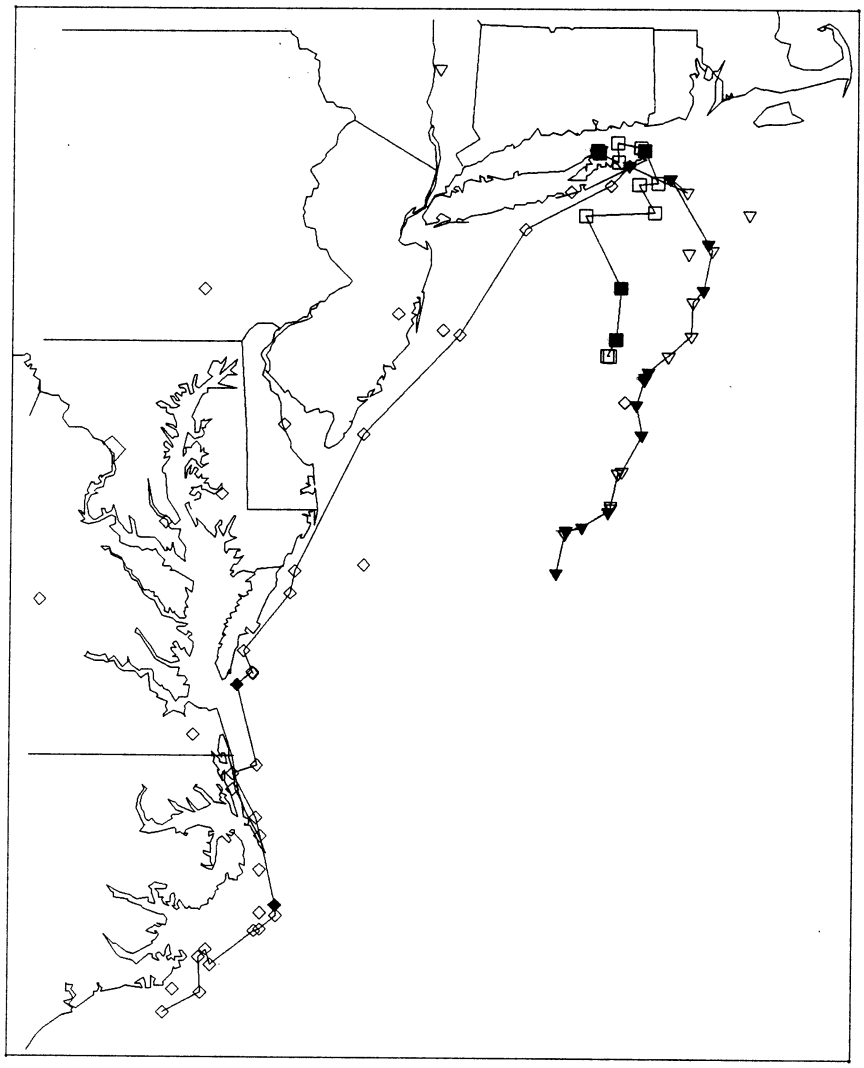


Fig. 21. Tracks of three loggerheads released in October 1992 and monitored via satellite. Diamonds represent the 870 km movement of QQY626 from Long Island to Cape Lookout over a period of 29 days. QQY609 (squares) was tracked for 150 km and QQY631 (triangles) for 330 km as they swam southward over periods of 9 and 14 days respectively. The transmitter of QQY609 washed ashore 25 days later on Cape Hatteras. Symbols are same as in Fig. 18.

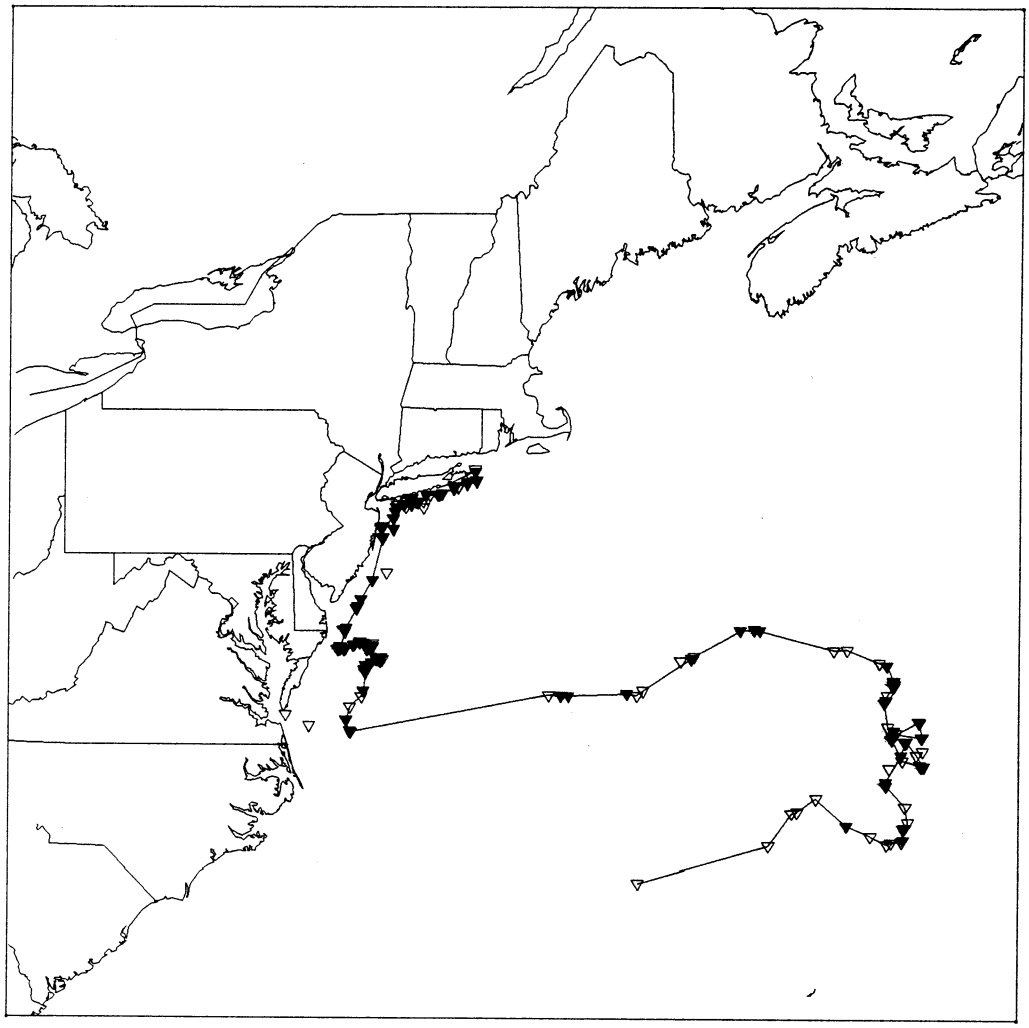


Fig. 22. Track of loggerhead QQY625, the only turtle monitored via satellite that was released after October. After initial movements along shore followed by three weeks of minimal activity, the turtle swam southward to Virginia. Moving along a temperature gradient, the turtle then entered the Gulf Stream and swam off-shore to a position northeast of Bermuda. By March it began to return toward the coast. Symbols are same as in Fig. 18.

prevailed over at least the past century (Morreale et al., 1989). Sea turtles begin arriving in New York waters in June and July and remain active through October, a period lasting up to 21 weeks. Each year during the activity season sea turtles are common within Long Island's eastern bays and in Long Island Sound. Additional evidence suggests that sea turtles also are present at this time throughout the Northeast (Shoop and Kenney, 1992). Because of their regular occurrence, the previous perception that these turtles were occasional vagrants, involuntarily and sporadically deposited into northeastern coastal waters by currents, is not supported. Rather, we have demonstrated that their predictable annual arrival and activity period corresponds to the period when water temperatures exceed 15°C. Moreover, through our direct observation of the behavior of numerous turtles, it is apparent that sea turtles of these size classes are strong swimmers that swim into and out of New York waters under their own control.

Although telemetric monitoring indicated that these juvenile turtles are capable of moving long distances in short periods of time, data from both the mark-recapture and telemetry studies demonstrated that many individuals actually remain within relatively confined areas for many weeks. The development and application of new technology during our studies (Standora and Morreale, 1991) yielded a detailed examination of the habitat usage and daily activities of turtles residing in the shallower inshore waters over extended periods. By using depth-sensitive transmitters, the diving behavior for Kemp's ridleys in the wild was described for the first time ever. The turtles that were monitored exhibited higher crepuscular activity, with the greatest diving frequencies recorded at dawn and dusk (Morreale and Standora, 1990; 1991).

There was a high degree of variability in diving and surfacing patterns both within and among individual profiles. For the most part, however, turtles were observed to be sub-surface animals. By day, most individuals spent greater than half of their time submerged; nearly one third of them spent more than 90% of the time underwater. When diving during daylight hours in shallower waters, once below the surface, turtles spent most of their time at the bottom. Although the deepest single dive ever recorded by us for a Kemp's ridley was 21 m (Morreale and Standora, 1990), dives in deeper water usually tailed off at depths less than 15 m regardless of bottom depth. Our observations suggested that turtles in deep water usually were swimming to or from another location as opposed to being resident in these areas. At night turtles mainly were observed resting on the bottom.

The propensity of the turtles to dwell in the benthic zone in shallower waters was most likely influenced by their diets. In several separate analyses, nearly all of the identifiable food items in fecal samples and gut contents of the turtles from the wild were also benthic organisms. In New York waters, Kemp's ridleys and loggerheads feed primarily on benthic crustaceans (Burke, 1990; Burke et al., 1993; 1994; Morreale and Standora, 1992*a; b*), while green turtles feed on algae and eelgrass (*Zostera marina*; Burke et al., 1992).

It was further shown that the diets of Kemp's ridleys were even more specifically limited to certain species of crabs. In addition, our findings indicate that the relative abundance of available crab species is not the primary factor governing prey selection (Morreale and Standora, 1991; 1992*b*). The species composition in nearly all of the Kemp's ridley feces was very different from that observed among the benthos at the sampling sites. Spider crabs and rock crabs were observed in much higher proportions in the turtles' diets than in most of the habitats surveyed, whereas, lady crabs and blue crabs were much less evident in the feces than would be expected.

We believe that the discrepancies between prey availability and prey composition in the turtles' diets can be explained by behavioral interactions between the crabs and the turtles. Since all Kemp's ridleys in New York waters are small, and presumably young juveniles, they probably are foraging in inshore waters for the first time in their lives. It is likely that these young turtles' inexperience at benthic foraging is reflected in a diet comprised mainly of slow-moving, more easily captured crabs such as the spider crab and the rock crab, rather than the more abundant lady crab and the similarly quick-moving blue crab (Morreale and Standora, 1991; 1992*b*; Burke et al., 1994). It also is probable that as these turtles become older and more experienced, they feed more readily on the faster swimming crabs, which would explain the observed dietary differences in other coastal regions (Burke et al., 1993).

With the high productivity of northeastern inshore waters, juvenile sea turtles apparently are able to take advantage of the plentiful resources. As a result of numerous recaptures of individuals after intervals of up to several weeks, it was demonstrated that the young turtles residing in New York waters are healthy and that many exhibit high growth rates. Although variability among individuals was high, loggerheads, Kemp's ridleys and green turtles all exhibited positive, and sometimes substantial, growth rates over the course of the activity season. Increases in carapace length of up to 4.8 cm with an attendant gain of more than 3.2 Kg were observed for loggerheads (Morreale and Standora, 1992*a*) and increases of up to 2.3 cm in length and 1.4 Kg were observed for Kemp's ridleys (Morreale and Standora, 1989) within a single season. Comparisons of the growth of New York's turtles with those of other regions proved to be very difficult to interpret for many reasons. However, if the growth rates for loggerhead and green turtles from this study are extrapolated to monthly or yearly rates, they fall between those reported in Hawaii (Bjorndal and Bolten, 1988*a*) and Florida (Mendonca, 1981) and those reported in the Bahamas (Bjorndal and Bolten, 1988*a; b*). There were no similar growth data for Kemp's ridleys in other studies from which to make comparisons to New York.

In general, New York's turtles remain active and continue foraging and growing until October, when water temperatures decline rapidly. After this time, turtles begin to make longer distance, directed movements in an easterly direction. This shift in movement patterns is associated with a behavioral shift as turtles spend more time at the surface. The noticeable changes in behavior appear to occur over a short period of time and probably represent a precursor to the initiation of long-distance migratory movements. In the course of six years of monitoring turtles with radio and sonic transmitters during the fall, we directly observed many individuals as they headed eastward toward open water, and some as they entered the ocean and began heading southward. In addition, seven turtles that were outfitted with satellite transmitters also were monitored as they entered the ocean and swam southward during the fall.

It is likely that nearly all of the turtles that are summer residents in New York waters similarly emigrate prior to the onset of winter. Of the 32 turtles monitored by radio, sonic, and satellite transmitters during the activity seasons, only one ever was retrieved later cold-stunned. This exceptional turtle was an individual that also had been found cold-stunned the previous winter. Among the more than 200 additional loggerhead, Kemp's ridley and green turtles released in the mark-recapture study during the six consecutive seasons, only two individuals were found later cold-stunned; one of these also was a rehabilitated cold-stunned Kemp's ridley from the previous winter. The combination of extremely low number of winter recaptures and the

conspicuous absence of turtles between the time of the last captures by fishermen (generally in late October) and the appearance of the first cold-stunned turtles (in late November), provides strong evidence that summer residents leave New York before winter arrives. It is likely that many of the turtles that have been found cold-stunned along New York's shoreline in the winter have been individuals that have travelled down the coast from more northern areas.

Thus, in New York there is a seasonal window of opportunity for sea turtles during which food resources remain abundant and temperatures are favorable. With the rich supplies of benthic biota, turtles grow and flourish in inshore waters. In the fall, however, after environmental conditions become more harsh turtles can no longer benefit by staying. As colder temperatures prevail throughout the region, sea turtles must emigrate from the Northeast to avoid the lethal winter climate. Although the cumulative evidence from our studies suggests that the coastal waters of New York play an important role in the early stages of development for many turtles, these northern waters are far removed from the southern regions which make up their functional reproductive range (i.e. waters where adults mate or where nesting occurs). This leaves open the question of whether the sojourn into northeastern waters represents part of a successful long-term strategy for young sea turtles.

Because adult Kemp's ridley, loggerhead, and green turtles are known to frequent southern waters, the emigration of young turtles to the Southeast would strongly suggest a connection between the northern developmental areas and the breeding populations. Through the combination of our mark-recapture studies, telemetric tracking in inshore waters, and the satellite tracking of emigrating turtles, a direct link between turtles of the Northeast and the southern populations clearly has become established. It is explicit from these long-term data that there is considerable movement of turtles between the Northeast and the South. By the end of the mark-recapture study, using conventional metal tags alone, 11 turtles of three species (loggerhead, Kemp's ridley, and green turtles) had been recovered in out-of-state waters. All were recovered in states located to the south; most were found in the Southeast, some as far south as Georgia and Florida. With the low probability inherent in the process of long-distance recaptures, including the proper identification and reporting of the tag number back to the source, these turtles are likely representative of a much larger number of animals which exhibited similar north-south migrations. The more recent development of satellite tracking techniques for small turtles resulted in perhaps a better estimate of the proportion of individuals that migrate southward. Excluding one turtle that probably was killed soon after release (Morreale and Standora, 1992*a*), a total of seven individuals were monitored at various times in three consecutive fall seasons. All three Kemp's ridleys and all four loggerheads swam initially eastward and, once in the open ocean, all headed southward.

The satellite tracks of these turtles also revealed some remarkable similarities among the specific routes of travel. Irrespective of the limitless possible directions of ocean travel, individuals soon established a course toward southern waters. Furthermore, all seven turtles, accomplished this by taking up one of only two observed routes of travel: one southwestward along shallow coastal waters; the other directly southward into deep slope waters. With the exception of one individual that swam offshore with the Gulf Stream in late December, it is possible that travel along either of these routes ultimately conveyed the turtles into southern nearshore waters. After maintaining such a steady course southward, by January, turtles easily

could be in Florida waters which are known overwintering sites for juvenile turtles (Henwood, 1987; Henwood and Ogren, 1987; Witherington and Ehrhart, 1989).

A synthesis of these observed migratory patterns with the less detailed information on long-distance and long-term recaptures of tagged turtles may provide important insight into the oceanic travel of sea turtles that inhabit the northwestern Atlantic. Not only is there an annual emigration of large numbers of turtles from the northeastern U.S. to southern waters, but such movements as were observed in this study may represent a portion of much longer-term migratory patterns (Fig. 23). We hypothesize that young juveniles, upon emerging from a previous life stage in which they feed primarily in oceanic surface waters, undergo a behavioral transition which prompts their movement into nearshore waters along the Atlantic coast. As a result of an accompanying dietary shift, they become benthic foragers among shallow inshore areas. Because of abundant resources and suitable temperatures during the summer and fall, sea turtles flourish in these habitats probably as far north as New England. As climate becomes less tolerable in late fall, turtles emigrate from northern waters and swim southward following the retreating warm waters into inshore areas of the South where they can comfortably overwinter. Henwood (1987) and Henwood and Ogren (1989) provide evidence of movements of juvenile loggerheads and Kemp's ridleys from Florida to as far north as Virginia and suggest that these represent seasonal migratory activity in which juveniles move up and down the Atlantic coast in conjunction with warmer waters. They further suggest that these patterns may persist until the turtles reach sexual maturity and become incorporated into the reproductive adult populations. Our data from northeastern sea turtles strongly support the notion of such seasonal migrations of juveniles along the coast, in addition to encouraging the extension of this scenario to include waters at least as far north as New York.

As a result of the continued intensity of our research efforts over many years, sufficient data have been accumulated not only to define the importance of New York waters to sea turtles but also to investigate some key aspects of their life cycles beyond those associated with nesting ecology. We have reported new findings that are crucial to understanding early life stage ecology of cheloniid turtles and that generate important ramifications to the conservation of these endangered and threatened species. We have documented a number of factors that jeopardize young sea turtles in inshore waters, the most insidious of which result directly from the high levels of human activity along the coast. As an obvious example, during the summer season of 1990 an astounding 40% of all dead turtles retrieved from New York waters had been struck by boats (Morreale and Standora, 1991). A more subtle concern, but one of great importance, is the steady degradation of estuarine environments. From our observations on activity and feeding behavior of juvenile sea turtles, it is evident that we need to protect benthic food resources within the shallow embayments that serve as their feeding grounds with as much intensity as we now preserve nesting areas. In addition, data presented here for the first time provide strong evidence that sea turtles are utilizing narrow corridors along which they negotiate extensive migratory movements through Atlantic coastal waters. This greatly augments the importance of such areas and should change the focus of future conservation strategies. Not only will it be important to protect sea turtle nesting and feeding grounds, but also the connecting corridors in between.

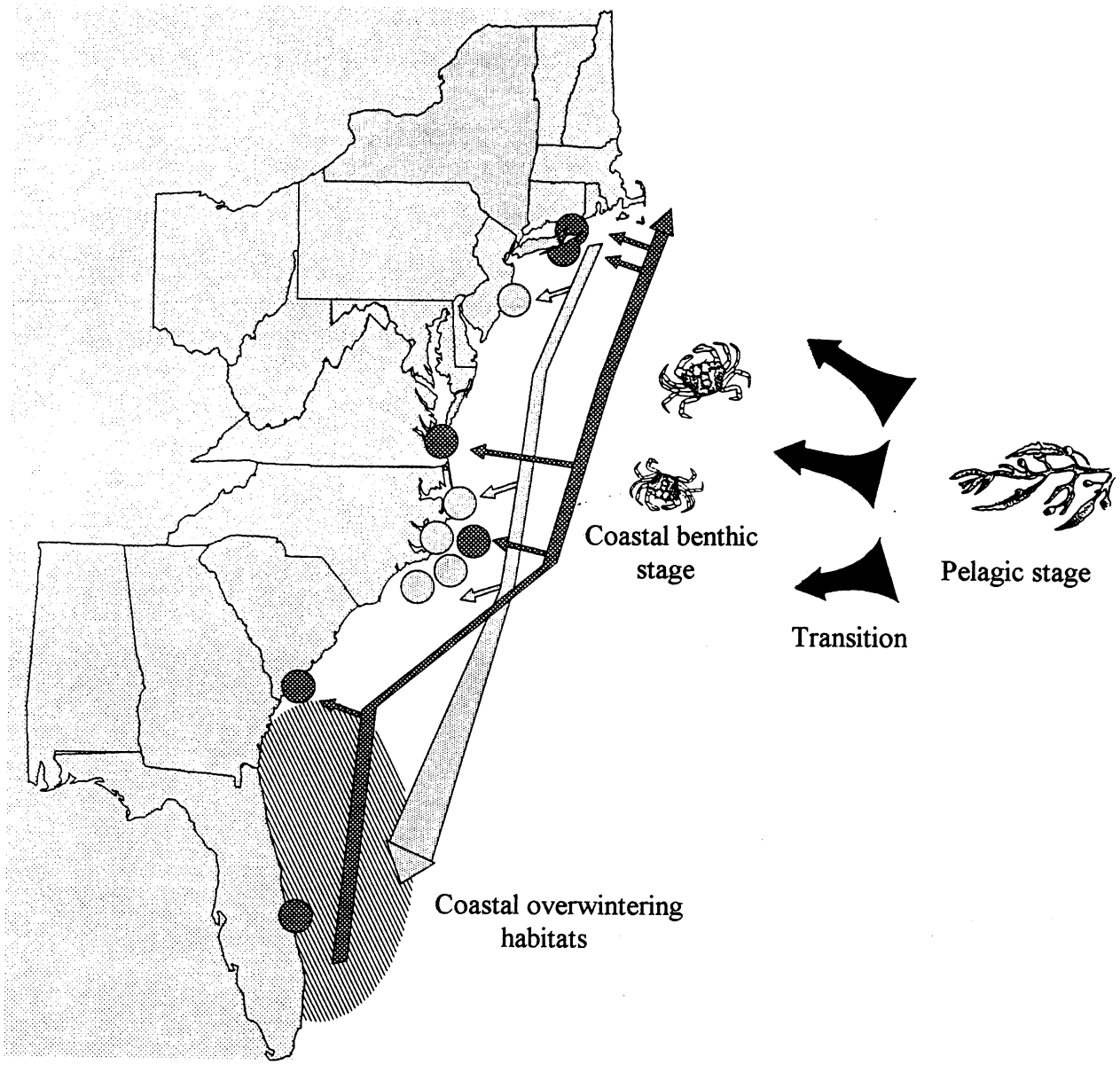



Fig. 23. Hypothesized transition between early life stages and a generalized scheme of subsequent migration patterns of juvenile sea turtles along the coastal U.S. Stippled circles represent within-season recovery locations of turtles tagged in New York; arrow represents their probable emigration route based on satellite telemetry data. Crosshatched symbols represent recoveries in a subsequent season and probable paths of migration northward from over-wintering sites.

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