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The Distribution of Loggerhead Turtles (*Caretta caretta*) in the Entrance Channel of Charleston Harbor, South Carolina, U.S.A.[1]

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ABSTRACT

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A 16-month survey of sea turtle populations was conducted in the entrance channel of Charleston Harbor in order to document the seasonal, diurnal and spatial variability in turtle densities within a portion of the channel that required dredging using hopper dredges. Fifty-three loggerhead turtles (*Caretta caretta*), and one Kemp's ridley turtle (*Lepidochelys kempi*) were captured, tagged and released during the survey period. Loggerhead turtle densities varied seasonally with highest densities observed during the summer months and lower densities observed during the spring and fall. Densities were positively correlated with water temperature and no turtles were captured in winter months when water temperatures were below 16 °C. The relative abundance of turtles varied significantly among the four zones representing different segments of the channel length, but not among the subzones representing different portions of the channel width. Highest densities were collected from a zone which contained both mud bottom and hard bottom habitats. Lowest densities were found in the zone closest to the seaward end of the channel jetties. Over the entire study period, approximately 60% of the turtles were captured at night; however, there was no significant difference in diel catch rates. Eight of the 53 loggerhead turtles collected in this study were recaptured specimens, and most of these turtles had been at large for several months. The study results suggest that turtle mortalities can be reduced or eliminated if dredging is accomplished during the winter months, and that the probable incidence of turtle entrainment will be greater in certain portions of the channel compared to others.

ADDITIONAL INDEX WORDS: *Entrance channel, sea turtle, dredging, loggerhead turtle, Kemp's ridley turtle.*

INTRODUCTION

The entrance channels to most shipping ports in the southeastern United States require periodic dredging to maintain navigational depths. Several of these channels have also been widened and deepened to accommodate larger vessels. Because the primary method of dredging entrance channels involves the use of hopper dredges, concerns have been raised about the incidental take of threatened and endangered sea turtles by these dredges (for reviews, see DICKERSON *et al.*, 1991; NATIONAL MARINE FISHERIES SERVICE, 1991). Of the five turtle species present in the southeastern region, three are at risk to dredging operations due to their life cycle or behavioral patterns (STUDT, 1987). These include the loggerhead (*Caretta caretta*), the Kemp's ridley (*Lepidochelys kempi*), and the green sea turtle (*Chelonia mydas*).

Sea turtle mortalities due to hopper dredges were first documented in 1980 at Port Canaveral, Florida (DICKERSON *et al.*, 1991). The large number of loggerhead turtle deaths resulting from this operation prompted a survey in 1981–1982 to evaluate the relative abundance of turtles in several channels along the Florida coast (BUTLER *et al.*, 1987). Loggerhead turtles were observed in all of the channels during that survey, but only the Port Canaveral channel harbored substantial concentrations of this species. In 1979, RICHARDSON and HILLESTAD (1979) conducted a trawl survey in six shipping channels along the South Carolina–Georgia coast to determine whether turtles were wintering-over in those channels. No turtles were captured during their February–March survey period, which suggested that sea turtles may be absent or rare in these channels during the colder periods of the year. However, data on the

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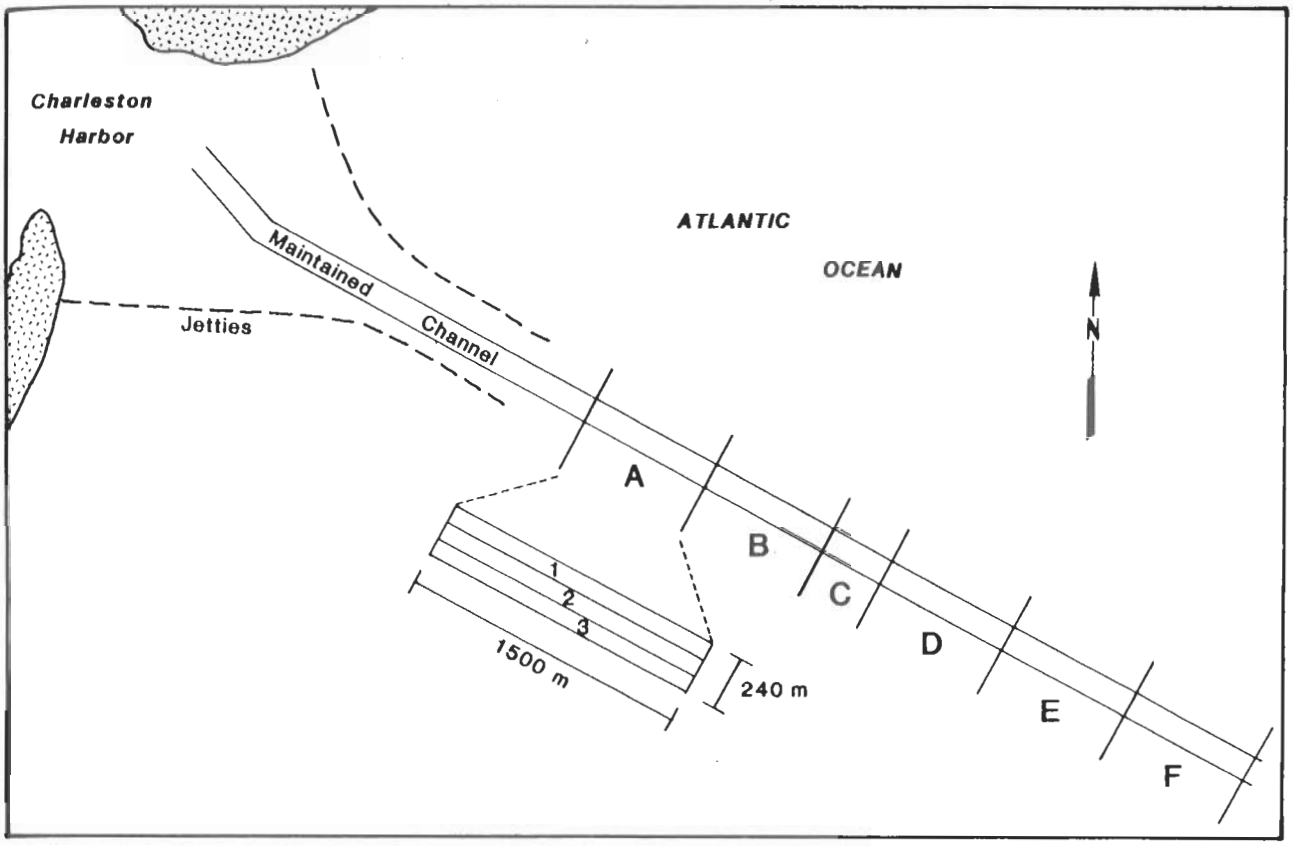

Figure 1. Areas surveyed by trawl in the Charleston Harbor entrance channel. Zone C was reduced in size and not trawled due to rough bottom. Zone F was also excluded from the survey effort due to rough bottom, which precluded trawling throughout most of that zone.

abundance and distribution of turtle populations in these channels were lacking for other seasons.

In South Carolina, sections of the entrance channel to Charleston Harbor require annual maintenance dredging, and a project to expand and deepen the Charleston channel is currently in progress. Because of concerns that this dredging program could cause high turtle mortalities similar to those observed in other southeastern channels (DICKERSON *et al.*, 1991), more information was needed to determine the spatial and temporal distribution of turtles in the Charleston Harbor entrance channel.

This study describes results obtained from a survey of turtle populations in the Charleston Harbor channel over a 16-month period. The major objectives of this survey were to: (1) characterize the seasonal and diurnal variability in turtle densities within the Charleston channel seaward of the jetties, and (2) evaluate the spatial distribution of turtles captured within this segment of the channel.

METHODS

Turtle populations were sampled in the entrance channel through an intensive trawl survey of four 1.5 km zones (A, B, D, E) located within a 7.5 km section of the channel beginning seaward of the harbor entrance jetties (Figure 1). Two other zones (C, F) were also proposed for inclusion in the survey, but bottom hazards precluded trawling in these areas. The four zones that could be trawled encompassed approximately 77% of the channel area outside the jetties that was scheduled for dredging in 1991–1992.

Each trawl zone was divided into three subzones representing the northern, central and southern portions of the channel to provide a total of 12 trawling stations (Figure 1). Trawling was conducted at all 12 stations (subzones) during each survey period using a systematic sampling procedure designed to minimize the effects of trawl disturbance in adjacent subzones. This procedure involved randomly selecting the order of subzones to be trawled and alternating trawling among the

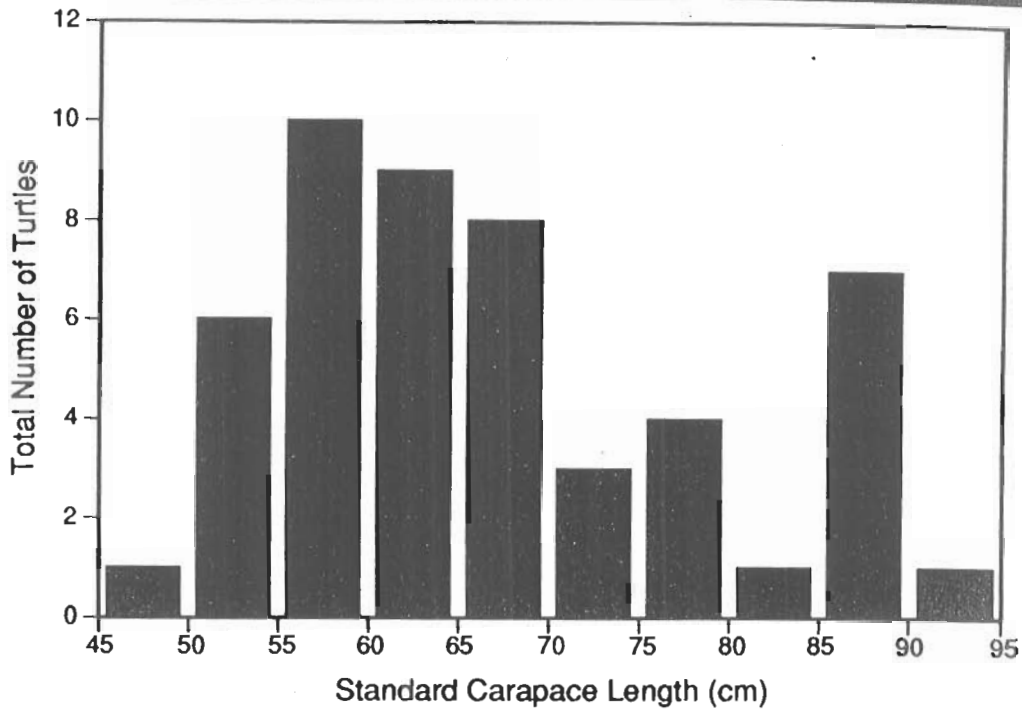

Figure 2. Size-frequency distribution of loggerhead (*Caretta caretta*) turtles captured by trawl in the Charleston entrance channel. Bars represent the total number of turtles captured from all zones during the 16-month survey period.

four larger zones (A, B, D, E) so that adjacent subzones were not trawled consecutively. Loran-C was used to position the vessel during all sampling periods.

Monthly trawling was conducted from September 1990 through December 1991. During the first 12 months of that period, all four zones were sampled. Zone E was dropped for the remainder of the study period because dredging activities were initiated in that area. Sampling frequency was increased to twice per month during April 1991 and November 1991 to characterize better the seasonal changes in the presence of turtles within the channel. Sampling frequency was also increased to twice per month in September 1990 and 1991 to compare catch variability within a month. Each sampling effort was completed within a 5-day period, with all stations sampled during the day and during the night.

Sampling within the subzones was accomplished by simultaneously towing two 18 m mongoose-style trawl nets equipped with mud rollers and having a stretch mesh dimension of 10 cm throughout the length of the net. Each net was spread with 2.4 × 1 m trawl doors and pulled using the *R/V Lady Lisa,* a 22.9-m double-rigged St. Augustine shrimp trawler. Trawl speeds were standardized so that the total bottom towing time was approximately 15–20 min/tow.

Data obtained from all captured sea turtles included species identification, sex of mature individuals (defined as ≥ 90 cm for *Caretta caretta* and ≥ 57 cm for *Lepidochelys kempi*), standard straight-line carapace length and width, and condition (*e.g.* injuries). The turtles were tagged on the posterior edge of the right front flipper with an inconel tag provided by the National Marine Fisheries Service before being released approximately 1.8 km (1 nau. mi.) from the channel (generally to the south). Basic hydrographic measurements were taken at high and low tide periods during each cruise using a Hydrolab® Surveyor® II system to provide information on bottom water temperature.

Statistical comparisons of turtle catches were completed to evaluate both spatial and temporal patterns in the number of turtles captured per trawl net (Catch Per Unit Effort, CPUE). Spatial comparisons were made using a two-way analysis of variance test (without replication) on the mean CPUE values derived for each station over the twelve month study period beginning September 1990 through August 1991. Samples collected from September through December, 1991 were not in-

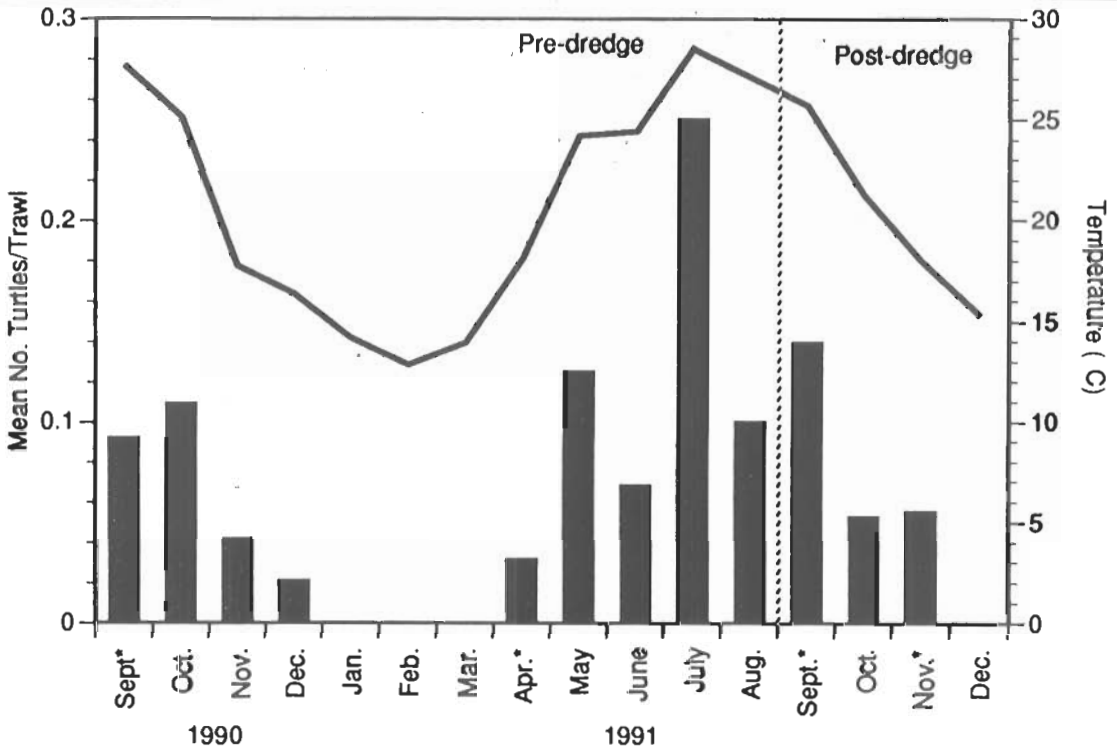

Figure 3. Mean number of turtles captured per trawl in the Charleston entrance channel (all zones combined), and average bottom water temperatures observed during each month. Months with * included two cruises.

cluded in this analysis because bottom habitat was altered within zone E, and dredging activities during this period may have altered turtle behavior. Day-night comparisons were made using a paired t-test on mean CPUE values (all stations combined) obtained for day versus night tows during each month. Linear regression was used to compare the relationship between bottom water temperatures and turtle densities using mean CPUE estimates obtained for each period. Data used for the paired t-test and regression analysis were also limited to the first 12 months of the study. For comparisons with other sources of data, CPUE estimates were also computed as the number per paired-trawl tow, since the numbers of turtles captured in each net were not available. Unless specified otherwise, all CPUE estimates reported here refer to CPUE/single net.

RESULTS

During the 16-month study, 53 loggerhead turtles (*Caretta caretta*) and one Kemp's ridley turtle (*Lepidochelys kempi*) were captured by trawl in the Charleston Harbor entrance channel. Carapace lengths (straight carapace length) of the loggerhead turtles ranged from 47.5 to 95.5 cm, but most were in the 50–70 cm size range (Figure 2). Only one of the loggerheads was classified as an adult, and this specimen was a 95.5 cm male. The Kemp's ridley turtle was a subadult (36 cm).

Loggerhead turtle capture rates changed seasonally and were positively correlated with water temperature (Figures 3, 4). Turtles were collected only when bottom water temperatures were greater than 16 °C. During the relatively mild winter of 1990, loggerhead turtles were captured through early December (bottom temperature = 16.40 °C). The Kemp's ridley was captured in November, when the water temperature was 17.9 °C. No turtles were captured in January, February and March of 1991. Turtles had returned to the channel by early April 1991 and were present through November. No turtles were captured during December 1991, when temperatures were 14.1 °C.

Differences in the density of loggerhead turtles among stations suggested that this species preferred certain portions of the channel (Figure 5). Turtle catch rates were significantly different among the zones sampled ($p = 0.017$), but they were not significantly different across the width of the channel ($p = 0.19$). Of the 45 loggerheads

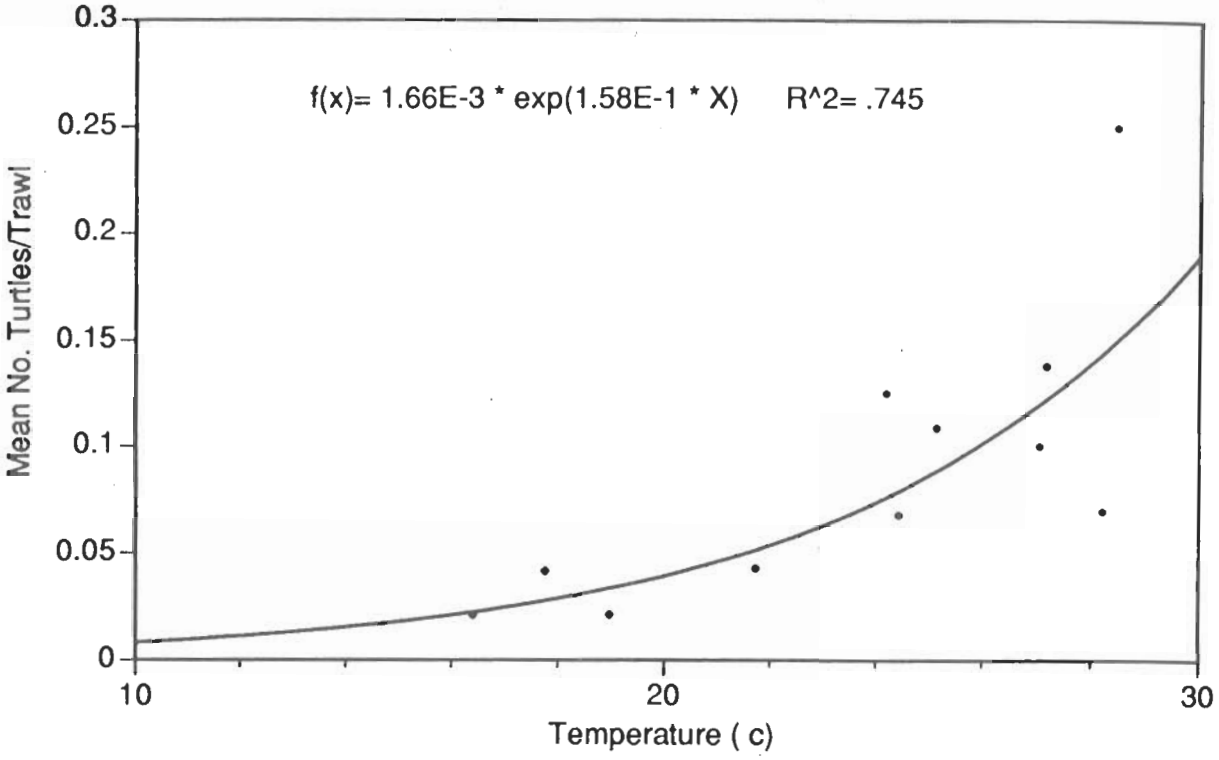

Figure 4. Regression of the mean number of turtles per trawl versus bottom water temperature during months when turtles were present.

collected during the pre-dredge period, most were collected within Zone D (57.8%) while substantially fewer were collected in zones E (17.7%), B (15.6%), and A (8.9%).

Over the entire study period, turtle capture rates were slightly greater during the night versus the day (Night/Day CPUE = 0.094/0.051). However, these differences were not statistically significant ($p = 0.097$) based on the paired t-test of mean densities captured each month. Comparison of turtle capture rates by the hour (all seasons combined) also showed no consistent CPUE patterns, although only a small percentage of the tows made during any hour contained turtles (Figures 6a and b).

Eight tagged turtles were recaptured during the study. Seven of these had originally been tagged during our sampling efforts. The other turtle was tagged and released by J. RICHARDSON (*personal communication*) during an independent trawling effort in the channel seaward of our zone E during September 1991. Although three of the turtles were recaptured within one month of their release, most of the recaptured specimens were collected during the following year after a winter absence.

DISCUSSION

The incidence of turtles captured during this survey indicates that the outer portion of the Charleston Harbor entrance channel supports a substantial aggregation of *Caretta caretta* during the spring, summer and fall months. Average catch rates of loggerhead turtles in our study area from May through September were comparable to loggerhead turtle densities observed by other investigators in the Savannah and Brunswick, Georgia entrance channels during the same months using similar gear (NELSON, USACOE Waterways Experiment Station, *unpublished data*). During the cooler months, turtle catch rates were much lower in the Charleston channel than they were during the summer, and turtles were not collected during the winter months when water temperatures were below 16 °C. The lower abundance of *Caretta caretta* observed in the Charleston channel during the fall was presumably due to a southerly or offshore migration of this species to warmer waters where they winter-over (THOMPSON, 1988). The absence of turtles in trawl samples taken during the winter supports RICHARDSON and HILLSTEAD'S (1979) conclusions that turtles are absent

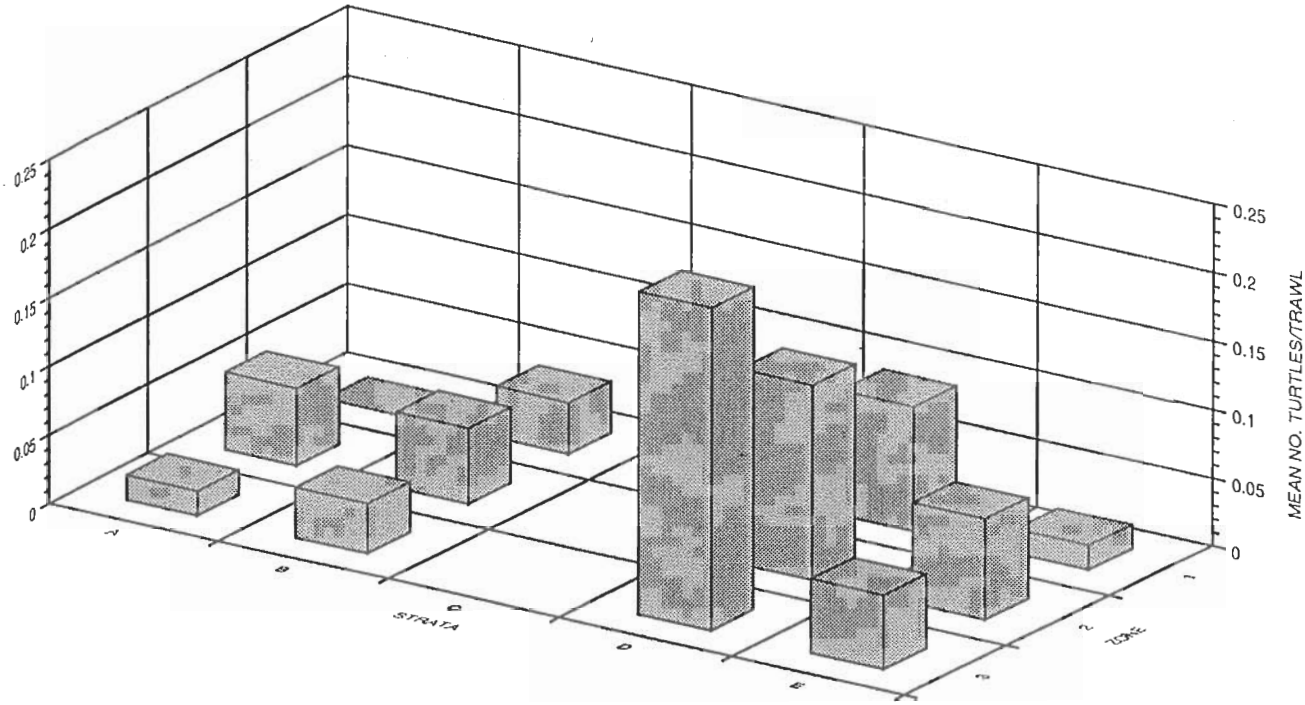

Figure 5. Mean number of turtles per trawl in each subzone of the Charleston entrance channel from September 1990 to September 1991. Catch rates represent day and night trawls combined.

or rare along the South Carolina–Georgia coastline during this time period. LUTCAVAGE and MUSICK (1985) also observed that loggerhead turtles were present only from May–November in the Chesapeake Bay area.

Two turtles were captured in the Charleston channel when bottom water temperatures were as low as 16.4 °C. It is possible that turtles were present in the study area when water temperatures were lower than 16 °C, but it is unlikely that any turtles wintered-over in this channel since none were collected in the 107 paired trawl tows taken during months when water temperatures were below 16 °C. Additional data are needed to more precisely determine the minimum water temperature at which loggerhead turtles are found in this and other channels, and measure the consistency of those distribution patterns among years.

Relatively little is known about the seasonal distribution and movements of subadult *Caretta caretta,* which comprised most of our catch. The general size range of turtles we captured is similar to the size ranges observed in other channel surveys along the east coast (EHRHART, 1983, 1987; NELSON, USACOE Waterways Experiment Station, *unpublished data*). HENWOOD (1987) has suggested that subadult loggerheads forage opportunistically along the Atlantic coast, moving northward as the water warms and southward with the onset of winter. He also provided evidence that a resident population of subadults winter-over in the Cape Canaveral area each year.

It is interesting to note that four of the eight subadults recaptured in this study were originally caught during the fall of 1990, and were not recaptured until the spring or summer of 1991. If these turtles migrated south during the fall to winter-over in warmer waters, their return during the following year suggests that at least some subadult loggerheads return to the same areas. It is also interesting to note that very few adult females were captured in the channel, even though they are commonly found nesting in the area during the spring and summer (HOPKINS-MURPHY, *personal communication*). In contrast, HENWOOD (1987) observed adult females to be abundant in the Canaveral channel during the nesting season.

Average turtle catches in the Charleston entrance channel were much greater than catch rates observed in trawls collected from non-channel habitats off South Carolina in similar water depths.

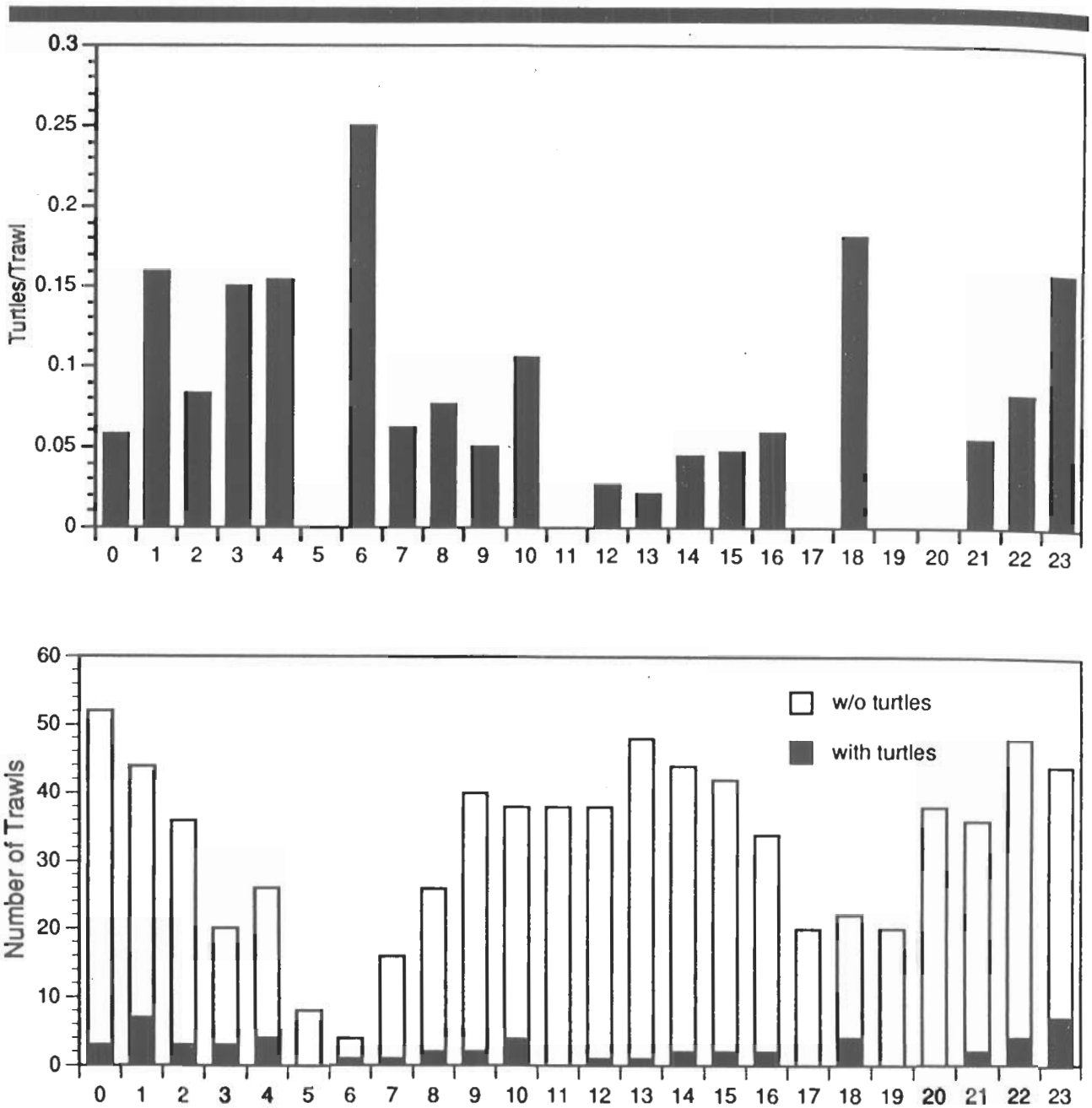

Figure 6. Mean number of turtles captured per trawl (A) and the total number of trawls made (B) in the Charleston Harbor entrance channel for each hour of the day during the twelve month period from September 1990 to September 1991. Bars represent all zones combined.

For example, during the summer months (July, August), the average turtle density in our day trawls was 0.125 loggerheads/trawl sample (average of 48 trawl samples). During the same months, the South Atlantic SEAMAP Program only collected an average of 0.043 loggerhead turtles/trawl at 46 stations sampled off South Carolina using the same research vessel and larger (23 m) mongoose trawl nets (BEATTY *et al.*, 1992). Their average turtle catch rates off Georgia were also much lower than turtle CPUE estimates obtained in the Savannah, Brunswick, and Kings Bay, Georgia channels during the fall of 1991 (BEATTY *et al.*, 1992; NELSON, USACOE Waterways Experiment Station, *unpublished data*). Although it is possible that the different catch rates are due to differences in net mesh size between BEATTY *et al.* (1992) and the other sampling ef-

forts, the large difference in catch rates among these studies suggests that loggerhead turtles are congregating in channel habitats along the southeastern United States during summer and fall months. Further comparative studies are needed to determine whether turtle densities are significantly higher in channel versus non-channel areas.

The spatial distribution of turtles in the Charleston channel clearly indicated that *Caretta caretta* were more concentrated in some areas of this channel. Evaluation of bottom characteristics in zone D, where turtles were most abundant, indicated the presence of both mud bottom and hard bottom habitat (VAN DOLAH *et al.*, 1992). CARR *et al.* (1980) and BUTLER *et al.* (1987) also observed that loggerhead turtles were more abundant in the portions of the Port Canaveral channel where muddy sediments occurred. CARR *et al.* (1980) noted that turtles were often imbedded in the mud and may have been hibernating there. We did not find any evidence that turtles collected from the Charleston channel were burying in the mud. While it is possible that loggerhead turtles prefer muddy habitats over others, trawl samples collected in zones D and E also contained evidence of hard bottom habitat based on the incidental catch of sessile sponges and corals, reef fish species, and/or rock rubble. Turtle catch rates were greater in these zones than in zones A and B, where there appeared to be little, if any, hard bottom present. Therefore, it is possible that the greater loggerhead turtle densities in zones D and E are related to the distribution of hard bottom habitat in these areas. Using satellite tracking, STONEBURNER (1982) documented the association of loggerhead turtles with live bottom habitats during inter-nesting intervals and suggested that they may be using these areas as feeding grounds. The presence of multiple bottom types in the zones where most of the turtles occurred during our study precludes confirmation of their preference for a particular bottom type. Further research is needed to determine bottom types preferred by immature turtles.

Our attempts to trawl in the channel seaward of zone E resulted in bottom hangs and net damage that was most likely due to hard bottom outcroppings based on the incidental catch of benthic fauna and rock rubble. Although we obtained no data on the relative density of turtles in this portion of the channel, USACOE personnel were able to collect some samples seaward of zone E during August and September using the same gear. Turtles were captured during the September cruise period, but the average number of turtles captured per paired trawl tow was only 0.06 (NELSON, USACOE Waterways Experiment Station, *unpublished data*). In contrast, the average number of turtles we captured in zones A–E during the same time period was 0.25 turtles per paired trawl tow. Therefore, it is likely that turtle densities are lower in the outer portion of the Charleston entrance channel compared to the area we surveyed.

The difference in turtle catch rates during the day versus the night was not statistically significant, and we observed no clear patterns in turtle capture rates during various hours of the day or night when samples from all months were considered together. Trawl sampling conducted in the Brunswick, Georgia, entrance channel also has not shown any clear patterns in turtle capture rates during the day versus the night (NELSON, USACOE Waterways Experiment Station, *unpublished data*). The slightly higher CPUE estimates obtained from our night tows in the Charleston channel may be related to turtle resting behavior. NELSON *et al.* (1987) observed that *Caretta caretta* were at the surface approximately 8% of the time during the day and only 4% of the time at night. HOPKINS and MURPHY (1981) also observed reduced activity of adult turtles during the night. If turtles were on the bottom for longer periods of time during the night, they may be more susceptible to capture by trawls or a dredge.

In conclusion, data obtained from this survey indicate that turtle densities in the Charleston entrance channel were sufficient to warrant concern over mortality from dredging operations. Seasonal changes in abundance of *Caretta caretta* in the survey area, which encompasses the area where most maintenance dredging occurs, indicates that turtle mortalities could be reduced or avoided if dredging were to be restricted to periods when water bottom temperatures are below 16 °C. Further studies are required to determine how variable turtle densities are in this channel among years, especially considering that the bottom characteristics have been altered significantly by the deepening project.

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LITERATURE CITED

BEATTY, H.R.; BOYLAN, J.M.; WEBSTER, R.P., and WENNER, E.L., 1992. *Results of Trawling Efforts in the Coastal Habitat of the South Atlantic Bight, FY 1991.* Final Report submitted to the Southeast Area Monitoring and Assessment Program, South Atlantic, National Marine Fisheries Service, Miami, Fla., 50p.

BUTLER, R.W.; NELSON, W.A., and HENWOOD, T.A., 1987. A trawl survey method for estimating loggerhead turtle, *Caretta caretta,* abundance in five eastern Florida channels and inlets. *Fishery Bulletin,* 85(3), 447–453.

CARR, A.; OGREN, L., and MCVEA, C., 1980. Apparent hibernation by the Atlantic loggerhead turtle, *Caretta caretta,* off Cape Canaveral. *Biological Conservation,* 19, 7–14.

DICKERSON, D.D.; RICHARDSON, J.I.; FERRIS, J.S.; BASS, A.L., and WOLF, M., 1991. Entrainment of sea turtles by hopper dredges in Cape Canaveral and King's Bay Ship channels. *U.S. Army Corps of Engineers Information Exchange Bulletin,* 10p.

EHRHART, L.M., 1983. Marine turtles of the Indian River lagoon system. *Florida Scientist* 6(3/4), 337–347.

EHRHART, L.M., 1987. Marine turtle mortality in the vicinity of Port Canaveral, Florida, 1977–84. *In:* WITZELL, W.N. (ed.), *Ecology of East Florida Sea Turtles.* NOAA Technical Report NMFS 53, U.S. Dept. of Commerce, pp. 1–20.

HENWOOD, T.A., 1987. Movements and seasonal changes in Loggerhead Turtle *Caretta caretta* aggregations in the vicinity of Cape Canaveral, Florida (1978–84). *Biological Conservation,* 40, 191–202.

HOPKINS, S.R. and MURPHY, T.M., 1981. *Reproductive Ecology of* Caretta caretta *in South Carolina.* Study Completion Report. October 1, 1976 to September 30, 1980. E-1, Study No. VI-A-1. South Carolina Wildlife and Marine Resources Department, 96p.

LUTCAVAGE, M. and MUSICK, J.A., 1985. Aspects of the biology of sea turtles in Virginia. *Copeia,* 2, 449–456.

NATIONAL MARINE FISHERIES SERVICE, 1991. Biological opinion: Dredging of channels in the Southeastern United States from North Carolina through Cape Canaveral, Florida, 27p.

NELSON, W.R.; BENIGO, J., and BURKETT, S., 1987. Behavioral patterns of loggerhead sea turtles, *Caretta caretta,* in the Cape Canaveral area as determined by radio monitoring and acoustic tracking. *In:* WITZELL, W.N. (ed.), *Ecology of East Florida Sea Turtles.* NOAA Technical Report NMFS 53, U.S. Department of Commerce, pp. 31–32.

RICHARDSON, J.I. and HILLESTAD, H.O., 1979. *Survey for Wintering Turtles in South Carolina and Georgia.* Final report to the National Marine Fisheries Service, Miami, Florida, under Contract No. 03-78-D08-0062, 50p.

STONEBURNER, D.L., 1982. Satellite telemetry of loggerhead sea turtle movement in the Georgia Bight. *Copeia,* 2, 400–408.

STUDT, J.E., 1987. Amelioration of maintainence dredging impacts on sea turtles, Cape Canaveral Florida. *In:* WITZELL, W.N. (ed.), *Ecology of East Florida Sea Turtles.* NOAA Technical Report NMFS 53, U.S. Department of Commerce, pp. 55–58.

THOMPSON, N.B., 1988. The status of Loggerhead, *Caretta caretta,* Kemp's Ridley, *Lepidochelys kempi,* and Green, *Chelonia mydas,* sea turtles in U.S. waters. *Marine Fisheries Review,* 50(3), 16–23.

VAN DOLAH, R.F.; MAIER, P.P.; HOPKINS-MURPHY, S.R.; ULRICH, G.F., and CUPKA, D.M., 1992. *A Survey of Turtle Populations in the Charleston Harbor Entrance Channel.* Final Report submitted to the U.S. Dept. of Interior, U.S. Fish and Wildlife Service, Charleston, S.C. under Agreement No. 14-16-0004-90-944. 26p.