Abstract.—Aerial surveys for sea turtles conducted in Core Sound and Pamlico Sound, North Carolina, 1989–91, indicated a spring immigration by the turtles into these sounds and a summertime dispersal followed by emigration in the late fall and early winter. Estimates of density in Core Sound were greater than estimates for Pamlico Sound. Core Sound density estimates were comparable to those reported for the lower Chesapeake Bay and those reported from offshore pelagic surveys in the region. The data were analysed by strip- and line-transect methods, and the choice of analysis did not influence the overall conclusions. The abundance of sea turtles in the inshore waters of the Atlantic Coast at densities at least as great as in the ocean indicates the importance of these estuarine habitats for the foraging and development of immature turtles.

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Aerial surveys for sea turtles in North Carolina inshore waters

Sheryan P. Epperly
Joanne Braun
Alexander J. Chester

Beaufort Laboratory, Southeast Fisheries Science Center
National Marine Fisheries Service, NOAA
Beaufort, NC 28516

Recent studies have demonstrated the importance of inshore waters as developmental and foraging habitats for threatened and endangered sea turtles along the Atlantic Coast of the United States (e.g. Medonça and Ehrhart, 1982; Ehrhart, 1983; Lutcavage and Musick, 1985; Keinath et al., 1987; Burke et al., 1992, 1993). A study of sea turtles in North Carolina waters used sightings reported by the public and documented the importance of Pamlico and Core Sounds for immature loggerhead, *Caretta caretta;* green, *Chelonia mydas;* and Kemp's ridley, *Lepidochelys kempii*, sea turtles (Epperly et al., in press, a). As part of the same study, aerial surveys were employed over a 3-yr period to provide independent quantitative verification of the importance of Pamlico and Core Sounds as sea turtle habitats.

We report the results of the aerial survey work in Pamlico and Core Sounds, part of the largest estuarine system in the southeast United States. Once aerial survey methodology was validated in inshore waters, our goals were 1) to obtain independent evidence for the seasonality and distribution patterns of turtles obtained from other sources, 2) to quantify the abundance of sea turtles in the sounds and compare those densities with other areas, and 3) to evaluate the consequences of the application of line vs. strip survey methodology to the data.

Materials and methods

Aerial surveys of Core and Pamlico Sounds

Pamlico and Core Sounds were divided into three areas (Fig. 1): Core Sound (34°41'N to 35°00'N), southern Pamlico Sound (35°00'N to 35°20'N), and northern Pamlico Sound (35°20'N to 35°48'N). Areas of each were 248 km^2, 2,501 km^2, and 1,951 km^2, respectively. The divisions were, in part, based on geography and on facilitating access to restricted airspace. In Core Sound, each flight surveyed approximately 26% of the total surface area of the sound (32, rarely 33 transects); for both southern and northern Pamlico Sound, approximately 6% of the total area was surveyed (8 transects in southern Pamlico Sound and 11 transects in northern Pamlico Sound). Surveys were taken from a Cessna 172 (from a side-viewing platform) at 128 km/h and at an altitude of 152 m. This altitude was chosen as a compromise between areal coverage and the ability to sight smaller turtles on the surface of inshore waters. Surveys were scheduled so that local apparent noon occurred approximately half-way through the survey. Surveys were undertaken only if winds were less than 28 km/h and seas were less than 0.6 m with no or few whitecaps (e.g. Beaufort Sea State ≤2). We attempted to perform

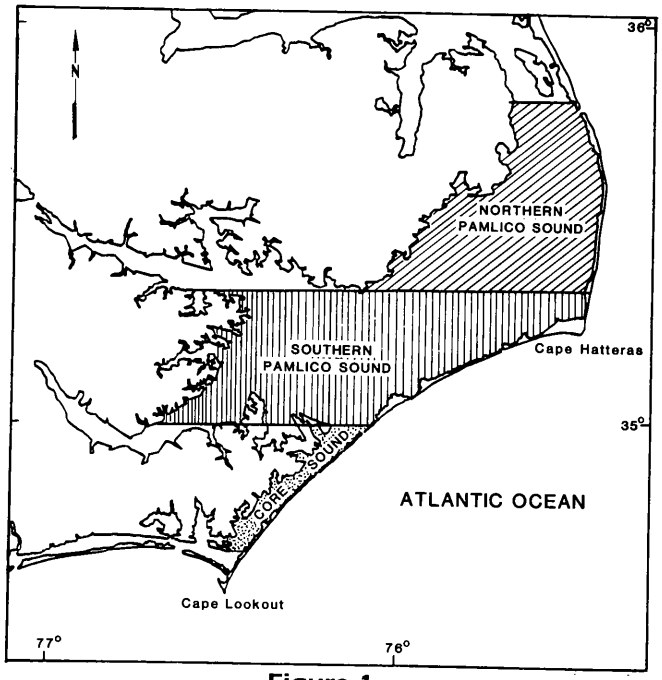

Figure 1

Core Sound and subareas of Pamlico Sound flown in aerial surveys for sea turtles in North Carolina inshore waters, 1989–91.

the surveys monthly beginning in spring 1989 and bimonthly May–November 1990 and 1991. Because it was difficult to obtain military airspace clearance over Pamlico Sound and because the results of the 1989–90 surveys indicated that our effort was best expended in Core Sound (greater sighting rates), the only area surveyed in 1991 was Core Sound.

We employed a systematic sampling design. The underlying assumption was that the systematic sample could be treated as a random sample. There was no reason to assume that the number of turtles sighted per transect would be autocorrelated (i.e. we assumed no areal trend in density or correlations between neighboring transect values). As recommended by Cochran (1977) and Eberhardt et al. (1979) in order to avoid potential selection biases of systematic sampling, the starting transect for each survey was chosen at random from all possible transects in the survey. Transect lines ran east-west and were spaced equi-distant from the starting transect. On the basis of the maximum known swimming speed of a loggerhead turtle (6 km/h, Keinath, 1993), transects were spaced far enough apart so that a turtle could not be sighted twice during any one survey. LORAN was used to maintain position on the prescribed transects. Beginning and ending longitudinal coordinates and time were recorded for each transect flown. Two observers on opposite sides of the plane scanned the waters, recording the time (with synchronized watches) and perpendicular angle to each turtle sighted (with handheld clinometers). On the assumption that groundspeed within a transect was constant, turtle positions were calculated by interpolating time and longitudinal coordinates and by converting sighting angle and survey altitude to perpendicular distance from the transect.

We used both strip- and line-transect theory to analyze the data. First, a histogram of all perpendicular sighting distances was constructed, one for Core Sound and one for Pamlico Sound (Fig. 2). From these histograms we empirically determined the strip width over which the probability of sighting a turtle was not reduced by nearness to the plane (acute viewing angle; turtles diving to avoid the plane) or by distance from the plane (reduced detection) to be 0.15–0.30 km from the flight line. Observations

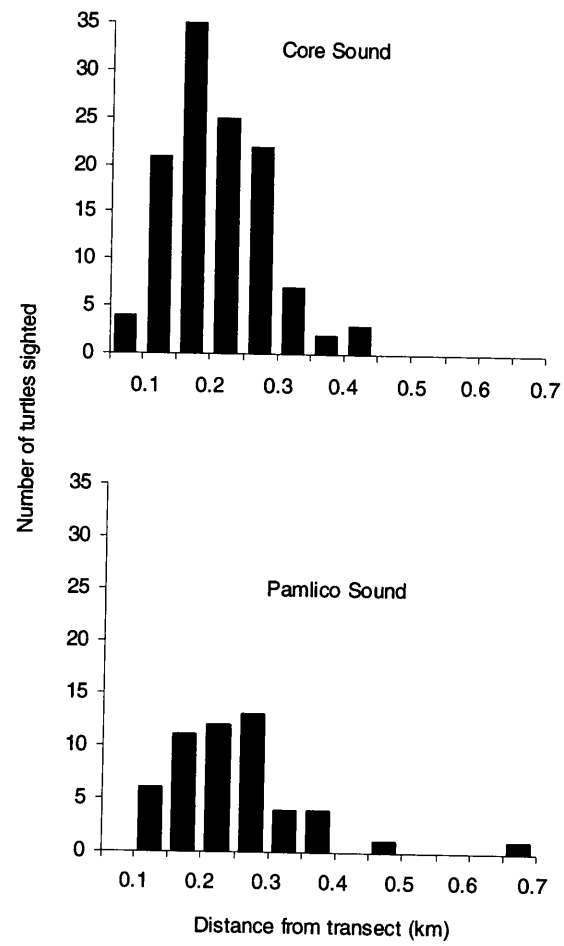

Figure 2

Histograms of distances at which turtles were sighted from the line of flight in Core and Pamlico Sound aerial surveys, 1989–91.

within this strip were then used to calculate ratio-to-size estimates of density ($\hat{D}_R$) for each survey by using a single-stage, sampling approach in which sampled transects were treated as clusters of unequal sizes (i.e. transect lengths varied; Cochran, 1977; Gates, 1979; Jolly and Watson, 1979):

$$\hat{D}_R = \frac{Y_R}{M_R},$$

the density of turtles on the surface of the sound; and

$$Y_R = \sum_{i=1}^{n} y_i,$$

the total number of turtles sighted during a survey,

where y_i = the number of turtles in the ith transect; and

$$M_R = \sum_{i=1}^{n} m_i, \text{ total area surveyed (km}^2\text{)},$$

where m_i = the area surveyed in the ith transect (km^2); and

n = the number of strip transects sampled.

Variances of the density estimates, $V(\hat{D}_R)$, were calculated as follows:

$$V(\hat{D}_R) = \frac{1-\frac{n}{N}}{n\overline{M}^2} \cdot \frac{\sum_{i=1}^{n} m_i^2 (D_i - \hat{D}_R)^2}{n-1},$$

where N = the total number of strip transects possible; and

$D_i = \frac{y_i}{m_i}$, the density of turtles in ith transect; and

$\overline{M} = \frac{M_R}{n}$, the average area of a single transect (km^2).

For line-transect analyses we used methods described by Burnham et al. (1980). The essential problem in line-transect analysis is to construct a probability density function (pdf) from the set of perpendicular distance observations of sighted organisms to estimate $f(0)$. The value of $f(0)$ is defined as the inverse of one-half the effective strip width (Burnham et al., 1980), mathematically equivalent to the value of the pdf exactly on the flight line (perpendicular distance=0). On the basis of the histograms of sighting distances, data were censored such that the probability of sighting a turtle was not reduced by proximity to the airplane. Distance data were rescaled such that x=0 at the point data were censored (0.15 km from flight line). Simple, generalized, and nonparametric models were examined with the program TRANSECT (Laake et al., 1979) to derive density estimators from the sighting distance data. Because only small numbers of turtles were seen during most sampling occasions, we could not conduct individual analyses for each survey. Instead, sighting information was combined for all Core Sound surveys and for all Pamlico Sound surveys, and an overall $f(0)_s$ was specified for each of the two water bodies (s). Density for each survey ($\hat{D}_R$) then was estimated as

$$\hat{D}_R = \frac{f(0)_s Y_R}{2L_R},$$

where $f(0)_s$ is the overall $f(0)$ for the water body, and is obtained from the TRANSECT program, and L_R (km) is the total length of all transects (l_i):

$$L_R = \sum_{i=1}^{n} l_i.$$

The estimated variance of the density estimate for each survey was computed as

$$V(\hat{D}_R) = \hat{D}_R^2 \left(\frac{V(Y_R)}{Y_R^2} + \frac{V(f(0)_s)}{f(0)_s^2} \right).$$

The variance of the number of turtles sighted during a survey $V(Y_R)$ is

$$V(Y_R) = \frac{L_R \sum_{i=1}^{n} l_i \left(\frac{y_i}{l_i} - \frac{Y_R}{L_R} \right)^2}{n-1},$$

and the variance of $f(0)_s$ is obtained from the pdf solution (Burnham et al., 1980).

Experiment to evaluate observer bias

Four observers participated in the study. An experiment was conducted on 29 August 1991 to evaluate the accuracy and comparability of observer sightings

and to validate methodology. Two planes, each carrying two observers positioned on the same side, conducted 12 flights over an area where painted plywood "turtles" were deployed. Turtle models representing loggerhead turtles of 30, 60, and 90 cm length, were attached to three anchored ground lines. Within an overflight pass, turtles of one size were grouped on a single line. All three lines could contain turtle models during any one pass. The number of turtle models of one size and the line on which they were placed during a single pass were chosen at random, but the experiment was constrained such that a total of six turtle models of each size were displayed within every three passes; the actual number of a given size displayed during a pass ranged from 0 to 4. The number, location, and size of the turtle models were unknown to the observers. Altitude and speed were identical to that used in the general survey (152 m and 128 km/h). The airplane flew on a line 0.10–0.30 km from the models. Analysis of variance techniques were used to examine the contribution of observers, turtle model size, and the interaction of observer and model size to the error in the counts.

Results and discussion

Under the ideal conditions under which the aerial survey experiment was performed, no significant differences were detected among observers (ANOVA, df=3, P=0.89). Within the range of sizes tested, turtle size was not a significant factor in the observers' ability to sight turtles (ANOVA, df=2, P=0.24). On average, 97.2% of the actual number of "turtles" were sighted during a pass (range 50–100%). We concluded that interobserver variability was not a major factor and that turtles could be sighted accurately in relatively turbid waters. The experiment did not test for the effect of fatigue on an observer's ability to sight turtles.

The inshore waters of temperate latitudes are seasonally repopulated with sea turtles. Nearly all sea turtles in Pamlico and Core Sounds, North Carolina, are immature individuals (Epperly et al., in press, a). Based on public reports, there is evidence that turtles immigrate into Core and Pamlico Sounds in the spring, disperse throughout the sounds in the summer, and emigrate from the sounds in the late fall and early winter (Epperly et al., in press, a). Results of the aerial surveys confirm this general

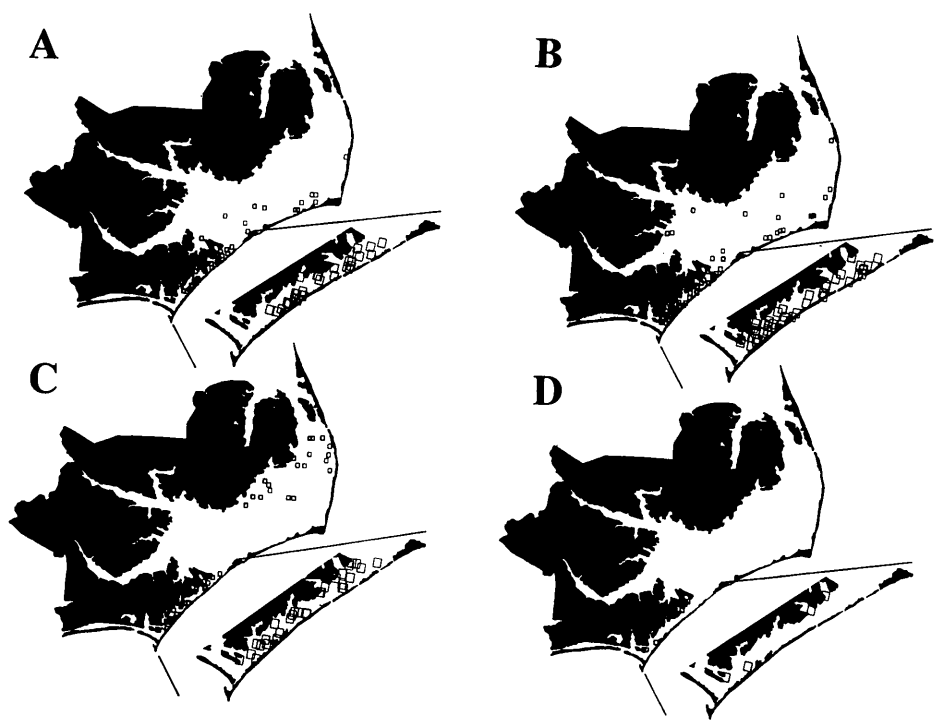

Figure 3

Seasonal sea turtle sightings in aerial surveys of Core and Pamlico Sounds, 1989–91. There were no fall surveys of southern Pamlico Sound, and Core Sound was the only area flown during the winter. The Core Sound area is enlarged to the right of each figure. (**A**) March–May; (**B**) June–August; (**C**) September–November; (**D**) December–February.

Table 1

Strip- and line-transect estimates of density for sea turtles, excluding leatherbacks, *Dermochelys coriacea*, on the surface of Core and Pamlico Sounds, North Carolina, 1989–91.

Survey	Number of turtles sighted within sound[1]	Total distance surveyed (km)	Strip-transect estimates of density: Turtles per 100 km²	Strip-transect estimates of density: SE of mean	Line-transect estimates of density: Turtles per 100 km²	Line-transect estimates of density: SE of mean
Core Sound						
1989						
22 May	30	197	30.48	7.62	37.19	11.63
12 Jul	22	203	22.95	5.75	36.00	9.67
16 Aug	10	227	7.35	2.96	12.55	4.85
12 Sep	15	224	19.34	3.69	25.41	7.09
13 Oct	6	217	1.54	1.20	3.75	2.41
6 Nov	5	231	5.78	2.07	7.05	2.91
14 Dec	5	219	6.08	2.85	9.28	4.49
1990						
4 Jan	0	216	0	—	0	—
15 Mar	0	219	0	—	0	—
24 Apr	3	212	3.15	1.69	5.76	3.16
3 May	2	204	3.27	1.81	3.99	2.70
6 Jun	2	228	2.93	1.64	3.57	2.73
7 Jul	0	219	0	—	0	—
2 Sep	0	234	0	—	0	—
4 Nov	0	228	0	—	0	—
1991						
25 May	2	222	1.50	1.19	1.83	1.59
7 Jul	1	228	1.46	1.17	1.78	1.75
31 Aug	16	212	17.30	5.48	21.11	9.28
3 Nov	6	217	6.15	2.32	11.26	4.97
Northern Pamlico Sound						
1989						
30 May	1	387	0.86	0.81	0.77	0.67
24 Jul	4	399	3.35	1.73	3.00	1.53
1 Sep	6	393	3.39	2.10	3.04	2.43
29 Sep	14	383	1.74	1.09	2.34	1.25
14 Oct	8	369	4.52	2.39	5.69	2.46
13 Nov	4	367	0.91	0.89	0.81	0.87
1990						
24 May	0	392	0	—	0	—
3 Jul	0	392	0	—	0	—
13 Sep	0	259	0	—	0	—
15 Nov	0	368	0	—	0	—
Southern Pamlico Sound						
1989						
29 May	14	523	4.46	1.33	6.30	1.39
15 Jul	14	510	6.53	2.15	7.63	2.59
1990						
19 May	1	504	0.66	0.62	0.59	0.54
4 Aug	2	534	0.62	0.58	0.56	0.49
3 Sep	0	512	0	—	0	—

[1] All turtles sighted, including those censored in calculations of density.

pattern (Table 1; Fig. 3). Volunteer commercial fishermen and the general public reported turtles in inshore waters April–December. Turtles were also sighted in the sounds during April–December aerial surveys. Spring aerial surveys (March–May) indicated that turtles were distributed mainly in Core Sound and along the eastern edge of southern Pamlico Sound. Summer (June–August) and fall (September–November) aerial surveys demonstrated that turtles were distributed throughout the sounds. No sea turtles were sighted during fall 1990 aerial surveys, but turtles were reported in the area by the public and by commercial fishermen (Epperly et al., in press, a). Turtles were still present in Core Sound in December 1989, but none was sighted during January or March 1990 aerial surveys.

Species were generally indistinguishable from the air because of their small size, except for leatherback sea turtles, *Dermochelys coriacea*, which were sighted only during the December 1989 survey (three individuals). The loggerhead turtle, with a reddish-brown carapace, was the species most often identified. Data from commercial fishermen indicated that the species composition in Pamlico and Core Sounds was 80% loggerhead, 15% green, and 5% Kemp's ridley sea turtles; leatherback turtles infrequently enter inshore waters, and hawksbills, *Eretmochelys imbricata*, are very rare (Epperly et al., in press, a). Nearly all of the turtles measured by fishermen were greater than 30 cm carapace length (measured over the curve)—the smallest model tested and successfully detected in the aerial survey experiment.

Density estimates from line- and strip-transect analysis are given in Table 1. The Fourier series estimator fit the sighting distance data from both sounds well (χ^2 goodness-of-fit test, $P>0.05$). Values of $f(0)$ differed substantially between the two sounds: $f(0)_{Core}=8.13$ (SE=0.75) and $f(0)_{Pamlico}=5.99$ (SE=0.52). Confidence intervals for the estimates of $f(0)_S$ overlapped at the 95% confidence level but not at the 90% confidence level. The cause of the difference in our ability to sight turtles between the two sounds was not obvious. Observer fatigue could have been a factor. Transects in Core Sound were short (2.7–14.9 km) and observers were able to take frequent breaks between them. Pamlico Sound transects were long (13.9–57.1 km in northern Pamlico Sound; 37.5–94.1 km in southern Pamlico Sound), and breaks occurred infrequently. Homogeneity of background could have been another factor. Core Sound waters were relatively clear, and bottom structures (channels, seagrass beds, etc.) were usually visible. This heterogeneous background served to attract observers and to intensify the observers' searches in order to detect turtles. Consequently, the visual sweep of the observers was confined to an area near the flight path. Conversely, the majority of Pamlico Sound waters usually were turbid and presented a homogeneous background, except for the easternmost portion of the sound which was very similar to Core Sound.

Line-transect estimates of density in Core Sound averaged 40% greater than estimates derived from strip-transect theory (Table 1). Line-transect estimates of density in Pamlico Sound were, on average, 14% greater than strip-transect estimates. Coefficients of variation of strip- and line-transect estimates of density were nearly identical within each sound (67% for strip- and 66% for line-transect estimates for Pamlico Sound; 47% and 54% for strip- and line-transect estimates, respectively, for Core Sound) (Table 1).

Application of line-transect and strip-transect analyses to the North Carolina aerial survey data requires several assumptions. Strip-transect analysis assumes that 1) transect lines are randomly located, 2) the strip over which all turtles are assumed to be seen and counted, 0.15–0.30 km, remains constant during a single survey and from survey to survey, i.e. sighting conditions (distance from plane, size of turtles, sun position and glare, sea state, weather, etc.) do not affect the ability to sight turtles, 3) no turtle is counted more than once in a given survey, and 4) sightings are independent events. In addition to the first, third, and fourth assumptions above, line-transect analysis requires that 1) all turtles on the line (defined as 0.15 km from the flight line) are seen with certainty, 2) turtles do not move prior to sighting or before distance measurements are made, 3) measurements are taken without error, and 4) the probability density function remains constant during a single survey and from survey to survey (i.e. the ability to sight turtles does not change).

The underlying assumptions of both methodologies are violated in important ways, primarily with respect to the ability to sight turtles. For strip-transect analysis, conditions are such that probabilities of sighting individual turtles within the strip are less than one. In addition, these probabilities vary within and among surveys. For line-transect theory, we do not know that all turtles on the line (x=0) are seen. The histogram of sighting distances (Fig. 2) indicates avoidance behavior in response to the aircraft in combination with poor downward visibility near the airplane, but we cannot be sure that locating the line (x=0) at 0.15 km from the flight line eliminated this effect entirely. In addition, the use of a pooled pdf may not be completely valid, because factors affecting the ability to sight turtles varied over the course of the study. As applied, strip-transect methods assuredly underestimate the density of turtles on the surface of the water. Line-transect methods, however, may over-

estimate or underestimate densities depending on the universality of the pdf. A criticism of strip-transect methods is that observations outside the strip are not included in the analysis and, in the study of rare animals, every observation is important (Eberhardt et al., 1979). In this study, however, only 22 of 171 turtles (13%) were sighted at distances greater than 0.30 km from the flight line. In the following comparative discussion, the results of strip-transect analysis are cited, but their use does not affect the overall conclusions.

Estimated densities of sea turtles on the surface of Core Sound were consistently higher than surface densities for Pamlico Sound (Table 1). Where comparative data exist, densities in southern Pamlico Sound were greater than in northern Pamlico Sound. Densities ranged from 0–30.5 turtles/100 km^2 in Core Sound to 0–4.5/100 km^2 in northern Pamlico Sound and to 0–6.5/100 km^2 in southern Pamlico Sound. Densities generally were highest during late spring through summer. Densities in northern Pamlico Sound tended to peak at least one month later than in southern Pamlico and Core Sounds. The estimated density of sea turtles on the surface of the sounds was quite different among the study years; turtles were more abundant in 1989.

The densities reported in this study are surface densities. Sea turtles are estimated to spend 3.8–41% of their time on the surface (Kemmerer et al., 1983; Keinath et al., 1987; Byles, 1989; Byles and Dodd, 1989; Musick et al.[1]). Thus, the estimated number of sea turtles on the surface represents a small fraction of those actually in the sounds. Because of the large range in proportion of time that monitored-turtles spend on the surface, we did not try to extrapolate surface estimates to an estimate of the submerged population in the sounds. For comparison purposes, density estimates from studies that made the extrapolation were converted to surface densities.

Comparison of density estimates among aerial survey studies is confounded by differences in platforms and altitudes. Aerial surveys utilizing aircraft equipped with bubble observation windows (Fritts et al., 1983; Thompson et al., 1991; Shoop and Kenney, 1992; Thompson[2]; Lohoefener et al.[3]) afforded observers a direct and unobstructed view of the flight line, thus maximizing the area sampled and the number of sea turtles observed per transect. Conversely, our study and other studies utilizing side-viewing aircraft (Keinath et al., 1987; Lohoefener et al., 1988; Keinath, 1993; Epperly et al., in press, b) did not have downward visibility directly beneath the plane, thereby minimizing the area sampled and the number of sea turtles observed per transect. Likewise, differences in altitude could affect the number of sea turtles sighted. Smaller turtles have a decreased chance of being sighted at higher altitudes. The altitude used in this study, 152 m, is consistent with that of the 1982–84 study of the offshore waters between Cape Hatteras and Key West, Florida (Schroeder and Thompson, 1987; Thompson[2]), surveys of the Chesapeake Bay and adjacent waters (Keinath et al., 1987; Keinath, 1993) and surveys off the northern North Carolina coast (Epperly et al., in press, b). It differs from the 229 m altitude used in the 1983–86 and the 1988–89 surveys of offshore waters of the Gulf of Mexico (Thompson et al., 1991; Lohoefener et al., 1990) and the 1979–81 surveys of the offshore waters between Nova Scotia and Cape Hatteras (Shoop and Kenney, 1992). Lohoefener et al. (1988), collected turtle data during their 1987 red drum surveys of the Gulf of Mexico using altitudes of 305–457 m. Fritts et al. (1983) collected turtle data during marine mammal, bird, and turtle surveys of the Gulf of Mexico and eastern Florida using altitudes of 91 m and 228 m.

Another factor affecting comparability of density estimates is the proportion of suitable habitat surveyed in each study. Comparisons of density estimates can be made only for surveys with comparable ratios of suitable to unsuitable habitats surveyed. Suitable habitat presumably accounts for all the area surveyed in inshore studies. Offshore studies generally extended well seaward of suitable habitat and in winter included habitat rendered unsuitable by low temperatures nearshore. Because of methodological differences in aerial survey studies, the application of strip- versus line-transect theory, and our inability to reliably correct surface densities for the proportion of the population that was submerged, comparisons of density estimates among studies are nearly impossible. We compare the results of this study only with other studies with comparable methodologies.

Our density estimates for Pamlico and Core Sounds, respectively, were comparable to those for the mid- (0–8.5 turtles/100 km^2) and lower (0–57.4 turtles/100 km^2) Chesapeake Bay, Virginia (Keinath et al., 1987). Densities in Core Sound and the lower Chesapeake Bay were particularly high, comparable to density estimates of sea turtles in offshore waters

[1] Musick, J. A., R. Byles, and S. Bellmund. 1983. Mortality and behavior of sea turtles in the Chesapeake Bay. Annual report for the year 1982, NEFC/NMFS Contract NA80-FAC-99994, Virginia Institute of Marine Science, Gloucester Point, VA, 41 p.

[2] Thompson, N. B. 1984. Progress report on estimating density and abundance of marine turtles: results of first year pelagic surveys in the southeast U.S. U.S. Natl. Mar. Fish. Serv., Miami, FL, 59 p.

[3] Lohoefener, R., W. Hoggard, K. Mullin, C. Roden, and C. Rogers. 1990. Association of sea turtles with petroleum platforms in the North-Central Gulf of Mexico. Report to the U.S. Dep. Interior, Minerals Manage. Serv., Gulf of Mexico Outer Continental Shelf Regional Off., New Orleans, MMS contract 14-12-0001-30398, OCS study MMS 90-0025, Natl. Mar. Fish. Serv., Pascagoula, MS, 90 p.

(0–126.1, Keinath, 1993; 0–12.3 turtles/100 km^2, Epperly et al., in press, b). The abundance of sea turtles in the inshore waters of the Atlantic Coast (North Carolina and Virginia), at densities at least as great as in the ocean, indicates the importance of these estuarine habitats for the foraging and development of immature turtles.

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Literature cited

Burke, V. J., S. J. Morreale, P. Logan, and E. A. Standora.
1992. Diet of green turtles (*Chelonia mydas*) in the waters of Long Island, N.Y. U.S. Dep. Commer., NOAA Tech. Memo. NMFS-SEFSC-302:140–142.

Burke, V. J., E. A. Standora, and S. J. Morreale.
1993. Diet of juvenile Kemp's ridley and loggerhead sea turtles from Long Island, New York. Copeia 1993: 1176–1180.

Burnham, K. P., D. R. Anderson, and J. L. Laake.
1980. Estimation of density from line transect sampling of biological populations. Wildl. Monogr. 72:1–202.

Byles, R. A.
1989. Satellite telemetry of Kemp's ridley sea turtle, *Lepidochelys kempi*, in the Gulf of Mexico. U.S. Dep. Commer., NOAA Tech. Memo. NMFS-SEFC–232:25–26.

Byles, R. A., and C. K. Dodd.
1989. Satellite biotelemetry of a loggerhead sea turtle (*Caretta caretta*) from the east coast of Florida. Dep. Commer., NOAA Tech. Memo. NMFS-SEFC-232:215–217.

Cochran, W. G.
1977. Sampling Techniques, 3rd ed. Wiley, New York, 428 p.

Eberhardt, L. L., D. G. Chapman, and J. R. Gilbert.
1979. A review of marine mammal census methods. Wildl. Monogr. 63:1–46.

Ehrhart, L. M.
1983. Marine turtles of the Indian River Lagoon system. Fla. Sci. 46:337–346.

Epperly, S. P., J. Braun, and A. Veishlow.
In press, a. Sea turtles in North Carolina waters. Conserv. Biol.

Epperly, S. P., J. Braun, A. J. Chester, F. A. Cross, J. V. Merriner, and P. A. Tester.
In press, b. The winter distribution of sea turtles in the vicinity of Cape Hatteras and their interactions with the summer flounder trawl fishery. Bull. Mar. Sci. 56(2).

Fritts, T. H., W. Hoffman, and M. A. McGehee.
1983. The distribution and abundance of marine turtles in Gulf of Mexico and nearby Atlantic waters. J. Herpetol. 17:327–344.

Gates, C. E.
1979. Line transect and related issues. *In* R. M. Cormack, G. P. Patil, and D. S. Robson (eds.), Sampling biological populations, p. 71–154. Int. Co-operative Publ. House, Farland, MD.

Jolly, G. M., and R. M. Watson.
1979. Aerial sample survey methods in the quantitative assessment of ecological resources. *In* R. M. Cormack, G. P. Patil, and D. S. Robson (eds.), Sampling biological populations, p. 203–216. Int. Co-operative Publ. House, Farland, MD.

Keinath, J. A.
1993. Movements and behavior of wild and head-started sea turtles. Ph.D. diss., College of William and Mary, Gloucester Point, VA, 206 p.

Keinath, J. A., J. A. Musick, and R. A. Byles.
1987. Aspects of the biology of Virginia's sea turtles: 1979–1986. Va. J. Sci. 38:329–336.

Kemmerer, A. J., R. E. Timko, and S. Burkett.
1983. Movement and surfacing behavior patterns of loggerhead sea turtles in and near Canaveral Channel, Florida (September and October 1981). U.S. Dep. Commer., NOAA Tech. Memo. NMFS-SEFC-112, 43 p.

Laake, J. L., K. P. Burnham, and D. R. Anderson.
1979. User's manual for program TRANSECT. Utah State Univ. Press, Logan, 26 p.

Lohoefener, R. R., W. Hoggard, C. L. Roden, K. D. Mullin, and C. M. Rogers.
1988. Distribution and relative abundance of surfaced sea turtles in the north-central Gulf of Mexico: spring and fall 1987. U.S. Dep. Commer., NOAA Tech. Memo. NMFS-SEFC-214:47–50.

Lutcavage, M., and J. A. Musick.
1985. Aspects of the biology of sea turtles in Virginia. Copeia 1985:449–456.

Medonça, M. T., and L. M. Ehrhart.
1982. Activity, population size and structure of immature *Chelonia mydas* and *Caretta caretta* in Mosquito Lagoon, Florida. Copeia 1982:161–167.

Schroeder, B. A., and N. B. Thompson.
1987. Distribution of the loggerhead turtle, *Caretta caretta*, and the leatherback turtle, *Dermochelys coriacea*, in the Cape Canaveral, Florida area: results of aerial surveys. *In* W. N. Witzell (ed.), Ecology of east Florida sea turtles, p. 45–53. U.S. Dep. Commer., NOAA Tech. Rep. NMFS 53.

Shoop, C. R., and R. D. Kenney.
1992. Seasonal distributions and abundances of loggerhead and leatherback sea turtles in waters of the northeastern United States. Herpetol. Monogr. 6:43–67.

Thompson, N. B., E. S. Denton, D. B. Koi, A. Martinez, and K. Mullin.
1991. Turtles in the Gulf of Mexico: pelagic distributions and commercial shrimp trawling. U.S. Dep. Commer., NOAA Tech. Memo. NMFS-SEFSC-286, 24 p.