

NOAA Technical Memorandum NMFS-SEFSC- 551

# PROTECTED SPECIES AERIAL SURVEY DATA COLLECTION AND ANALYSIS IN WATERS UNDERLYING THE R-5306A AIRSPACE

## FINAL REPORT SUBMITTED TO U.S. MARINE CORPS, MCAS CHERRY POINT

M. APRIL GOODMAN JOANNE BRAUN-MCNEILL ERIK DAVENPORT ALETA A. HOHN



U. S. DEPARTMENT OF COMMERCE National Oceanic and Atmospheric Administration National Marine Fisheries Service Southeast Fisheries Science Center Beaufort Laboratory 101 Pivers Island Road Beaufort, NC 28516

January 2007

This page left blank intentionally



NOAA Technical Memorandum NMFS-SEFSC- 551

#### PROTECTED SPECIES AERIAL SURVEY DATA COLLECTION AND ANALYSIS IN WATERS UNDERLYING THE R-5306A AIRSPACE

#### FINAL REPORT SUBMITTED TO U.S. MARINE CORPS, MCAS CHERRY POINT

M. APRIL GOODMAN<sup>1</sup> JOANNE BRAUN-MCNEILL<sup>1</sup> ERIK DAVENPORT<sup>1</sup> ALETA A. HOHN<sup>1</sup>

<sup>1</sup>NOAA, National Marine Fisheries Service, Southeast Fisheries Science Center, NOAA Beaufort Laboratory, 101 Pivers Island Rd, Beaufort, NC 28516

> U. S. DEPARTMENT OF COMMERCE Carlos M. Gutierrez, Secretary NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION Conrad C. Lautenbacher, Jr., Administrator NATIONAL MARINE FISHERIES SERVCICE William T. Hogarth, Assistant Administrator for Fisheries

> > January 2007

This Technical Memorandum series is used for documentation and timely communication of preliminary results, interim reports, or similar special-purpose information. Although the memoranda are not subject to complete formal review, editorial control, or detailed editing, they are expected to reflect sound professional work.

The National Marine Fisheries Service (NMFS) does not approve, recommend or endorse any proprietary product or material mentioned in this publication. No reference shall be made to NMFS, or to this publication furnished by NMFS, in any advertising or sales promotion which would indicate or imply that NMFS approves, recommends or endorses any proprietary product or proprietary material herein or which has as its purpose any intent to cause directly or indirectly the advertised product to be used or purchased because of NMFS publication.

This report should be cited as follows:

Goodman, M.A., J.B. McNeill, E. Davenport, and A.A. Hohn. 2007. Protected species aerial survey data collection and analysis in waters underlying the R-5306A Airspace: Final report submitted to U.S. Marine Corps, MCAS Cherry Point: NOAA Technical Memorandum NMFS-SEFSC-551, 25 p.

Copies of this report can be obtained from:

M. April Goodman NOAA Fisheries 101 Pivers Island Road Beaufort, NC 28516-9722 April.goodman@noaa.gov

National Technical Information Center 5825 Port Royal Road Springfield, VA 22161 (800) 553-6842 or (703) 605-6000 http://www.ntis.gov/numbers.htm

Photo credits:

Larisa Avens<sup>1</sup>, April Goodman<sup>1</sup>, Tom Ninke<sup>1</sup>,

<sup>1</sup>NOAA, National Marine Fisheries Service, Southeast Fisheries Science Center, NOAA Beaufort Laboratory, 101 Pivers Island Rd, Beaufort, NC 28516

# Protected Species Aerial Survey Data Collection and Analysis in Waters Underlying the R-5306A Airspace

## Final Report Submitted to U.S. Marine Corps, MCAS Cherry Point

#### **Executive Summary**

To be in compliance with the Endangered Species Act and the Marine Mammal Protection Act, the United States Department of the Navy is required to assess the potential environmental impacts of conducting at-sea training operations on sea turtles and marine mammals. Limited recent and area-specific density data of sea turtles and dolphins exist for many of the Navy's operations areas (OPAREAs), including the Marine Corps Air Station (MCAS) Cherry Point OPAREA, which encompasses portions of Core and Pamlico Sounds, North Carolina.

Aerial surveys were conducted to document the seasonal distribution and estimated density of sea turtles and dolphins within Core Sound and portions of Pamlico Sound, and coastal waters extending one mile offshore. Sea Surface Temperature (SST) data for each survey were extracted from 1.4 km/pixel resolution Advanced Very High Resolution Radiometer remote images. A total of 92 turtles and 1,625 dolphins were sighted during 41 aerial surveys, conducted from July 2004 to April 2006.

In the spring (March – May; 7.9°C to 21.7°C mean SST), the majority of turtles sighted were along the coast, mainly from the northern Core Banks northward to Cape Hatteras. By the summer (June – Aug.; 25.2°C to 30.8°C mean SST), turtles were fairly evenly dispersed along the entire survey range of the coast and Pamlico Sound, with only a few sightings in Core Sound. In the autumn (Sept. – Nov.; 9.6°C to 29.6°C mean SST), the majority of turtles sighted were along the coast and in eastern Pamlico Sound; however, fewer turtles were observed along the coast than in the summer. No turtles were seen during the winter surveys (Dec. – Feb.; 7.6°C to 11.2°C mean SST). The estimated mean surface density of turtles was highest along the coast in the summer of 2005 (0.615 turtles/km<sup>2</sup>, SE = 0.220). In Core and Pamlico Sounds the highest mean surface density occurred during the autumn of 2005 (0.016 turtles/km<sup>2</sup>, SE = 0.009). The mean seasonal abundance estimates were always highest in the coastal region, except in the winter when turtles were not sighted in either region. For Pamlico Sound, surface densities were always greater in the eastern than western section. The range of mean temperatures at which turtles were sighted was 9.68°C to 30.82°C. The majority of turtles sighted were within water  $\geq 11^{\circ}$ C.

Dolphins were observed within estuarine waters and along the coast year-round; however, there were some general seasonal movements. In particular, during the summer sightings decreased along the coast and dolphins were distributed throughout Core and Pamlico Sounds, while in the winter the majority of dolphins were located along the coast and in southeastern Pamlico Sound. Although relative numbers changed seasonally between these areas, the estimated mean surface density of dolphins was highest along the coast in the spring of 2006 (9.564 dolphins/km<sup>2</sup>, SE = 5.571). In Core and Pamlico Sounds the highest mean surface density occurred during the autumn of 2004 (0.192 dolphins/km<sup>2</sup>, SE = 0.066). The estimated mean surface density of dolphins was lowest along the coast in the summer of 2004 (0.461 dolphins/km<sup>2</sup>, SE = 0.294). The estimated mean surface density of dolphins was lowest in Core and Pamlico Sounds in the summer of 2005 (0.024 dolphins/km<sup>2</sup>, SE = 0.011). In Pamlico Sound, estimated surface densities were greater in the eastern section except in the autumn. Dolphins were sighted throughout the entire range of mean SST (7.60°C to 30.82°C), with a tendency towards fewer dolphins sighted as water temperatures increased.

Based on the findings of this study, sea turtles are most likely to be encountered within the OPAREAs when SST is  $\geq 11^{\circ}$ C. Since sea turtle distributions are generally limited by water temperature, knowing the SST of a given area is a useful predictor of sea turtle presence. Since dolphins were observed within estuarine waters year-round and throughout the entire range of mean SST's, they likely could be encountered in the OPAREAs any time of the year. Although our findings indicated the greatest number of dolphins to be present in the winter and the least in the summer, their movements also may be related to other factors such as the availability of prey.

#### Introduction

To be in compliance with the Endangered Species Act and the Marine Mammal Protection Act, the United States Department of the Navy is required to assess the potential environmental impacts of conducting at-sea training operations to sea turtles and marine mammals. Marine Corps Air Station (MCAS) Cherry Point's restricted airspace, R-5306A, encompasses portions of Core and Pamlico Sounds, and is used on a regular basis by the U.S. Marine Corps for training activities that involve the deployment of ordnance from aircraft at two operations areas (OPAREAs): the Piney Island Bombing Range (BT-11), and the Brant Island Shoal Bombing Target (BT-9) (Figure 1). Both sea turtles (Epperly *et al.*, 1995a,b) and marine mammals (Read *et al.*, 2003a,b; NMFS at NOAA Beaufort Lab, unpublished data) inhabit the estuarine waters of North Carolina and are likely to occur in the vicinity of these OPAREAs.

Since 1988, National Marine Fisheries Service (NMFS) research has demonstrated the importance of North Carolina's inshore waters as developmental habitat for neritic, juvenile loggerhead (*Caretta caretta*), green (*Chelonia mydas*), and Kemp's ridley (*Lepidochelys kempii*) sea turtles (Epperly *et al.*, 1995a,b; NMFS at NOAA Beaufort Lab, unpublished data). Aerial surveys (Epperly *et al.*, 1995b) and public sighting records (NMFS at NOAA Beaufort Lab, unpublished data) have documented the occurrence of sea turtles in R-5306A; some sightings were within the vicinity of bombing targets BT-9 and BT-11. Telemetry and biopsy surveys in Pamlico and Core Sounds (NMFS at NOAA Beaufort Lab, unpublished data), along with boatbased surveys of the Neuse River estuary (Gannon, 2003) and Pamlico Sound including BT-9 and BT-11 ranges (Read *et al.*, 2003b), have demonstrated these areas are frequently used by bottlenose dolphins (*Tursiops truncatus*) as well.

The use of Core and Pamlico Sounds by sea turtles and dolphins changes seasonally. As water temperatures warm in the spring, sea turtles enter the sounds and distribute themselves throughout these estuarine waters during the summer. Cooling water temperatures in the fall result in the migration of turtles from the sounds to warmer coastal waters (Epperly et al., 1995a, b). Turtles are rarely encountered in water temperatures < 11°C (Epperly et al., 1995c; Coles and Musick, 2000; NMFS at NOAA Beaufort Lab, unpublished data). While bottlenose dolphins are known to reside in the estuarine waters of North Carolina year-round (Read et al., 2003b), little is known of their seasonal distribution. Although data are limited, it appears bottlenose dolphins are found primarily in the northern areas of Pamlico Sound in summer. In the winter, bottlenose dolphins are commonly found in the southern Pamlico Sound, particularly in the southern part of the Neuse River, including coastal areas of Cherry Point MCAS. However, it is hypothesized that during the coldest months, when water temperatures do not support populations of prey, dolphins move from the estuary to nearshore coastal areas that border Pamlico Sound, particularly south of Cape Hatteras (NMFS at NOAA Beaufort Lab, unpublished data). Verification of the seasonal use of Pamlico Sound by these protected species may provide a window when impacts of training activities would be minimal or negligible. If water temperature is a primary factor influencing the movements of turtles and dolphins into and out of

the Sounds, documentation of the sea surface temperature at which sightings occur may allow for predicting those windows when operations are more or less likely to impact these species.

The Cherry Point OPAREA lies within the developmental habitat for both sea turtles and dolphins, and training exercises at the two bombing ranges (BT-9 and BT-11) occur on a regular basis. However, previous aerial surveys such as those conducted by Epperly *et al.* (1995b) have been limited within the OPAREAs due to restricted access, so the use of R-5306A by these species is unknown. As a result of restricted access, estimates of impacts to these species from training operations would be based on insufficient data. Aerial surveys are the most feasible means to obtain this information since R-5306A is a large area that encompasses a complex intersection of water bodies and land masses.

We were contracted by MCAS Cherry Point for assistance in achieving the following three specific objectives:

- 1. Survey the waters of Core and Pamlico Sounds within R-5306A to document the seasonal distribution of sea turtles and marine mammals sighted;
- 2. Provide relative numbers of animals sighted as an index of abundance that can be compared among seasons within the scope of this survey; and
- 3. Provide observer training to MCAS Cherry Point personnel sufficient to allow these personnel to conduct pre-exercise range sweeps and post-exercise impact surveys for protected species.

# Methods

## **Aerial Survey**

From July 2004 to April 2006 aerial surveys were conducted in a high-wing, twin-engine aircraft over portions of Core and Pamlico Sounds that lie within R-5306A and extend approximately one mile offshore of those limits (Figure 2). We used survey methods similar to Epperly et al. (1995b). Surveys consisted of either 15 or 16 east-west oriented transects, with the starting transect randomly selected to reduce bias (Cochran, 1977; Eberhardt et al., 1979). Transects were equi-distant from the starting transect, and spaced 4.5 km apart. We surveyed approximately 3.8% of the coastal area and 6.9% of Core and Pamlico Sounds during each flight. Surveys were conducted at an altitude of 147 m and a ground speed of 166-175 km/hr, using a Garmin GPSMap 295 to maintain position along each transect during a survey. It took approximately five hours to complete all transects. We scheduled flights so that mid-survey would occur as close to noon as possible. Although we attempted weekly surveys, flights were undertaken only when winds were less than 18 km/hr and wave height was less than 0.6 m, with no or few whitecaps (Beaufort Sea State  $\leq$  3). If conditions deteriorated after a survey began, we aborted the survey. Two observers positioned on opposite sides of the plane reported sea turtle and dolphin sightings to a data recorder, who logged in positional data and associated time with a hand-held Garmin GPS 12XL. The data recorder also noted sea state, glare, flight speed, altitude, change in weather, fishing activity, visibility, and turbidity throughout the flight. Due to the difficulty of distinguishing species at high altitudes, we did not identify turtles to species except in the case of leatherback turtle (*Dermochelys coriacea*) sightings. All dolphins sighted were assumed to be bottlenose dolphins since they are the only dolphin species inhabiting the area surveyed. Group size and direction of movement was also recorded for dolphins. The data recorder was always positioned on the same side of the plane as the observer with the least amount of experience sighting animals and reported sightings only when actively engaged in training an observer, or when it became apparent that the observer did not see an animal. A minimum of two training sessions were required before MCAS Cherry Point personnel were considered trained.

#### **Distribution and Density Data**

All estimates of density are surface estimates, and therefore do not account for animals below the water's surface. We derived density estimates using strip-transect methods. A number of assumptions should be considered when using the strip-transect method to analyze data: 1) transect lines are located randomly; 2) sighting conditions such as sun position and glare, sea state, weather, size of animals, and sightability differences within the 0.15-0.30 km strip do not effect the observers ability to sight animals, and all animals are sighted; 3) animals are only counted once during each survey; and 4) sightings are independent events (Burnham and Anderson, 1984). We conservatively chose a strip width of 0.15 km based on previous aerial surveys of Core and Pamlico Sounds (Epperly *et al.*, 1995b). Densities were derived by season: Spring (March-May), Summer (June-August), Autumn (September-November) and Winter (December-February) and by geographic area: Coastal, Pamlico and Core Sounds, Western Pamlico Sound (Figure 2).

We estimated the density of animals per km<sup>2</sup> for each season and geographic area using the following equation:

where:

D = N / A

D = Density of animals observed N = Number of animals observedA = Area surveyed (km<sup>2</sup>)

#### Sea Surface Temperature Data

Sea surface temperature (SST) data was recorded during surveys using a Cyclops 300 independent infrared temperature sensor mounted onto the outside of the survey aircraft. We also extracted SST data after surveys from 1.4 km/pixel resolution Advanced Very High Resolution Radiometer (AVHRR) remote images collected by NOAA Polar Orbiting Environmental Satellites (NPOES) 15, 16, 17, and 18. Images were downloaded from the U.S. southeastern regional node of NOAA's Comprehensive Large Array-data Stewardship System (CLASS) website (NOAA Satellite and Information Service, 1989). Only images taken in the daytime were used. Data extracted from the images were pixel temperature values from the same day and were geo-located with turtle and dolphin sightings. We digitally reconstructed geo-coordinates (latitude and longitude) along transects from beginning and end waypoints using

Matlab Software (The Mathworks, Inc., 1994). Geo-coordinates were converted from reconstructed flight lines and those associated with turtle sightings to row and column pixel locations based on the Mercator projection of the images (1248 rows x 1160 columns) and the bounding box (Northwest corner, 36.8943 °N, 87.8404 °W, and Southeast corner, 72.7996 °W, 22.5862 °N) of the remote images. Row and column pixel locations were used to index and extract SST data and removed SST pixels identified by NOAA's Coastwatch as missing data, land, or clouds (NOAA Satellite and Information Service, 1989). Minimum, maximum, and mean values of the remaining pixels were used to describe the SST observed among satellites along each survey transect and during dolphin and turtle sightings. The null hypothesis that observing sea turtles and marine mammals was independent of the mean SST of surveys was tested by performing a  $\chi^2$  test.

## Results

Due to inclement weather, the project timeframe, military training exercises, pilot availability, and a NOAA issued aviation safety stand-down, surveys were not evenly distributed seasonally among years. We surveyed 8 times in the spring, 13 times in the summer, 14 times in the autumn, and 6 times in the winter for a total of 41 surveys. A total of 92 turtles and 1,625 dolphins were sighted.

#### Seasonal Distribution and Sea Surface Temperature

In the spring the majority of turtles were sighted along the coast, mainly from the northern Core Banks northward to Cape Hatteras (Figure 3). A couple of turtles were sighted just within the eastern Pamlico Sound and one was within the vicinity of BT-11. By the summer turtles were fairly evenly dispersed along the entire survey range of the coast and Pamlico Sound, with only a few sightings in Core Sound and the Pamlico and Neuse Rivers. The only leatherback turtle sighted was just south of Cape Hatteras. In the autumn, the majority of turtles sighted were along the coast and in eastern Pamlico Sound; however, fewer turtles were observed along the coast than in the summer. One turtle was seen in the Neuse River. The greatest number of turtles sighted within Core Sound occurred in autumn, with four individuals being seen. No turtles were seen in the entire study area during the winter surveys.

Dolphins were distributed along the entire survey range of the coast and within eastern Pamlico Sound in the spring, with only a few animals sighted in Core Sound, the Pamlico and Neuse Rivers, and West Bay (Figure 4). By summer the number of observed dolphins along the coast had declined, but were relatively evenly distributed in Pamlico Sound and could still be found in the Pamlico and Neuse Rivers. A few groups were sighted just outside Bay River, within West Bay, and in Core Sound. By autumn dolphin sightings increased along the coast once again, and large groups of 10–50 individuals were seen in and around the Neuse and Bay Rivers. In the winter, the majority of dolphins were along the coast and just inside Pamlico Sound, with some small groups of 1-6 individuals found in the Neuse River and West Bay.

We were able to use the temperature sensor during only nine surveys due to inclement weather and equipment malfunctions. Since a valid statistical analysis would not be possible using these, we present only the results of SST data collected from images obtained from NOAA Polar Orbiting Environmental Satellites (NPOES). SST data collected from the temperature sensor will be provided to MCAS Cherry Point separately.

The minimum SST encountered along transects for all surveys was  $5.53^{\circ}$ C and the maximum was  $32.83^{\circ}$ C (Table 5). The minimum mean temperature for all transects was  $7.60^{\circ}$ C (SE= 0.10), and the maximum mean temperature was  $30.82^{\circ}$ C (SE= 0.21). SST values were not available for all days, due to heavy cloud cover. The range of mean temperatures at which turtles were sighted was  $9.68^{\circ}$ C to  $30.82^{\circ}$ C (Figure 5). The range of mean temperatures at which dolphins were sighted was  $7.60^{\circ}$ C to  $30.82^{\circ}$ C (Figure 6). We rejected our null hypothesis (p < 0.05) of independence of turtle sightings and SST; turtles were found more often in warmer water. We could not do so with dolphin sightings; sightings were distributed across all temperatures, albeit with a tendency towards fewer dolphins sighted as water temperatures increased.

#### **Seasonal Density**

The estimated mean surface density of turtles was highest along the coast in the summer of 2005 (0.615 turtles/km<sup>2</sup>, SE = 0.220) (Table 1). In Core and Pamlico Sounds the highest mean surface density occurred during the autumn of 2005 (0.016 turtles/km<sup>2</sup>, SE = 0.009). The mean seasonal abundance estimates were always highest in the coastal region, except in the winter when turtles were not sighted in either region. For Pamlico Sound, surface densities were always greater in the eastern than western section (Table 2).

The estimated mean surface density of dolphins was highest along the coast in the spring of 2006 (9.564 dolphins/km<sup>2</sup>, SE = 5.571) (Table 3). In Core and Pamlico Sounds the highest mean surface density occurred during the autumn of 2004 (0.192 dolphins/km<sup>2</sup>, SE = 0.066). The estimated mean surface density of dolphins was lowest along the coast in the summer of 2004 (0.461 dolphins/km<sup>2</sup>, SE = 0.294). The estimated mean surface density of dolphins was lowest in Core and Pamlico Sounds in the summer of 2005 (0.024 dolphins/km<sup>2</sup>, SE = 0.011). In Pamlico Sound, estimated surface densities were greater in the eastern section except in the autumn (Table 4).

#### **Observer Training**

The following MCAS Cherry Point personnel received training to conduct pre-exercise range sweeps and post-exercise impact surveys for protected species: Robin Ferguson (8 Aug. 2004, 9 July 2005), Bill Rogers (22 May 2005), Gary Haught (11 March 2006), Bobby Luna (27 Aug. 2004, 21 Nov. 2005), Will Gainey (10 July 2004), and Lissa Grimes (24 June 2005).

## Discussion

#### Seasonal Distribution and Sea Surface Temperature

While we observed more sea turtles in coastal than in estuarine waters, they were present in Core and Pamlico Sounds at all times of the year except for winter, similar to observations reported by Epperly *et al.* (1995b). The absence of turtle sightings during winter surveys

indicates their emigration from these waters as SST fell below their tolerance level. As poikilotherms, sea turtles distributions are generally limited by water temperature (Bell and Richardson, 1978). The majority of turtles we sighted were within water  $\geq 11^{\circ}$ C. This finding is similar to what Epperly *et al.* (1995c) observed during aerial surveys in North Carolina nearshore and offshore waters from Nov. 1991 – March 1992. Likewise, Coles and Musick (2000), who conducted aerial surveys off North Carolina from May 1991-September 1992, observed turtles only in water  $\geq 13.3^{\circ}$ C. Although we sighted one turtle when the mean SST was 9.68°C, it was observed in coastal waters where fine-scale water temperatures were likely greater than the mean SST.

Dolphins were observed within estuarine waters and along the coast year-round; however, there were some general seasonal movements. Most notable were during the summer when sightings decreased along the coast, and dolphins were distributed throughout Core and Pamlico Sounds, and in the winter when the majority of the dolphins were located along the coast and the southeastern Pamlico Sound. These observations coincide with the hypothesis (Hohn, unpublished data) that dolphins migrate from the estuary to the nearshore coastal areas that border Pamlico Sound, particularly south of Cape Hatteras during the coldest months, when water temperatures do not support prey populations of fish. Dolphins were sighted throughout the entire range of mean SST (7.60°C to 30.82°C), indicating that these temperatures are within their thermal limits.

#### **Seasonal Density**

Our density estimates for turtles in Core and Pamlico Sounds appear lower than those found in Epperly *et al.* (1995b). They estimated surface density of turtles per survey to range from 0-.305 turtles/km<sup>2</sup> in the Core Sound, and from 0-0.065 turtles/km<sup>2</sup> in the southern Pamlico Sound, with the greatest densities from late spring through the summer. Our surface density estimates per survey for the Core and Pamlico Sounds were calculated together and range from 0-0.054 turtles/km<sup>2</sup>. For comparison, the greatest number of turtles sighted in the Core and Pamlico Sounds occurred on 6 November 2005, with six turtles sighted in the Pamlico Sound (0.044 turtles/km<sup>2</sup>) and two sighted in Core Sound (0.171 turtles/km<sup>2</sup>). A statistical comparison between our results and those from Epperly *et al.* (1995b) is inappropriate to make because survey timeframe and the number of surveys conducted in the Core and Pamlico Sounds varied between studies. Also, they used clinometers to measure the distance of animals from the trackline, and although observers recorded their own sightings during the survey, they were not engaged in training other observers during the survey.

Boat surveys conducted by Read et al. (2003a) during July 2000 estimated the density of dolphins in Pamlico Sound (excluding BT-9 and BT-11) to be 0.24 dolphins/km<sup>2</sup>. They also estimated the density of BT-9 and BT-11 to be 0.11 dolphins/km<sup>2</sup>, and 1.23 dolphins/km<sup>2</sup> respectively, based on boat surveys conducted from July 2002 through June 2003 (excluding April, May, Sept. and Jan.) (Read *et al.*, 2003b). Gannon (2003) estimated the density of dolphins in Turnagain Bay to be 0.65 dolphins/km<sup>2</sup>, and 0.30 dolphins/km<sup>2</sup> for South River based on boat surveys conducted from 1998-1999. (Both Turnagain Bay and South River are within the Neuse River estuary). These density estimates are much greater than what we found in western Pamlico Sound, the only area with which we can make a comparison. For example,

our density estimates ranged from 0.027 dolphins/km<sup>2</sup> in the winter, to 0.215 dolphins/km<sup>2</sup> in the autumn. It is likely that these differences in density estimates are not an indication of a decrease in population density of dolphins, but might reflect a difference in survey methods. Both the Read *et al.* (2003a, b) and Gannon (2003) studies were boat-based surveys. Because aerial surveys are conducted at a greater speed than boat surveys, it is more likely an animal will be missed during the survey, resulting in an underestimating of density (Marsh and Sinclair, 1989). Therefore, the boat based density estimates of Read *et al.* (2003a, b) and Gannon (2003) may be more accurate than the uncorrected estimates derived from our aerial surveys. However, our surveys cover a broader area and allow for relative comparisons within that larger area. In addition, their surveys in small areas were not conducted during all months of the year. For these reasons, a direct comparison with their density estimates is not possible.

Our estimates of density may have been affected by a number of different factors. Since we did not measure the distance of turtles and dolphins from the transect line, it is possible that some animals outside the 0.15 km survey strip were included in our analysis. Epperly *et al.* (1995a) found that 13% of the turtles sighted were outside the 0.15 survey strip. Using this estimate, 14 of the 92 turtles sighted may have been outside our survey strip. Also, although the spacing of transects (4.5km apart) is sufficient when surveying for sea turtles, it is not ideal when surveying for bottlenose dolphins since they can reach a maximum known speed of 20.5 km/hr (Rohr *et al.*, 2002). However, given the size of our survey area, transects spaced farther apart would likely have compromised our ability to provide accurate estimates of density. Likewise, our use of the data recorder as an observer while training observers, and the high number of observers needing to be trained may have affected our ability to sight animals. There were no corrections for these factors in the density calculations.

Finally, our density estimates represent the number of turtles and dolphins on the surface of the water and do not account for animals that are below the surface, and thus, undetectable. An adult, female bottlenose dolphin that was radio tagged and monitored by satellite-based receivers spent an average of 87.1% (SE= 0.6) of the time submerged, with a mean dive duration of 25.8 (SE=0.5) seconds (Mate *et al.*, 1995). Therefore, given our flight speed of 166-175 km/hr, it is reasonable to assume that surveys did not account for all dolphins because some would have been submerged, and, thus, undetectable.

Using data collected by means of radio and acoustic telemetry from loggerhead turtles within the Chesapeake Bay, Byles (1988) estimated that turtles spend 5.3% of their time on the surface during the summer and fall months. Therefore, for every one turtle on the surface there are 18.9 turtles estimated to be below the surface. Recent work in Virginia by Mansfield (2006) suggests that the surfacing behavior of turtles varies with season. She found that the mean time turtles spent on the surface in the spring ranged from 9.9%-30.0%. Turtles with higher surfacing times were also tracked in deeper, cooler waters of the Bay mouth or Atlantic coastline. Nelson (1996) also observed seasonal variations in surfacing behavior among juvenile loggerheads tracked in Georgia, with turtles spending a greater percentage of their time (19.0%) at the surface in the spring compared to later in the season. Because the variability in sightability (surfacing behavior) of turtles depends upon season and geographic location, we did not incorporate their correction factor into our density estimates. Determining the surfacing behavior of turtles and

dolphins inhabiting North Carolina estuarine and coastal waters would provide more accurate density estimates.

# Conclusion

Based on the findings of this study, sea turtles are most likely to be encountered within the OPAREAs when SST is  $\geq 11^{\circ}$ C. Since sea turtles distributions are generally limited by water temperature, knowing the SST of a given area is a useful predictor of sea turtle presence. Since dolphins were observed within estuarine waters year-round and throughout the entire range of mean SST's, they likely could be encountered in the OPAREAs any time of the year. Although our findings indicated the greatest number of dolphins to be present in the autumn and the least in the winter, their movements also may be related to other factors such as the availability of prey.

# Acknowledgments

We would like to thank all of the aerial observers (Tanya Bean, Bud Daniels, Ron Clayton, Denene Blackwood, Lisa Goshe, Matthew Godfrey, Wendy Cluse, Robin Ferguson, Bill Rogers, Sue Huntsman, Carol Price, Jon Altman, Gary Haught, Craig TenBrink, Blake Price, Bobby Luna, Stacy Kubis, Will Gainey, Emma Jugovich, Julie Dyble, Lissa Grimes) and pilots (Jack Meagher, Curtis Hinkley, Gary Ambrose, Mark Honeycutt, Leland Gibbs, and Phil Platt) who made this project possible. Their patience when the weather wasn't cooperating, willingness to survey on short notice and holidays, and the enthusiasm and good humor they brought to each survey was much appreciated. Thanks also to Eric Griffith for statistic advice, Barbie Byrd for GIS tips, Wayne Hoggard for advice on using the temperature probe, and Larisa Avens and Larry Hansen for reviewing this report. Also, we would like to extend our gratitude to the air traffic controllers at Cherry Point for providing us with weather updates during flights, and for making sure we were aware of what was going on in the airspace at all times.

## References

- Bell, R. and J. Richardson. 1978. An analysis of tag recoveries from loggerhead sea turtles (*Caretta caretta*) nesting on Little Cumberland Island, Georgia. Florida Marine Research Publications 33: 20-24.
- Burnham, K. and D. Anderson. 1984. The need for distance data in transect counts. Journal of Wildlife Management 48: 1248-1254.
- Byles, R. A. 1988. The Behavior and Ecology of Sea Turtles in Virginia. Ph.D. Dissertation. Virginia Institute of Marine Science, College of William and Mary, Gloucester Point, Virginia. 112 p.
- Cochran, W. G. 1977. Sampling Techniques, 3<sup>rd</sup> ed. Wiley and Sons, New York, 428 p.
- Coles, C. C. and J. A. Musick. 2000. Satellite Sea Surface Temperature Analysis and Correlation with Sea Turtle Distribution off North Carolina. Copeia 2000: 551-554.
- Eberhardt, L. L., D. G. Chapman, and J. R. Gilbert. 1979. A review of marine mammal census methods. Wildlife Monographs 63: 1-46.
- Epperly, S. P., J. Braun, and A. Veishlow. 1995a. Sea turtles in North Carolina. Conservation Biology 9: 384-394.
- Epperly, S. P., J. Braun, and A. J. Chester. 1995b. Aerial surveys for sea turtles in inshore waters. Fishery Bulletin 93: 254-261.
- Epperly, S. P., J. Braun, A. J. Chester, F. A Cross, J. V. Merriner, and P. A. Tester. 1995c. Winter distribution of sea turtles in the vicinity of Cape Hatteras and their interactions with the summer flounder trawl fishery. Bulletin of Marine Science 56: 547-568.
- Gannon, D. 2003. Behavioral ecology of an acoustically mediated predator-prey system: Bottlenose dolphins and sciaenid fishes. Ph.D. Dissertation, Duke University, Durham, North Carolina. 244 p.
- Mansfield, K. L. 2006. Sources of mortality, movements and behavior of sea turtles in Virginia. Ph.D. Dissertation. Virginia Institute of Marine Science, College of William and Mary, Gloucester Point, Virginia, 367 p.
- Marsh, H. and D. F. Sinclair. 1989. Correcting for visibility bias in strip transect aerial surveys of aquatic fauna. Journal of Wildlife Management 53: 1017-1024.
- Mate, B. R., K. A. Rossbach, S. L. Nieukirk, R. S. Wells, A. B. Irvine, M. D. Scott, and A. J. Read. 1995. Satellite-monitored movements and dive behavior of a bottle-nosed-dolphin (*Tursiops truncates*) in Tampa Bay, Florida. Marine Mammal Science 11: 452-463.

- The Mathworks, Inc. 1994. The MathWorks MATLAB and Simulink for Technical Computing. <u>http://www.mathworks.com/</u>. Last accessed 8 December 2006.
- Nelson, D. A. 1996. Subadult loggerhead sea turtle (*Caretta caretta*) behavior in St. Mary's entrance channel, Georgia, USA. Ph.D. Dissertation, Virginia Institute of Marine Science, College of William and Mary, Gloucester Point, Virginia. 132 p.
- NOAA Satellite and Information Service. 1989. NOAA's Comprehensive Large Array-data Stewardship System. <u>http://www.class.noaa.gov/nsaa/products/welcome</u>. Last accessed 8 December 2006.
- NOAA Satellite and Information Service. 1989. NOAA Coastwatch Central Operations Homepage. <u>http://coastwatch.noaa.gov/cw\_index.html</u>. Last accessed 8 December 2006.
- Read, A., K. Urian, B. Wilson, and D. Waples. 2003a. Abundance of bottlenose dolphins in the bays, sounds, and estuaries of North Carolina. Marine Mammal Science 19: 59-73.
- Read, A., J. Maher, K. Urian, and D. Waples. 2003b. Monitoring bottlenose dolphin use of the Brant Island shoal bombing target (BT-9) and the Piney Island bombing range (BT-11). Final report to MCAS Cherry Point. Duke University Marine Laboratory, 135 Duke Marine Lab Road, Beaufort, North Carolina, 28516.
- Rohr, J. J., F. F. Fish, and J. W. Gilpatrick. 2002. Maximum swim speeds of captive and freeranging delphinids: Critical analysis of extraordinary performance. Marine Mammal Science 18: 1-19.

30.5 13.1 37.1 SЕ 6.2 6.8 9.9 Seasonal Abundance Estimate Mean 10 13 52 85 26 33 0 Estimated turtles 262 105 105 157 131 24 26 62 0 26 0 0 52 26 26 26 26 52 0 26 26 26 0 0 0 52 0 0 0 0 0 C 0 0 0 Coastal Region (138.5 km<sup>2</sup>) 0.0489 0.0445 0.0716 0.2199 0.2678 0.0947 SE Seasonal Density Estimate 0.1894 0.0726 0.3788 0.0947 0.6155 0.0000 Mean 0.0947 0.0000 0.0000 0.0000 1.1364 0.7576 (km² ) 0.5682 0.0000 0.9470 0.0000 Density 0.1736 1894 0000.0 0.0000 0.0000 0.0000 0.0000 0.0000 0.3788 1.8939 0.1894 0.1894 0.3788 1894 0.1894 0.000.0 0.3788 0.1894 0.000 0.000 0.189 83 000.0 000.0 000.0 0.000 0.00 00.0 S Transects surveyed (km<sup>2</sup> ) 5.76 5.76 5.76 5.28 5.76 5.28 5.28 5.28 5.28 5.28 5.28 5.28 5.28 5.28 5.76 5.28 Animals 9 0 0  $\circ$ e 0 0  $\neg$ 0 0 0 0 ဖ 0 0 4 4 ഹ 0 C 0 0 0 2 C 10.6 19.3 SЕ 10.1 5.6 7.3 3.8 Seasonal Abundance Estimate Mean 23 25 35 0 4  $\sim$ Estimated turtles 15 15 13 62 15 44 29 42 28 30 15 15 12 59 0 27 0 0 0 0 0 0 0 30 121 0 0 0 0 0 0 0 0 .38 km²) 0.0087 0.0017 0.0025 0.0048 0.0033 0.0032 SE Sounds (2,221 Mean Seasonal Density Estimate 0.0017 0.0033 0.0115 0.0157 0.0000 0.0103 0.0033 0.0000 0.0068 0.0060 0.0000 0.0000 0.0128 0.0264 0.0067 0.0543 0.0000 (km² ) 0.0000 0.0000 0.0000 0.0068 0.0000 0.0000 Density 0.0000 0.0131 0.0000 0.0068 0.0200 0.0000 0.0190 0.0133 0.0267 0.0068 0.0000 0.0000 0.0000 0.005 0000.0 0000.0 0.000 0.011 0.000 0.000 5 Transects surveyed (km² ) 167.6 179.6 180.4 147.5 150.8 149.6 145.3 145.4 146.7 150.3 168.2 158.3 152.3 152.3 151.8 157.8 156.7 154.0 147.9 147.5 151.7 149.9 146.9 149.5 147.4 147.0 50.2 147.0 146.4 147.3 148.9 167.4 152.2 147.3 146.4 147.4 174.4 153.1 149.7 154.7 153.1 Animals ß 0 0 0 0 0 0 0 0 0 ć 0 4 0 0 ω C 27 Aug 9 Jul 6 Aug 4 Sep 3 Oct 10 Oct 30 Oct 29 Oct 6 Nov 11 Nov 6 Mar 14 May 6 Nov 20 Nov Dec 31 Mar 23 Apr 10 Jul 25 Jul 8 Aug 19 Aug 24 Oct 20 Nov 13 Feb 22 May 30 May 4 Jun Jun 21 Aug Sep 9 Oct 27 Nov 23 Dec 16 Apr 11 Jun 24 Jun 21 Jan Jan 25 Feb 3 Jul Mar Day 18, 28 Season Spring Summer Autumn Spring Summer Autumn Winter Winter Year 2004 2005 2006

Table 1. Survey effort and strip-transect estimates of seasonal density by year for turtles on the surface of the Core and Pamlico Sounds, and the coastal region of North Carolina, 2004-06.

|                   |         | Western Pamlico              | Sound (1,108 kr | m²)                  |         | Eastern Pamlico              | Sound (893 km <sup>2</sup> | 5)                   |
|-------------------|---------|------------------------------|-----------------|----------------------|---------|------------------------------|----------------------------|----------------------|
| Season            | Animals | Transects<br>surveyed (km² ) | Density (km²)   | Estimated<br>turtles | Animals | Transects<br>surveyed (km² ) | Density (km²)              | Estimated<br>turtles |
| Spring<br>2005-06 | 1       | 538.9                        | 0.0018          | 2                    | 2       | 449.2                        | 0.0045                     | 4                    |
| Summer<br>2004-05 | 6       | 808.4                        | 0.0111          | 12                   | 12      | 673.8                        | 0.0178                     | 16                   |
| Autumn<br>2004-05 | 1       | 875.7                        | 0.0011          | L                    | 14      | 730                          | 0.0192                     | 17                   |
| Winter<br>2005-06 | 0       | 404.2                        | 0               | 0                    | 0       | 336.9                        | 0                          | 0                    |

Table 3. Survey effort and strip-transect estimates of seasonal density by year for dolphins on the surface of the Core and Pamlico Sounds, and the coastal region of North Carolina, 2004-06.

|            | SE  | 40.8   | 276.8  |         | 131.7                                | 222.0   | 113.5  | 524.9   | 771.7   |
|------------|---|--|--|---------|--------------------------------------|---|--|---|---|
|            | Mean<br>Seasonal<br>Abundance<br>Estimate   | 64   | 623<br>511   |         | 446                                  | 485   | 1243   | 1325  |   |
| (m2)       | Estimated dolphins  | 216<br>24<br>0<br>79<br>0                      | 26<br>52<br>52<br>52<br>52<br>52<br>133<br>133<br>341<br>2230  | 2754    | 890<br>393<br>472<br>289             | 52<br>656<br>52<br>289<br>0<br>131<br>131<br>1889<br>498  | 603<br>0<br>603<br>813<br>525<br>367                     | 1128<br>3253<br>210<br>708<br>918               | 1207<br>3541<br>367<br>184                      |
| n (138 E I | B<br>B<br>B<br>B<br>B<br>B<br>B<br>B<br>B<br>B<br>B<br>B<br>B<br>B<br>B<br>B<br>B<br>B<br>B | 0.2943   | 1.9988   |         | 0.9510                               | 1.6031  | 0.8194   | 3.7901  | 5.5716  |
| tal Radio  | Mean<br>Seasonal<br>Density<br>Estimate   | 0.4609   | 4.4981   |         | 3.6892                               | 3.2197  | 3.5038   | 8.9773  | 9.5644  |
| Sec J      | Density<br>(km² )   | 1.5625<br>0.1736<br>0.0000<br>0.5682<br>0.0000 | 0.1894<br>0.1894<br>0.3788<br>0.3788<br>0.3788<br>2.0833<br>4.7348<br>9.6591<br>9.6591<br>2.4621<br>16.0985  | 19.8864 | 6.4236<br>2.8409<br>3.4091<br>2.0833 | 0.3788<br>4.7348<br>0.3788<br>2.0833<br>2.0833<br>0.0000<br>0.9470<br>13.6364<br>13.5985        | 4.3561<br>0.0000<br>4.3561<br>5.8712<br>3.7879<br>2.6515 | 8.1439<br>23.4848<br>1.5152<br>5.1136<br>6.6288 | 8.7121<br>8.7121<br>25.5682<br>2.6515<br>1.3258 |
|            | Transects<br>surveyed<br>(km² )   | 5.76<br>5.76<br>5.76<br>5.28<br>5.76           | 5.28<br>5.28<br>5.28<br>5.28<br>5.28<br>5.28<br>5.28   | 5.28    | 5.76<br>5.28<br>5.28<br>5.28         | 5.28<br>5.28<br>5.28<br>5.28<br>5.28<br>5.28<br>5.28  | 5.28<br>5.28<br>5.28<br>5.28<br>5.28                     | 5.28<br>5.28<br>5.28<br>5.28                    | 5.28<br>5.28<br>5.28<br>5.28                    |
|            | Animals   | <u>0 - 0 00</u>                                | 85<br>13<br>13<br>13<br>25<br>11<br>22<br>11<br>22<br>11<br>22<br>25<br>11<br>22<br>25<br>11<br>22<br>25<br>11<br>22<br>22<br>21<br>22<br>22<br>22<br>22<br>22<br>22<br>22<br>22<br>22 | 105     | 37<br>15<br>18<br>11                 | 25<br>25<br>11<br>11<br>19<br>19  | 23<br>23<br>31<br>20<br>14                               | 43<br>124<br>8<br>27<br>35                      | 46<br>135<br>14<br>7                            |
|            | SE  | 33.6   | 147.3  |         | 27.8                                 | 24.8  | 32.6   | 111.8   | 113.6   |
| (m²)       | Mean<br>Seasonal<br>Abundance<br>Estimate   | 139  | 426  |         | 71                                   | 54  | 100  | 211   | 323   |
|            | Estimated dolphins  | 80<br>148<br>153<br>252<br>62                  | 200<br>324<br>914<br>153<br>443<br>167<br>1197   | 263     | 92<br>0<br>58<br>131                 | 59<br>211<br>87<br>87<br>0<br>30<br>15<br>30  | 45<br>0<br>119<br>166<br>60<br>212                       | 503<br>464<br>60<br>0<br>0                      | 20<br>181<br>364<br>121<br>626                  |
| 01 38 h    | S<br>S<br>S   | 0.0151   | 0.0663   |         | 0.0125                               | 0.0111  | 0.0147   | 0.0503  | 0.0512  |
| 0 () opu   | Mean<br>Mean<br>Seasonal<br>Density<br>Estimate   | 0.0625   | 0.1917   |         | 0.0317                               | 0.0242  | 0.0451   | 0.0951  | 0.1454  |
| Sour       | Density<br>(km² )   | 0.0358<br>0.0668<br>0.0688<br>0.1135<br>0.0277 | 0.0000<br>0.1459<br>0.0936<br>0.0936<br>0.0688<br>0.0688<br>0.0688<br>0.0688<br>0.0750<br>0.5389   | 0.1183  | 0.0416<br>0.0000<br>0.0263<br>0.0591 | 0.0263<br>0.0951<br>0.0000<br>0.0000<br>0.0136<br>0.0136<br>0.0133                              | 0.0200<br>0.0000<br>0.0535<br>0.0746<br>0.072<br>0.0953  | 0.2264<br>0.2090<br>0.0272<br>0.0000            | 0.0814<br>0.1639<br>0.0543<br>0.2820            |
|            | Transects<br>surveyed<br>(km² )   | 167.6<br>179.6<br>174.4<br>167.4               | 147.5<br>147.5<br>150.8<br>149.6<br>145.4<br>145.4<br>146.7<br>146.7<br>150.3  | 152.2   | 168.2<br>158.3<br>152.3<br>152.3     | 151.8<br>157.8<br>156.7<br>156.7<br>156.7<br>156.7<br>147.9<br>147.5<br>151.7<br>151.7<br>149.9 | 149.7<br>146.9<br>149.5<br>149.5<br>147.4<br>147.3       | 150.2<br>153.1<br>147.0<br>146.4<br>154.7       | 147.4<br>146.4<br>146.3<br>147.3                |
|            | Animals   | 6<br>12<br>19<br>5                             | 81 1 2 3 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0   | 18      | 7<br>0<br>9                          | 2 1 2 0 6 0 1 4   | 0 0 1 4 1 8 0 0 3 4 4 1 4 4 1 4 4 1 4 4 1 4 1 4 1 4 1 4  | 34<br>32<br>0<br>4                              | 12<br>24<br>8<br>8<br>42                        |
|            | Day   | 10 Jul<br>25 Jul<br>8 Aug<br>19 Aug<br>27 Aug  | 21 Nov<br>24 Sep<br>3 Oct<br>10 Oct<br>24 Oct<br>29 Oct<br>6 Nov<br>20 Nov   | 13 Feb  | 6 Mar<br>14 May<br>22 May<br>30 May  | 4 Jun<br>11 Jun<br>24 Jun<br>3 Jul<br>9 Jul<br>6 Aug<br>21 Aug                                  | 2 Sep<br>9 Oct<br>30 Oct<br>6 Nov<br>20 Nov<br>27 Nov    | 10 Dec<br>23 Dec<br>21 Jan<br>28 Jan<br>25 Feb  | 23 Apr<br>23 Apr<br>23 Apr                      |
|            | Season  | Season Summer Autumn Autumn                    |  | Winter  | Spring                               | Summer  | Autumn   | Winter  | Spring  |
|            | Year  | Year S   2004 Si                               |  |         | · · · · · ·                          | 2005  | ·  |   | 2006  |

| North          |          |
|----------------|----------|
| sounds,        |          |
| amlico S       |          |
| ern Pa         |          |
| d East         |          |
| ern an         |          |
| Weste          |          |
| of the         |          |
| urface         |          |
| the si         |          |
| ins or         |          |
| r dolpł        |          |
| son fo         |          |
| by sea         |          |
| ensity         |          |
| s of d         |          |
| stimate        |          |
| sect es        | <u>.</u> |
| ip-tran:       | 04-200   |
| 4. Stri        | าล, 20(  |
| Table <i>i</i> | Carolir  |

|                   |         | Western Pamlico              | ) Sound (1,108 kr | m²)                   |         | Eastern Pamlico              | ) Sound (893 km <sup>2</sup> | 2)                    |
|-------------------|---------|------------------------------|-------------------|-----------------------|---------|------------------------------|------------------------------|-----------------------|
| Season            | Animals | Transects<br>surveyed (km² ) | Density (km²)     | Estimated<br>dolphins | Animals | Transects<br>surveyed (km² ) | Density (km²)                | Estimated<br>dolphins |
| Spring<br>2005-06 | 51      | 538.94                       | 0.0946            | 105                   | 51      | 449.25                       | 0.1135                       | 101                   |
| Summer<br>2004-05 | 30      | 808.41                       | 0.0371            | 41                    | 31      | 673.89                       | 0.0460                       | 41                    |
| Autumn<br>2004-05 | 189     | 875.78                       | 0.2158            | 239                   | 37      | 730.05                       | 0.0506                       | 45                    |
| Winter<br>2005-06 | 11      | 404.2                        | 0.0272            | 30                    | 60      | 336.93                       | 0.1780                       | 159                   |

|        |          |          |          | Standard | Turtlo    | Dolphin   | Turtle     | Dolphin      |
|--------|----------|----------|----------|----------|-----------|-----------|------------|--------------|
| Data   | Minimum  | Maximum  | Mean     | Error of | Sightings | Sightings | Sightings  | Sightings in |
| Date   | SST (°C) | SST (°C) | SST (°C) | Mean SST | in Sounds | in Sounds | in coastal | coastal      |
|        |          |          |          | Mean 001 | in Sounds | in Sounds | region     | region       |
| 2004   |          |          | -        |          |           |           |            |              |
| 10 Jul | 28.64    | 32.2     | 29.83    | 0.14     | 1         | 6         | 0          | 9            |
| 25 Jul | 27.08    | 31.05    | 29.16    | 0.32     | 5         | 12        | 0          | 1            |
| 8 Aug  | 22.83    | 29.38    | 25.88    | 0.22     | 0         | 12        | 1          | 0            |
| 19 Aug | 25.98    | 29.55    | 27.43    | 0.16     | 2         | 19        | 1          | 3            |
| 27 Aug | 26.02    | 28.63    | 27.15    | 0.08     | 1         | 5         | 0          | 0            |
| 4 Sep  | 26.02    | 28.23    | 27.2     | 0.11     | 0         | 0         | 0          | 1            |
| 3 Oct  | 23.91    | 25.64    | 24.67    | 0.03     | 0         | 22        | 3          | 2            |
| 10 Oct | 21.77    | 24.43    | 22.95    | 0.09     | 0         | 14        | 0          | 2            |
| 24 Oct | NA       | NA       | NA       | NA       | 0         | 63        | 0          | 11           |
| 29 Oct | 15.92    | 18.15    | 16.94    | 0.06     | 0         | 10        | 1          | 25           |
| 6 Nov  | 17.32    | 19.74    | 18.31    | 0.06     | 0         | 29        | 0          | 51           |
| 11 Nov | 11.53    | 15.39    | 14.08    | 0.12     | 1         | 11        | 0          | 13           |
| 20 Nov | 12.36    | 13.38    | 12.69    | 0.09     | 3         | 81        | 0          | 85           |
| 2005   |          | -        |          |          | -         |           | -          | -            |
| 13 Feb | 6.36     | 8.99     | 7.86     | 0.13     | 0         | 18        | 0          | 105          |
| 6 Mar  | 6.87     | 9.46     | 7.97     | 0.14     | 0         | 7         | 0          | 37           |
| 14 May | 19.38    | 21.08    | 20.14    | 0.08     | 0         | 0         | 6          | 15           |
| 22 May | 17.66    | 18.18    | 17.88    | 0.03     | 0         | 4         | 0          | 18           |
| 30 May | NA       | NA       | NA       | NA       | 2         | 9         | 2          | 11           |
| 4 Jun  | NA       | NA       | NA       | NA       | 0         | 4         | 0          | 2            |
| 11 Jun | 24.42    | 25.75    | 25.18    | 0.11     | 3         | 15        | 10         | 25           |
| 18 Jun | 26.38    | 27.12    | 26.72    | 0.06     | 2         | 0         | 4          | 2            |
| 24 Jun | 23.74    | 27.09    | 25.33    | 0.13     | 0         | 6         | 4          | 11           |
| 3 Jul  | 25.09    | 27.83    | 27.09    | 0.05     | 1         | 0         | 1          | 0            |
| 9 Jul  | NA       | NA       | NA       | NA       | 2         | 2         | 1          | 5            |
| 6 Aug  | 29.07    | 32.83    | 30.82    | 0.21     | 4         | 1         | 5          | 72           |
| 21 Aug | 27.86    | 32.49    | 30.42    | 0.26     | 2         | 2         | 1          | 19           |
| 2 Sep  | 27.17    | 32.25    | 29.6     | 0.21     | 4         | 3         | 1          | 23           |
| 9 Oct  | 14.6     | 16.29    | 15.53    | 0.06     | 1         | 0         | 2          | 0            |
| 30 Oct | 24.35    | 24.85    | 24.57    | 0.07     | 1         | 8         | 0          | 23           |
| 6 Nov  | 16.98    | 19.31    | 17.87    | 0.06     | 8         | 11        | 1          | 31           |
| 20 Nov | NA       | NA       | NA       | NA       | 0         | 4         | 1          | 20           |
| 27 Nov | 8.71     | 10.4     | 9.68     | 0.10     | 0         | 14        | 1          | 14           |
| 10 Dec | 10.59    | 10.88    | 10.78    | 0.14     | 0         | 34        | 0          | 43           |
| 23 Dec | 5.53     | 8.49     | 7.6      | 0.10     | 0         | 32        | 0          | 124          |
| 2006   |          |          |          |          |           |           |            |              |
| 21 Jan | 8.96     | 9.66     | 9.37     | 0.04     | 0         | 4         | 0          | 8            |
| 28 Jan | 10.3     | 11.83    | 11.17    | 0.10     | 0         | 0         | 0          | 27           |
| 25 Feb | NA       | NA       | NA       | NA       | 0         | 2         | 0          | 35           |
| 11 Mar | 12.68    | 17.55    | 14.95    | 0.13     | 0         | 12        | 0          | 46           |
| 31 Mar | 14.03    | 19.34    | 15.07    | 0.12     | 0         | 24        | 0          | 135          |
| 16 Apr | 17.67    | 20.62    | 19.61    | 0.09     | 1         | 8         | 0          | 14           |
| 23 Apr | 19.72    | 22.66    | 21.72    | 0.09     | 0         | 42        | 2          | 7            |

Table 5. Minimum, maximum, and mean sea surface temperature (SST) along aerial survey transects, and sea turtles and dolphins sighted in the Core and Pamlico Sounds, and the coastal region of N.C., 2004-06.









Figure 3. Seasonal distribution of turtle sightings from aerial surveys of Core and Pamlico Sounds, and extending one mile offshore, 2004-06. (A). Spring (Mar-May); (B). Summer (June-Aug); (C). Autumn (Sept-Nov); (D). Winter (Dec-Feb). Note: Each symbol represents one animal. Survey effort was not equal amongst seasons, and therefore the number of sightings shown may reflect differences in effort, not actual abundance.



Figure 4. Seasonal distribution of dolphin sightings in aerial surveys of Core and Pamlico Sounds, and extending one mile offshore, 2004-06. (A). Spring (Mar-May); (B). Summer (June-Aug); (C). Autumn (Sept-Nov); (D). Winter (Dec-Feb). Note: Each symbol represents one animal. Survey effort was not equal amongst seasons, and therefore the number of sightings shown may reflect differences in effort, not actual abundance.

![](_page_26_Figure_0.jpeg)

Figure 5. Mean number of turtles sighted at each mean sea surface temperature (SST) during aerial surveys of the Core and Pamlico Sounds, NC, 2004-06. Mean SST is the mean SST during a survey.

![](_page_26_Figure_2.jpeg)

Figure 6. Mean number of dolphins sighted at each mean sea surface temperature (SST) during aerial surveys of the Core and Pamlico Sounds, NC, 2004-06. Mean SST is the mean SST during a survey.