SOURCES OF MORTALITY, MOVEMENTS AND BEHAVIOR OF SEA TURTLES IN VIRGINIA

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APPROVAL SHEET

This dissertation is submitted in partial fulfillment of

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DEDICATION

I dedicate my doctoral research and this dissertation to "Josephine" and the Jett and Burroughs families. These families provided the VIMS Sea Turtle Program with live-caught sea turtles over the course of three decades despite hurricanes, fisheries closures and prevailing politics. Data obtained from their turtles provided the foundation for a large portion of my research and have proven valuable to the conservation of sea turtles in Virginia. The humor, knowledge and kindness offered by these families gave me an invaluable education on the human side of fisheries management.

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ABSTRACT

Annual sea turtle strandings in Virginia have increased 200%-300% since 1979. Most of these strandings are juvenile loggerhead (*Caretta caretta*) and Kemp's ridley (*Lepidochelys kempii*) sea turtles. This increase may be partially due to a larger sea turtle population or changes in mortality over time.

Sea turtles utilize the Chesapeake Bay as benthic foraging habitat. Aerial surveys are commonly used to evaluate in-water turtle abundances. Bay turtles are directly visible only when at the sea surface. A correction is applied to account for turtles diving or foraging below the surface. Historic abundance estimates assumed that surfacing behavior remained constant among seasons; only summer/fall observations were used to correct for surfacing behavior. Using radio/acoustic telemetry, seasonal differences in sea turtle respiratory behavior were determined among Kemp's ridleys and loggerheads. Mean time spent at surface in the spring ranged between 9.9%-30.0% with significant differences among individuals and species. Turtles with higher surfacing times were tracked in deeper, cooler waters of the Bay mouth or Atlantic coastline. Observed surfacing times were higher than historic summer/fall observations (Byles 1988; 5.3%), indicating that historic springtime abundances were overestimated by 50%-80%. Aerial surveys conducted from 2001-2004 indicated a 65%-75% decline in the Chesapeake Bay sea turtle population since the 1980's. Current sea turtle estimates, corrected for seasonal surfacing behavior, and extrapolated for the entire Bay, range between 2,500 and 5,500 turtles compared to 6,500-9,000 turtles observed in the Lower Bay alone in the 1980's.

Satellite telemetry was used to track long-term movements of adult and juvenile turtles utilizing Virginia's waters. Loggerheads and Kemp's ridleys were found to exhibit significant fidelity to Bay and coastal waters south to Cape Hatteras. Several individuals established winter habitat south of Cape Hatteras, adjacent to the outer continental shelf and Gulf Stream. Fall migrations commenced when surface temperatures dropped below 20°C. Some turtles migrated south to Georgia, Florida and the Gulf of Mexico. Two turtles were transported by the Gulf Stream to the north Atlantic and the Grand Banks, indicating some plasticity in habitat use.

The Virginia pound net fishery was considered a primary source of sea turtle mortality in the 1980's. Fisheries surveys (2000-2002) indicated a significant reduction in fishery effort and the use of hazardous large mesh and string leaders. No subsurface bycatch mortalities were observed during side scan sonar surveys conducted from 2001-2002. Pound nets are no longer a significant source of sea turtle mortality in Virginia. Pound net recaptures of live turtles (1979-2002) indicated strong philopatry to specific foraging areas, including strong inter-annual site fidelity. Over 20% of individual loggerheads tagged were recaptured in study nets over one to eleven seasons. Two of 48 tagged Kemp's ridleys were recaptured. Satellite telemetry was used to track the movements of one adult loggerhead captured multiple times from 1999-2002. Home range analyses of these tracks indicated a concentrated seasonal home range near the study site, with a 73.9% overlap in the total range over a three-year period. Strong site fidelity and high recapture rates among loggerheads, suggest that loggerheads actively interact with pound nets.

SOURCES OF MORTALITY, MOVEMENTS AND BEHAVIOR OF SEA TURTLES IN VIRGINIA

CHAPTER 1

INTRODUCTION: VIRGINIA'S SEA TURTLES

INTRODUCTION

Sea turtles are long-lived, highly migratory marine/estuarine species. These animals utilize geographically diverse habitats during various ontogenetic stages. Musick and Limpus (1997) describe these stages as early pelagic/oceanic juvenile habitat, demersal juvenile developmental habitat, adult foraging habitat and adult inter-nesting or breeding habitat. The coastal and estuarine waters of Virginia play an important role in the life histories of several Atlantic populations of sea turtle. Five species of sea turtles are found within Virginia's waters, the vast majority of which are loggerheads (*Caretta caretta*), followed by Kemp's ridley (*Lepidochelys kempii*) sea turtles (Lutcavage 1981; Lutcavage and Musick 1985; Byles 1988; Coles 1999). Leatherback (*Dermochelys coriacae*), and green (*Chelonia mydas*) sea turtles are also found in Virginia's waters, but remain relatively rare. Only two hawksbill (*Eretmochelys imbricata*) sea turtles have been documented in Virginia since 1979.

Western Atlantic loggerhead nesting beaches range from Florida north to Virginia. Hatchlings emerge from these beaches, swim offshore, and connect with oceanic currents that entrain them within gyre and current systems of the Atlantic Ocean where they live pelagically for several years until they reach a size that is no longer sustained by available food: ~40.0 to 60.0 cm curved carapace length (CCL) (Musick and Limpus 1997; Turtle Expert Working Group [TEWG] 2000; Snover 2002). These larger juveniles recruit to tropical and temperate near shore and/or estuarine systems such as the Chesapeake Bay, Mediterranean Sea, and Atlantic coastal areas of the United States, feeding on benthic organisms (Musick and Limpus 1997; Hopkins-Murphy et al. 2003). Some of these turtles, particularly foragers within northern temperate waters, will migrate seasonally between summer foraging grounds such as the Chesapeake Bay, and southern waters south of Cape Hatteras, North Carolina to over-winter (Musick and Limpus 1997; Keinath 1993). Loggerhead sea turtles reach sexual maturity at approximately age 25 to 30 years, at approximately 92.0 cm straight carapace length (SCL) (Klinger 1988; Klinger and Musick 1995; Snover 2002; TEWG 2000). Once mature, turtles emigrate from their juvenile developmental habitat to adult foraging, breeding and nesting grounds. (Musick and Limpus 1997). Juvenile loggerheads feed primarily on blue crabs (*Calinectes sapidus*), horseshoe crabs (*Limulus polyphemus*), channel and knobbed whelk (*Busycon canaliculatum*; *Busycon caricas*) while resident in Virginia's waters (Seney 2002; Seney and Musick in press).

Kemp's ridleys follow a similar life-history strategy. Their primary developmental habitat is within the Gulf of Mexico, though they are found in waters as far north as Cape Cod, Massachusetts, including a small seasonal population in the Chesapeake Bay (Musick and Limpus 1997; Coles 1999; Schmid et al. 2003). Kemp's ridleys may reach sexual maturity as early as an estimated 8 to 12 years or as late as 15 to 20 years (Chaloupka and Zug 1997; Schmid and Witzell 1997; Snover 2002; Heppell at al. 2005). Size at maturity is estimated at approximately 60 cm SCL (TEWG 2000; Snover 2002; Heppell et al. 2005). Juvenile Kemp's ridleys feed on blue crabs and other small benthic crustaceans while resident in Virginia (Seney 2002; Seney and Musick 2005).

All species of sea turtles found within the United States and its territories are federally protected under the Endangered Species Act (ESA) of 1973. Threatened species are defined as those species likely to become endangered in the foreseeable future unless current population trends are reversed (National Research Council [NRC] 1990). Endangered species or subspecies are defined as those species in imminent danger of extinction throughout all or a significant portion of their range (NRC 1990). Federal laws state that no part or product of a sea turtle may be taken, imported, exported, transported, sold or possessed within the United States, its territories and seas. Sea turtle nesting beaches and foraging grounds are also protected; alterations to these critical habitats are either prohibited or restricted (ESA: 16.USC 1532 (s)(A)).

The Department of the Interior, with the authority of the ESA, authorizes the protection of both threatened and endangered species found within the United States and its territories. The US Fish and Wildlife Service (USFWS) has jurisdiction over terrestrial sea turtle habitat (nesting beaches), coastal strandings, and human activities that occur on land that may impact sea turtles. The National Marine Fisheries Service (NMFS) has jurisdiction over sea turtles while in a marine environment as well as in-water human activities that may impact these species, including bycatch mortalities or other human induced takes.

Loggerhead sea turtles are considered threatened throughout their range. Kemp's ridleys are the most endangered species of sea turtle, and among the most endangered species of animal worldwide (TEWG 2000). Leatherback and hawksbill sea turtles are also endangered, as are the sub-population of green turtles found within Atlantic waters along the southeastern United States and Gulf of Mexico. Virginia's in-water sea turtle habitat includes the entire mainstem Chesapeake Bay extending approximately five to ten miles up the Bay's tributaries (Musick et al. 1984; Byles 1988) and all coastal waters. Nesting beach habitat encompasses the Eastern Shore's ocean beaches and those along the Virginia Beach oceanfront south to the North Carolina border (Lutcavage and Musick 1985; Back Bay National Wildlife Refuge 1993; Cross et al. 2001).

The majority of Virginia's sea turtles are demersal juveniles. The Chesapeake Bay and coastal waters of Virginia play an unique role in the life history of Atlantic sea turtles; the Chesapeake Bay is identified as an important developmental habitat for both juvenile loggerhead and Kemp's ridley sea turtles in the Atlantic (Lutcavage 1981; Lutcavage and Musick 1985; Byles 1988; Musick and Limpus 1997; Coles 1999). These turtles seasonally utilize Virginia's coastal waters and the Chesapeake Bay as foraging habitat (Lutcavage and Musick 1985; Musick and Limpus 1997). Turtles are resident in Virginia waters from May through October or early November (Byles 1988; Keinath 1993; Coles 1999).

Each year, large numbers of sea turtle strandings are recorded in Virginia, the majority of which are juvenile loggerheads or Kemp's ridleys. A 'stranding' is defined by the National marine Fisheries Service Office of Protected Resources as a live, dead or weakened sea turtle found on a beach or floating in a marine environment (B. Schroeder, pers. comm.). Since the establishment of the Virginia Sea Turtle Stranding Network in 1979, annual state stranding numbers have increased 200% to 300% (Figure 1.1) (Musick and Mansfield 2004). This may be due to a number of factors, including but not limited to, increased turtle populations over time, changes in fishery effort and/or other human induced sources of sea turtle mortality, or increased effort in the collection of stranding data by state stranding network cooperatives.

In 2001, NMFS adopted an initiative addressing sea turtle bycatch mortalities or incidental takes in the Atlantic Ocean and Gulf of Mexico. The NMFS Protected

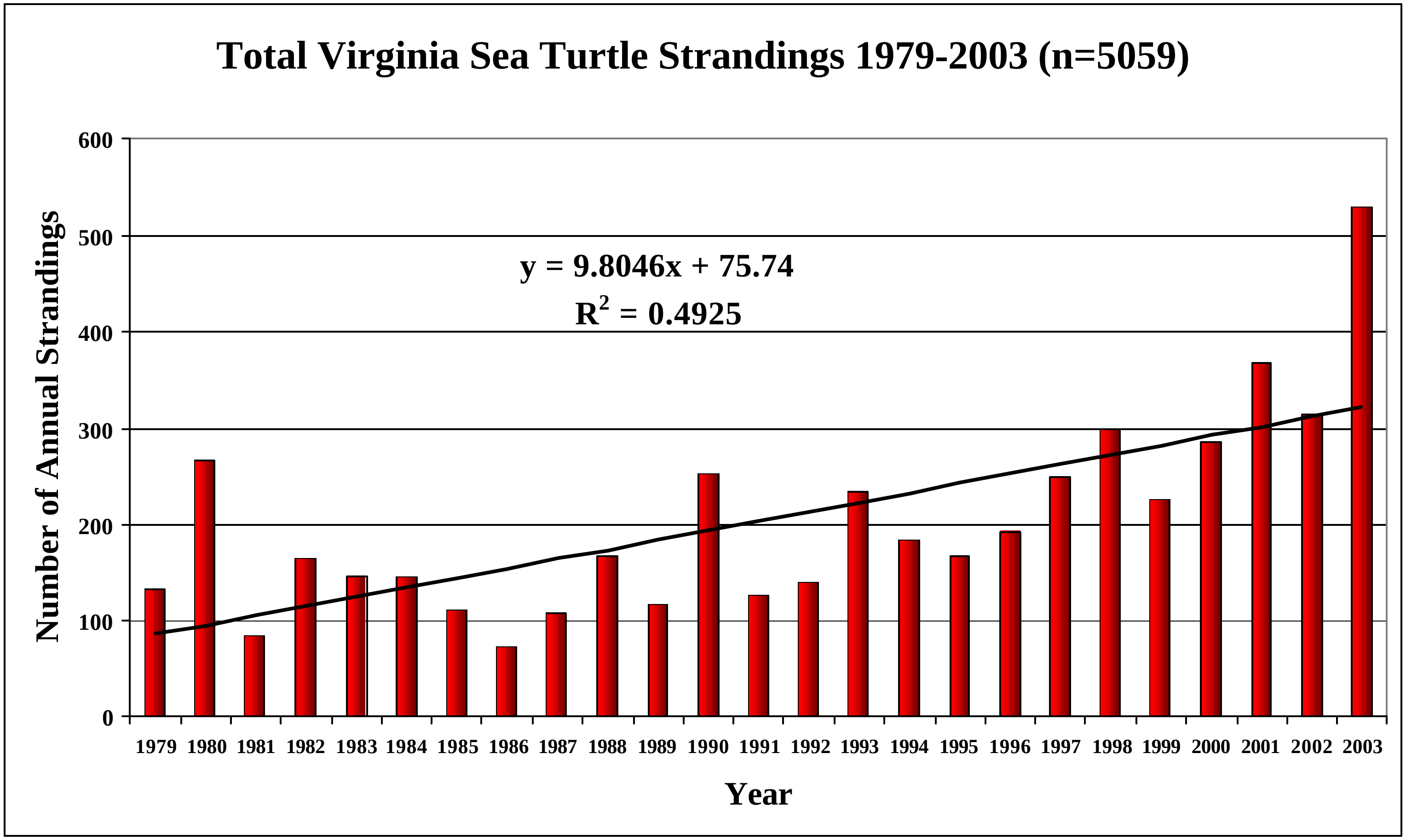


Figure 1.1 Annual sea turtle strandings, 1979-2003. Data courtesy of the Virginia Sea Turtle Stranding Network

Resources Division defines an incidental take as a live or dead sea turtle found in actively fished or operated gear (B. Schroeder, pers. comm.). This NMFS Strategy for Sea Turtle Conservation and Recovery in Relation to Atlantic Ocean and Gulf of Mexico Fisheries (2001) has several key elements, including characterizing federal and state fisheries within this region, taking a gear-based approach in evaluating the significance of bycatch mortalities within these fisheries, integrating oceanographic, environmental, fishery, and sea turtle data into federal regulations to reduce incidental takes per gear type.

This initiative has impacted Virginia fishermen over the past several years with NMFS implementing several regulations targeting Virginia fisheries, particularly the pound net fishery. The pound net fishery was identified in the mid-1980's as a significant source of sea turtle bycatch mortality in Virginia. However, pound net fishing effort has declined considerably over the past 20 years. Until recently, surveys to assess sea turtle bycatch in pound nets had not been conducted in over 15 years.

Another goal set forth by NMFS and the Turtle Expert Working Group (TEWG) in the recovery plan for Atlantic sea turtles is to identify the maximum number of individual turtles (per species) that may be taken incidentally by a fishery while still allowing for the recovery of the species (TEWG 2000). Under Section 7 of the ESA (1973), all federal agencies are directed to participate in the conservation of protected species. Agencies such as the Army Corps of Engineers (ACOE) must have a permit to take sea turtles while dredging channels within know sea turtle habitats, and must cease operations and/or take mitigating action if determined take limits are met. Section 10 of the ESA (1973) authorizes NMFS to issue permits allowing the incidental take of listed species during non-federal activities such as commercial fishing. To date, no take limits have been established for Virginia fisheries. In order to meet the goals set forth by NMFS and the TEWG, it is imperative that the status and condition of existing sea turtle stocks be fully understood, including population levels at each life history stage (TEWG 2000).

Population models for sea turtles in the Atlantic rely heavily on data collected from the reproductive output of adult females on nesting beaches. Significant data gaps exist in these models for the juvenile life stages of all species of sea turtles (TEWG 2000; Heppell et al. 2005). In the 1980's and early 1990's, data were collected by researchers at the Virginia Institute of Marine Science on juvenile mortality rates, sources of sea turtle mortality, population estimates, and sea turtle movements and behavior in Virginia's waters. A large data gap exists between the early 1990's and present. Aerial population surveys have not been conducted since the early 1990's and fisheries surveys of gear types identified as significant sources of sea turtle mortality have not been conducted since the late-1980's. Environmentally and/or seasonally driven sea turtle surfacing behaviors were identified as a potential source of error in determining population densities based on aerial observations in the 1980's, yet no work was conducted to determine seasonal differences in surfacing behavior (Byles 1988; Keinath 1993). If turtles spend more time at the surface during different seasons or temperature regimes, they are more likely to be counted by aerial censuses and therefore historic density estimates may over-estimate Virginia's sea turtle population.

This dissertation addresses these data gaps and the key management issues currently affecting sea turtles in Virginia, comparing recent data to those collected 15 to 25 years ago. This research examines historic and current sea turtle mortalities rates; identifies changes in sources of incidental takes over time; tests methods of assessing sub-surface mortalities; identifies biases in aerial census methods; updates historic and current sea turtle density estimates; and refines sea turtle movements, migration routes, and habitat utilization in the Chesapeake Bay and coastal waters of Virginia. Finally, this research is applied to the larger management issues in Virginia and the mid-Atlantic, providing recommendations based on available data, local sea turtle behavior and environmental influences.

CHAPTER 2

SEA TURTLE MOVEMENTS AND BEHAVIOR IN VIRGINIA

ABSTRACT

The primary objectives of this study were to determine whether there is a seasonal or geographic difference in sea turtle surfacing behavior in the Chesapeake Bay, and to examine the long-term foraging and migratory behavior of Virginia's sea turtles to determine whether these turtles exhibit fidelity to Virginia waters. Springtime surfacing behaviors of juvenile Kemp's ridleys (n=6) and loggerheads (n=7) were determined in the lower Bay during 2002-2004 using radio/sonic telemetry and compared to summer and fall surfacing behaviors estimated by Byles (1988) in the 1980's. Among daytime loggerhead observations, the mean percent time turtles spent at surface during the spring and early summer was 9.9% (+/- 2.9% SD; for every one turtle at the surface, there were ten below: 1:10) in 2002 (n=5 loggerheads), and 25.0% (+/-16.3% SD; 1:4) in 2003 (n=2). In 2004, only one loggerhead was tracked. This turtle spent 12.3% (1:7 to 1:8) of its total daytime track at the surface. Mean time spent at surface among all loggerheads ranged as high as 36.5%. Among Kemp's ridleys, mean time spent at surface during the spring and early summer was 45.7% in 2002 (n=1), 32.9% (+/- 23.1% SD; 1:3) in 2003 (n=2), and 30.0% (+/- 25.8% SD; 1:3) in 2004 (n=3), with mean time at surface ranging as high as 59.8%. There were significant differences among all individuals tracked (ANOVA, $p < 0.05$). The highest overall mean surfacing times were observed among the Kemp's ridleys (30.0% to 59.8%). Turtles with highest 2002-2004 surfacing times (both species) were tracked in deeper, cooler waters of Bay mouth and/or Atlantic coastline. Observed surfacing times among these turtles were higher than those estimated by Byles (5.3%; 1988) in the summer and fall.

Long-term movements and behavior of loggerheads (n=12) and Kemp's ridleys (n=4) were examined between 2001 and 2006 using satellite telemetry. With the exception of two animals, all turtles remained in Virginia's or North Carolina's waters during all or a significant portion of their track. Southern migratory movements for these turtles typically began when sea surface temperatures dropped below 20º C. Individual track locations were overlaid on bathymetric, sea surface temperature and geographic datasets. Among the Kemp's ridleys tracked, mean minimum travel speeds ranged between 1.6 km/hr (+/- 2.7 km/hr SD) and 3.0 km/hr (+/- 3.1 km/hr SD). On average, these turtles were found in depths ranging between 2.5 m (+/- 3.2 m SD) to 15.4 (+/- 14.0 m SD), with a maximum depth up to 109 m. Average distance from shore ranged from 0.4 km (+/- 0.6 km SD) to 15.4 km (+/- 20.4 km SD). AVHRR sea temperature data indicated that these turtles were found to remain within temperatures ranging between 15.8º C and 30.4º C. Mean travel speeds for loggerheads ranged between 2.3 km/hr (+/- 2.5 km/hr SD) and 4.2 km/hr (+/- 3.6 km/hr). Most turtles remained between the shoreline and outer continental shelf. These turtles were found within mean depths of 15.7 m (+/- 11.2 m SD) to 56.6 m (+/- 281.6 m SD), remaining, on average, between 11.7 km (+/- 12.6 km SD) to 337.1 (+/- 250.5 km SD) from the nearest shore. Three loggerhead turtles spent significant time farther from the continental shelf. Two juveniles entered the Gulf Stream near Cape Hatteras, following the current to the north Atlantic. One of these turtles remained in the north Atlantic gyre south of the Grand Banks for over two years. Both juveniles were found in water depths up to 4650.0 m (+/- 1400.5m). All turtles remained within mean surface water temperatures of 19.1º C to 26.2º C.

INTRODUCTION

As ectothermic reptiles, the distribution, biology and behavior of sea turtles are strongly linked to the thermal regimes of their environment (Spotila et al. 1997). Temperatures within any given environment can vary geographically, seasonally, or by depth. The body temperature of loggerhead sea turtles can only exceed ambient water temperatures by 1° or 2° C (Spotila and Standora 1985), and therefore must compensate for their inability to thermoregulate via other mechanisms. Behavioral methods of thermoregulation among reptiles include: habitat selection, temporal/seasonal changes in activity, "mudding in" or burrowing, aggregation and altering posture to conserve body heat (reviewed by Zug et al. 2001). Within Virginia's waters, sea turtles are not known to aggregate in the colder months, nor are they physically capable of altering their posture. Turtles have been observed to burrow into mud or silt in waters of the Carolinas and Georgia (Byles 1988); however, no such observations have been documented in Virginia (Byles 1988). Virginia's sea turtles are known, however, to perform migrations that are correlated to seasonal temperature fluctuations (Bellmund et al. 1987; Keinath et al. 1987; Byles 1988; Musick 1988; Keinath 1993; Coles 1999). Basking, either on land or at the sea surface, is another form of thermoregulation associated with sea turtles (Balazs and Ross 1974; Sapsford and van der Riet 1979; Sato et al. 1995; Nelson 1996). Keinath et al. (1995) and Nelson (1996) suggested that juvenile loggerheads (*Caretta caretta*) observed in Georgia and South Carolina may spend more time basking on the surface in spring months in response to colder (<19° C) water temperatures and highly stratified vertical temperature profiles.

Virginia's estuarine and coastal waters are subject to a large range in temperature over the course of four seasons. Temperatures in winter drop as low as 1 º C, while summer Bay temperatures may reach 30º C. Sea turtles are resident in Virginia waters between May and November (Lutcavage 1981, Musick et al. 1985), with a few strandings and sightings occurring as early as mid-April or as late as December. Analysis of sea surface temperatures during residency seasons indicate that turtles first migrate into Virginia's waters when sea temperatures warm to approximately 18º C (Lutcavage and Musick 1985; Bellmund et al. 1987; Keinath et al. 1987; Byles 1988; Musick 1988; Keinath 1993; Coles 1999). When sea surface temperatures drop in the fall, turtles begin their southern migration out of the Bay and coastal waters, over-wintering in waters ranging from North Carolina south to Georgia, Florida and the Gulf of Mexico (Keinath 1993; Mansfield et al. 2001). Prolonged exposure to temperatures lower than 8° to 10° C may result in cold stunning, or a disruption in the turtle's metabolic pathways, resulting in loss of buoyancy and inability to dive or swim (Schwartz 1976; Morreale et al. 1992; Spotila et al. 1997). Sea turtles are not physiologically capable of utilizing Virginia's waters as over-wintering habitat.

Work conducted by the Virginia Institute of Marine Science (VIMS) in the 1980's suggested that environmental temperatures affect sea turtles differently during the spring migration versus the fall migration. Byles (1988) concluded that yearly migrations into the Chesapeake Bay were strongly associated with vernal warming and that the greatest concentrations of sea turtles were found south of the 18° C isotherm (sea surface temperature). Byles suggested that the fall southerly migration started with the onset of winter storms, rather than declining sea temperature. Coles (1999; Coles and Musick

2000) analyzed aerial data for the North Carolina and Virginia coasts by plotting sea turtle locations against Advanced Very High Resolution Radiometer (AVHRR) satellite imagery of sea surface temperatures (SSTs). Loggerheads were found within temperatures ranging between 13.3º C and 28.0º C with most turtles found in sea surface temperatures below 29.0º C (Coles and Musick 2000). Satellite and radio telemetry studies from Florida to Virginia suggested that the spatial occurrence of loggerhead and Kemps ridley (*Lepidochelys kempii*) sea turtles is not randomly distributed, but may be limited or influenced by sea surface temperatures (Byles and Dodd 1989; Keinath 1993; Nelson 1996; Coles and Musick 2000).

Using radio telemetry, Byles (1988) determined that loggerhead sea turtles spent approximately 5.3% of their time at the surface while foraging in the Bay during summer months—or for every one turtle observed at the surface, there were approximately 18.9 turtles below the surface. No data were collected for respiratory behavior during the spring when turtles first migrate into the Bay. Surfacing behavior may vary with season, particularly early in the springtime when sea surface temperatures are cooler and the water column is more stratified (Keinath 1993; Nelson 1996). Nelson (1996) observed seasonal variations in surfacing behavior among juvenile loggerheads tracked in Georgia: turtles spent a greater percentage of their time (19.0%) at the surface in the spring compared to later in the season. Nelson attributed this difference to colder, more stratified water temperatures during the spring months. Seasonal migrations of sea turtles into Virginia waters in the spring may also influence turtle surfacing behavior. Loggerhead sea turtles have been documented to spend 6% to 20% of their time at the surface when migrating along the Atlantic coast (Keinath 1993). This increase in time spent at the surface may be due to the metabolic costs of migration: higher oxygen consumption due to increased swimming activity (Jackson and Prange 1979; Byles 1988; Lutz et al. 1989; Keinath 1993; Brill et al. 1995).

Aerial population surveys only record sea turtles visible at the surface of the water. To estimate population densities, a correction must be applied to turtle densities accounting for the percent time turtles spend below the surface. Historically, Byles's estimate of surfacing time (5.3%) has been used to estimate turtle densities throughout the residency period. If sea turtles spend more time at the surface in the spring versus the summer, then they are more likely to be observed and counted during aerial surveys, and historic aerial population estimates may have overestimated juvenile sea turtle abundances in the Chesapeake Bay. To improve estimates of regional abundance from surface densities, more data are needed on the amount of time turtles are visible on the sea surface throughout their residency in Virginia waters—particularly during the spring season. Determining whether sea turtles exhibit a difference in their inter-seasonal diving behaviors will help determine their vulnerability to different fishing/commercial gears, affecting incidental takes of turtles in near-shore fisheries.

The Chesapeake Bay is recognized as an important foraging habitat for benthic juvenile Kemp's ridleys and loggerheads (Lutcavage 1981; Lutcavage and Musick 1985; Byles 1988; Musick and Limpus 1997; Coles 1999). Significant data gaps exist in Atlantic sea turtle population models of the juvenile life stages for all species of sea turtles (TEWG 2000; Heppell et al. 2005). These data are needed to determine appropriate take limits for local fisheries and permitted federal activities that are known to take turtles as by-catch, such as maintaining shipping channels using hopper dredges.

In 2001, 2002, and 2003, dredging operations in the lower Chesapeake Bay exceeded or came close to exceeding their incidental take limits for loggerhead and Kemp's ridley sea turtles. This resulted in temporary and voluntary cessation of dredge operations. Allowable sea turtle take limits for Virginia's commercial fisheries have not yet been established. Under federal law it is assumed that no turtle takes are allowed, and local fisheries have been subjected to blanket closures as a result. The threat to Virginia's sea turtles can be minimized by gathering life history data on the sea turtles inhabiting Virginia's waters. Examining sea turtle residency periods and diving patterns will help determine their vulnerability to different fishing/commercial gears, aiding the development of management approaches that may reduce the number of incidental turtle takes in near-shore fisheries and dredging activities.

The primary objectives and hypotheses for this study were to:

1. Determine whether there is a seasonal or geographic difference in sea turtle surfacing behavior in the Chesapeake Bay;

   H_{01} There are no differences among surfacing times observed in the summer/fall in the western Chesapeake (Byles 1988; 5.3%) versus spring and early summer in the Bay mouth.

2. Examine the long-term foraging and migratory behavior of Virginia's sea turtles. Determine whether turtles captured in Virginia exhibit fidelity to Virginia waters;

H_{02} Foraging sea turtles exhibit random movements and distribution relative to their release sites.

METHODS

Turtles were obtained from cooperative pound net fishermen in the Potomac River and Mobjack Bay; the Virginia Sea Turtle Stranding and Salvage Network; and from local dredge/relocation trawler operators. All turtles were measured, weighed and flipper tagged using inconel and/or passive integrated transponder tags prior to release.

Radio/Acoustic Telemetry:

Turtles tracked in 2002 were outfitted with Lotek VHF radio (RMMT_3) and location-only acoustic (Lotek CAFT16_3) tags. In 2003 and 2004, turtles were tracked with Lotek radio (RMMT_3) and Vemco acoustic (V16TP-5H) transmitters. Two radio frequencies were used: 148.380 MHz and 149.800 MHz. Each radio tag had a three second pulse rate and was encoded with a unique number to identify individual turtles while tracking. Sonic frequencies ranged between 60.0 kHz and 85.0 kHz. Lotek acoustic tags had a frequency of 150.066 KHz with a three second pulse rate. These tags were also encoded with a unique number matching those of the radio tags. Vemco acoustic tags were un-coded and had a continuous pulse rate. These transmitters utilized a two-channel coding scheme that synchronized the tags' pulse with a 1150 millisecond interval, followed by data pulses, repeating this cycle continuously once deployed. The data pulses included real-time temperature (º Celsius) and pressure data that were converted to depth (meters).

Turtles' scutes were lightly sanded with 100 grit sandpaper and cleaned with acetone. Transmitters were placed on the turtles' carapace at the second to third vertebral scute. This location provided optimum transmission when the turtles surfaced to breathe. Quick setting Power-Fast™ marine epoxy resin with amine hardener was used to form an attachment base for each tag. Fibre Hair Body Filler™ or Sonic Weld™ was used as a secondary coat to buffer the tag and create a hydrodynamic surface for each attachment site. Acoustic (sonic) transmitters were placed along the ninth and tenth marginal scute, typically along the left side of the turtle, or just anterior of the post-marginal scutes. These transmitters were either placed in a bed of quick setting marine epoxy or attached to a plastic loop formed by a cable tie embedded in approximately two ounces of epoxy. The later method was used in 2003 and 2004 and tags were secured to the plastic loop via two to three cable ties.

Prior to tracking, a series of range tests were conducted to determine relative distances of tags from the tracking vessel based on received signal strength with the receiver set at graduated gain settings. All turtles were released in the Bay mouth just outside the Chesapeake Bay Bridge Tunnel (CBBT) within the Thimble Shoal or Chesapeake Channel, or just inside the CBBT if prevailing the winds and seas provided a more favorable tracking environment. Due to the large size of the adult female loggerhead, she was released from the VIMS beach in the York River. Two other turtles were released within the York Spit channel at the mouth due to either engine malfunctions with the tracking vessel or predicted foul weather. Turtles were tracked continuously for up to 24 hours post-release. Tracking time was heavily dependent upon weather and sea state. Temperature profiles of the water column were taken at the time of release for each turtle using an YSI 600XL Sonde with temperature and conductivity sensors. Additional temperature profiles were taken every one to four hours post-release.

A Lotek receiver (SRX 400) was used to monitor the respiratory behavior of the sea turtles through direct observation of radio signals onboard the tracking vessel. The first turtle was tracked with a polarized 150 MHz H antenna. Due to the limited range of this antenna, subsequent turtles were tracked with a three or four-element AN-3YG or AN-4YG Yagi antenna. Turtles were tracked approximately every other week from late-May or early-June through at least July. When turtles surfaced to breathe, the radio tags emitted a coded signal, based on time intervals of a three second pulse, to the receiver located onboard the tracking vessel (Pemberton 2000). Radio transmissions ceased when turtles were subsurface.

Turtles were tracked subsurface via acoustic signals emitted by the sonic tags, ensuring that the tracking vessel remain within the signaling range of the turtles' radio transmissions. Bearings and locations were recorded approximately every ten minutes. Turtle locations were estimated from GPS locations of the tracking vessel and the relative strength and direction of radio and sonic signals relative to the tracking vessel (Pemberton, 2000). In 2002, a Lotek directional hydrophone was used with the SRX 400 receiver, and acoustic frequencies were monitored in between surfacing events. Two VEMCO receivers (VR60) and hydrophones (directional VH10 and omni-directional VH65), were used to track and download real-time temperature and depth data from the sonic tags in 2003 and 2004. One receiver and the directional hydrophone were designated for tracking and bearings of the turtle in-water. The other receiver and omni-directional hydrophone were connected to an on-board laptop to provide a continuous stream of temperature and depth data from deployed tags. VEMCO V-SCAN software was used to receive, convert and archive temperature, depth, and time data.

Mean surface and dive times were calculated and daytime surface ratios were determined by dividing total surfacing time by total track time. The first two hours post-release were eliminated from these calculations to minimize the effects of handling and displacement (Byles 1988). Analyses of variance (ANOVA) were conducted for differences in surface and dive times among individuals (individual turtle tracks were treated as independent samples) with significance based on $p<0.05$. Due to annual variations in temperatures and upwelling events, each year was treated separately. In 2003 and 2004, real-time temperature and depth data obtained from acoustic tags were imported into SAS (Version 8e) to parse out temperature from depth data and to determine the frequency of time spent at different depths or within different temperature regimes per turtle. Day and night depth and temperature frequencies were determined for turtles tracked close to 24-hours.

All location data were imported into either ArcView 3.2 (Mercator projection) and plotted using a graduate color scheme to indicate movements occurring during ebb and flood tides. Significance of travel direction was determined using circular point statistics and the Raleigh's z statistic, with significant values based on $p <0.05$ (Zar 1999).

Satellite telemetry:

Telonics, Inc. ST-14, ST-6 and ST-18; Wildlife Computers SDR-T16; Sirtrack Kiwisat 101; and Microwave Telemetry high rate archival popup platform terminal transmitters (PTTs) were used to track the at-sea movements and long term movements of some radio-tracked turtles between 2001 and 2005. Sirtrack Kiwisat 101 PTTs and Microwave telemetry high rate archival popup tags were used to track the long term movements of turtles in 2005. Turtles receiving popup tags (n=4) were also tagged with a Sirtrack PTT. All tags weighed less than 1% of the turtles' body weight. With the exception of the popup tags, tag duty cycles were set to 12-hours on, 24 or 48-hours off and were attached using the methods described above for attaching radio transmitters. The popup tags had a deployment period of ten days prior to detachment. An initial duty cycle of 1-second on, ten days off was added to two of the Sirtrack tags (#10693 and #10401) to minimize any frequency interference between popup and Sirtrack PTTs. After the initial ten day period, these tags changed to the standardized 12-hours on, 24 or 48-hours off duty cycle. Popup tags were attached using the cable tie-tether method described above. These tags were programmed to collect real-time temperature and depth data for a maximum of ten days post-release. At the end of the ten day period, or when the tag's memory was full, the tags detached from the turtle, floated to the surface and transmitted data. A constant-depth release function was enabled for the first three tags deployed and disabled for the fourth due to pre-mature release associated with shallow foraging behaviors of the test turtles.

The Sirtrack tags had surface time counters that measured the amount of time per 24-hour period that a tag's salt water switch was dry. These sensor data provided a minimum estimate of percent time spent at the surface per any given 24-hour period. Percent time spent at depth was calculated using archival data sorted into 2-m interval binned datasets. Percent time spent at temperature intervals of 1° C was also calculated from archival data received from the popup tags.

Position and sensor data were transmitted to NOAA Tiros Satellites when the turtles surfaced to breathe. Locations were determined via Doppler shift. The shift in frequency in each signal received by the satellite determines the satellite's speed relative to the tag and the ratio of this speed to the satellite's ground speed results in a tag's relative bearing (Kenward, 2001). At least two such bearings are needed in order for tag position to be estimated. Position accuracy was determined by the number of bearings (or satellite passes) available per transmission. All position data were sorted based on accuracy codes received with each data transmission (0-3, A, B and Z; Appendix A). All data were transferred from the NOAA satellites to the ARGOS data processing system, which in turn sent the data in email format to a VIMS email account. Position data from the popup tags were not used due to inaccuracies associated with geoposition estimates derived from light intensity (Musyl et al. 2001).

Data from PTTs were archived and filtered using the Satellite Tracking and Analysis Tool (STAT) (Coyne and Godley 2005). Data were filtered based on accuracy of transmission (LC 0-3, A and B were selected; Appendix A), likely swim speed between locations (< 5 km hour), minimum turning angle (> 3°) combined with likely distance between points (<50 km), locations received in time intervals greater than or equal to one hour, and topography (< 0.5 m). Tracks were reconstructed in STAT and mapped in reference to bathymetry overlays and 50 m Bathymetric contours derived from the General Bathymetric Chart of the Oceans (GEBCO) using a one-minute spatial resolution or ETOP2 Global 2-Minute Elevations derived from a 2-minute grid (IOC, IHO and BODC 2003; Coyne and Godley 2005). Location data were quantified to determine the range in depth of the water column that the turtle traveled, mean distance from shore, speed over ground, and mean bearing of travel path. Location data were also overlaid on NOAA GOES SST or AVHRR datasets from the NOAA NESDIS archives. GOES datasets provide a six-kilometer spatial resolution of SST; and AVHRR derived datasets provide a resolution of approximately 5.6 km (Coyne and Godley 2005). Turtle location counts within different SST ranges were quantified to provide mean SST for each track.

Filtered location data were imported into ArcView 3.2 and tracks were reconstructed for spatial movement analyses (Mercator projection). Migratory routes were identified, and foraging habitats were determined using tests for Monte Carlo random walk simulations, a test for site fidelity comparing observed tracks with randomly generated walks (1000 replicates) using Spatial Analyst and Animal Movement extensions (Hooge and Eichenlaub 2001). Significance was based on $p<0.05$. Low r^2 values represent higher relative site fidelity (Hooge and Eichenlaub 1997).

When sample size permitted, home ranges for tracks exhibiting significant fidelity to a particular area were determined using a fixed kernel density model (Hooge and Eichenlaub 1997; 2001). Typically, animal movement data are autocorrelated; however, non-parametric kernel analyses do not assume independence of location data. Temporally sub-sampling track data to reduce the effects of autocorrelation may negatively bias the biological significance of the observed animal's movements (de Solla et al. 1999). For comparison among turtle tracks, a fixed ad hoc smoothing parameter (H) of 5.0 was used (projection units in km) (Silverman 1986). This value provided the best spatial fit of all track data within the constraints of aquatic sea turtle distribution. Kernel output contours were set at 95% and 50% confidence levels. The 95% contour is typically used to determine the area the animal actually inhabits or uses, and the 50% contour is used to determine the "core area of activity" (Hooge and Eichenlaub 2001).

Minimum sample size of location data required to estimate concentrated home ranges (50% kernel contour) was determined for each track using cumulative home range analysis. Cumulative home ranges were calculated using kernel densities estimated at daily intervals (day one, days one and two combined, days one, two and three, etc.) (McGrath 2005). These estimates were plotted over time to determine the asymptotic point at which the actual home range was achieved. A minimum two-week sample period was necessary to obtain the concentrated home range per individual. Site fidelity and kernel analyses were only conducted for the time turtles were observed as resident within Virginia or neighboring waters, excluding directed migratory movements. Timing of turtle movements south of Virginia's waters, direction of travel, and significance of travel direction were determined using circular point statistics and Raleigh's z statistic with significant values based on $p < 0.05$ (Zar 1999).

RESULTS

Radio and Acoustic Tracking:

From 2001 to 2005, 27 individual turtles were tracked via radio/acoustic and/or satellite telemetry. This included eight individual Kemp's ridleys and 19 loggerheads. Five of these turtles received both radio/acoustic and satellite tags. A total of 20 satellite tags and 16 radio/acoustic tags were deployed. With the exception of one adult female and one adult male loggerhead, all turtles were considered juvenile based on size. In 2002, six loggerheads (including one adult female) and one Kemp's ridley were radio-tracked between May 23 and July 17, 2002. In 2003, four Kemp's ridleys and two loggerheads were radio-tracked between June 18 and August 15, 2003. Three Kemp's ridleys and one loggerhead were radio-tracked from June 3 to July 22, 2004 (Table 2.1). Satellite tags were deployed on one loggerhead in 2001, one Kemp's ridley in 2002, Kemp's ridleys and four loggerheads in 2003, and two loggerheads in 2004. In 2005, five loggerheads were tracked, four of which received both regular and popup satellite tags. One loggerhead tracked in 2005 was an adult male. Four Kemp's ridleys and one loggerhead received both satellite and radio/acoustic tags (Table 2.1).

Mean straight carapace length (SCL; notch to notch) for all juvenile loggerhead turtles (n=17) was 63.2 cm (+/- 6.7 SD), ranging between 49.8 cm and 73.1 cm. Kemp's ridley SCL measurements ranged between 42.2 cm and 54.5 cm; mean SCL for all Kemp's ridleys (n=8) was 48.4 cm (+/- 4.7 SD). The adult female loggerhead measured 91.6 cm SCL and the adult male loggerhead was 92.0 cm SCL (Table 2.1).

2003 was an unusual sea turtle season: Virginia experienced a very late, cold spring and sea turtles did not enter Virginia's waters in significant numbers until mid-to late June. Peak sea turtle densities recorded by aerial surveys and peak state strandings did not occur until the second and third week in June, well over three weeks later than average. A coastal upwelling event was also recorded off of Virginia's coastline, resulting in vertically stratified water temperatures ranging between 23° and 25° C at the surface, and as low as 9° C on the bottom. These conditions provided a unique

Table 2.1 Summary data for seven sea turtles tracked in the Chesapeake Bay, 2001 to 2005. CC= loggerhead, LK= Kemp's ridley. Hours= radio/acoustic telemetry only; days = satellite telemetry only. R= radio/acoustic track, S=satellite track, P=archival popup track.

Track ID	Species	Primary Tag #	SCL (cm)	Release Date	Release Location	Hours (or Days) Tracked	Track Type
01234	CC	XXF779	73.1	9/13/01	36.510N; -75.533W	(40)	S
198[1]	CC	XXF794	49.8	5/23/02	37.324N; -76.301W	12	R
199	CC	XXT521	57.0	5/28/02	37.020N; -76.112W	8.5	R
192[2]	LK	XXF767	54.5	6/4/02	36.983N; -76.063W	8 (40)	R/S
142	CC	XXT523	56.9	6/11/02	36.989N; -76.079W	12	R
165	CC	XXF775	62.8	6/17/02	37.006N; -76.080W	24.5	R
167	CC	XXF771	70.4	6/24/02	36.983N; -76.078W	18	R
211[3]	CC	SSB919	91.6	7/17/02	37.247N; -76.507W	24	R
10401	LK	XXN292	42.3	6/18/03	37.247N; -76.507W	(78)	S
197	LK	XXF723	42.2	6/16/03	37.133N; -75.943W	2	R
137[5]	CC	XXF731	63.2	7/15/03	36.984N; -76.073W	23 (927+)	R/S
205	CC	XXT517	72.7	7/17/03	36.985N; -76.071W	13 (15)	R/S
138[4]	LK	138	47.3	7/31/03	36.989N; -76.073W	24 (8)	R/S
168[4]	LK	168	48.4	8/14/03	36.983N; -76.069W	24 (338)	R/S
41335	CC	XXT526	65.0	10/22/03	36.672N; -75.913W	(36)	S
41336	CC	QQN709	66.5	10/22/03	36.672N; -75.913W	(15)	S
147	LK	SSV626	54.4	6/03/04	36.990N; -75.077W	24	R
195	LK	XXF738	48.1	6/29/04	37.108N; -76.079W	14	R
170	LK	XXF774	50.3	7/06/04	37.108N; -76.079W	4	R
141	CC	XXT538	68.2	7/21/04	36.983N; -76.071W	24	R
10378	CC	XXF706	53.2	6/10/04	37.241N; -76.504W	(371)	S
10692	CC	XXT542	64.0	11/16/04	35.183N; -75.783W	(458)	S
10693[5]	CC	XXT552	57.2	6/17/05	37.245N; -76.344W	(212+)	S/P
10401b	CC	XXT550	69.0	6/17/05	37.245N; -76.344W	(225)	S/P
11993	CC	XXT561	65.3	8/30/05	36.918N; -76.127W	(220)	S/P
11585[5]	CC	XXT558	60.9	8/30/05	36.918N; -76.127W	(247+)	S
10378b[3,5]	CC	XXT563	92.0	11/1/05	36.603N; -75.723W	(123+)	S/P

[1] Insufficient data due to small antenna

[2] Turtle not tracked continuously for entire eight hours due to weather/seas

[3] Turtles confirmed as mature adults

[4] These turtles received a Passive Integrated Transponder (PIT) flipper tag only

[5] Satellite tags still active as of 1/28/06

opportunity to observe sea turtle dive behavior within very different temperature regimes. Due to this unusually cold season and pronounced coastal upwelling event, each radio tracking season (2002, 2003 and 2004) was treated separately in determining mean surfacing times.

The loggerhead turtles radio-tracked during the spring and early summer months of 2002 exhibited a mean daytime surfacing time of 23 seconds (+/-0:00:09) and a mean daytime dive duration of 0:05:00 (+/-0:01:52). Mean daytime surfacing times for all turtles was 0:00:27 (+/- 0:00:04) and mean daytime dive duration was 0:05:01 (+/- 0:02:10). Mean nighttime surfacing time was 0:00:46 (+/-0:00:18 SD) and mean nighttime dive duration was 0:07:09 (+/-0:02:30) (Table 2.2), however overall nighttime sample size was small. There were significant differences in daytime surface times among individual juvenile sea turtles (ANOVA, $p<0.0001$) as well as significant differences in daytime dive times (ANOVA, $p<0.0001$). The mean ratio of surface to submergence time among the juvenile loggerheads was 9.9% (+/-3.0% SD). These ratios ranged from 7.1% to 12.7% (Table 2.3). The adult female turtle (#211) exhibited a mean surface to submergence ratio of 2.7% (Table 2.4). The only Kemp's ridley observed in 2002 was tracked inconsistently for an 8-hour period due to high seas and was observed to remain at the surface 45.7% of the time tracked (Table 2.4).

Excluding Turtle #197 which was only tracked successfully for two hours, the mean ratio of surface to submergence time among loggerheads in 2003 was 25.0% (+/- 16.3% SD) (Table 2.3) . These ratios ranged from 13.5% to 36.5% and were much higher than the ratios observed in 2002 (7.1% to 12.7%) (Table 2.3). The mean Kemp's ridley surfacing ratio was 32.9% (+/- 23.1% SD), and ranged between 16.5% and 49.2%

Table 2.2 Summary of day and night respiratory behavior (hh:mm:ss), 2002.

	Time	Mean Surface Time	SD-Surface	Mean Dive Time	SD-Dive	Range: Surf. Time	Range: Dive Time
199	**Day**	0:00:32	0:00:51	0:06:57	0:07:32	Min: 0:00:06 Max: 0:06:00	Min:0:00:14 Max: 0:40:23
192	**Day**	0:01:26	0:01:49	0:03:08	0:03:05	Min: 0:00:06 Max: 0:07:34	Min: 0:00:10 Max: 0:12:47
142	**Day**	0:00:23	0:00:23	0:03:01	0:02:41	Min: 0:00:06 Max: 0:02:15	Min: 0:00:14 Max: 0:16:33
165	**Day**	0:00:24	0:00:30	0:03:17	0:04:14	Min: 0:00:06 Max: 0:04:44	Min: 0:00:06 Max: 0:26:05
167	**Day**	0:00:29	0:00:39	0:06:50	0:08:27	Min: 0:00:06 Max: 0:03:12	Min: 0:00:06 Max: 0:39:31
211	**Day**	0:00:08	0:00:07	0:04:53	0:05:46	Min: 0:00:06 Max: 0:01:17	Min: 0:00:06 Max: 0:38:05
TOTAL-All Turtles		**0:00:34**	**0:00:27**	**0:04:41**	**0:01:50**		

Turtle #	Time	Mean Surface Time	SD-Surface	Mean Dive Time	SD-Dive	Range Surf. Time	Range Dive Time
199	**Night**	0:00:57	0:00:39	0:04:15	0:02:52	Min: 0:00:06 Max: 0:01:50	Min:0:00:15 Max: 0:08:00
192	**Night**	n/a	n/a	n/a	n/a	n/a	n/a
142	**Night**	0:00:53	0:00:35	0:04:30	0:02:33	Min: 0:00:06 Max: 0:02:28	Min: 0:00:8 Max: 0:11:55
165	**Night**	0:00:54	0:01:12	0:05:40	0:08:10	Min: 0:00:06 Max: 0:07:50	Min: 0:00:06 Max: 0:28:15
167	**Night**	0:00:56	0:00:55	0:08:33	0:07:40	Min: 0:00:06 Max: 0:05:23	Min: 0:00:06 Max: 0:29:39
211	**Night**	0:00:19	0:00:31	0:09:55	0:09:00	Min: 0:00:06 Max: 0:03:07	Min: 0:00:07 Max: 0:32:49
TOTAL-All Turtles		**0:00:46**	**0:00:18**	**0:07:09**	**0:02:30**		

Table 2.3 Summary of percent time spent at surface per turtle tracked, 2002-2004.

Track Year	Track ID	Species	% Time at Surface	Hours of Observation
2002	199	CC	7.7%	8.5
	192*	LK	45.7%	8
	142	CC	12.7%	12
	165	CC	12.2%	24.5
	167	CC	7.1%	18
	211	CC	2.7%	24
2003	197	LK	7.2%	2
	137	CC	36.5%	23
	205	CC	13.5%	13
	138	LK	16.5%	24
	168	LK	49.2%	24
2004	147	LK	13.7%	24
	195	LK	16.6%	14
	170	LK	59.8%	4
	141	CC	12.3%	24

*Turtle not tracked continuously

Table 2.4 Summary of day and night respiratory (hh:mm:ss) behavior from radio tracking data, 2003.

Track ID	Time	Mean Surface Time	SD-Surface	Mean Dive Time	SD-Dive	Range: Surf. Time	Range: Dive Time
197	**Day**	0:00:09	0:00:05	0:01:42	0:01:39	Min: 0:00:06 Max: 0:00:24	Min: 0:00:06 Max: 0:09:27
137	**Day**	0:00:46	0:04:02	0:05:42	0:08:47	Min: 0:00:06 Max:0:42:45	Min: 0:00:06 Max: 0:44:31
205	**Day**	0:00:28	0:00:29	0:03:57	0:04:06	Min: 0:00:06 Max:0:02:00	Min: 0:00:06 Max: 0:23:34
138	**Day**	0:00:54	0:00:52	0:03:44	0:03:23	Min: 0:00:06 Max: 0:04:41	Min: 0:00:08 Max: 0:15:23
168	**Day**	0:07:32	0:11:26	0:05:10	0:06:20	Min: 0:00:05 Max: 1:09:44	Min: 0:00:05 Max: 0:23:00
TOTAL- All Turtles		**0:01:58**	**0:03:08**	**0:04:03**	**0:01:33**		

Turtle #	Time	Mean Surface Time	SD-Surface	Mean Dive Time	SD-Dive	Range Surf. Time	Range Dive Time
197	**Night**	n/a	n/a	n/a	n/a	n/a	n/a
137	**Night**	0:13:50	0:38:41	0:05:31	0:04:56	Min: 0:00:06 Max: 2:40:45	Min: 0:00:06 Max: 0:16:28
205	**Night**	0:01:01	0:00:45	0:06:19	0:05:26	Min: 0:00:06 Max: 0:02:45	Min: 0:00:11 Max: 0:20:56
138	**Night**	0:01:14	0:00:55	0:08:37	0:04:08	Min: 0:00:07 Max: 0:06:22	Min: 0:01:40 Max: 0:23:29
168	**Night**	0:12:03	0:03:21	0:18:01	0:07:34	Min: 0:006:34 Max: 0:18:11	Min: 0:00:06 Max: 0:23:46
TOTAL- All Turtles		**0:04:46**	**0:06:19**	**0:10:59**	**0:06:12**		

(Table 2.3). All sea turtles tracked during 2003 exhibited a mean daytime surfacing time of 0:01:58 (+/- 0:03:08 SD) and a mean daytime dive duration of 0:04:03 (+/-0:01:33) (Table 2.4). Mean nighttime surfacing time was 0:04:46 (+/- 0:06:19 SD) and mean nighttime dive duration was 0:10:59 (+/-0:06:12) (Table 2.4). The 2003 mean surfacing times were approximately four to five times greater than the combined mean surfacing times observed in 2002 (day: 0:00:34 +/- 0:00:27; night: 0:00:43 +/- 0:00:21). Among individuals, there were significant differences in surfacing and dive times for both day and nighttime radio telemetry data (ANOVA; $p<0.0001$).

In 2004, mean daytime ratio of surface to submergence time among Kemp's ridleys was 30.03 % (+/-25.82% SD) (Table 2.3). These times ranged from 13.7% to 59.8% and were similar to those observed in 2003 (16.5% to 49.2%) (Table 2.3). The one loggerhead tracked in 2004 spent 12.3% of its time at the surface during the day. All turtles tracked during 2004 exhibited a mean daytime surfacing time of 0:01:33 (+/- 0:01:34 SD) and a mean daytime dive duration of 0:04:59 (+/-0:04:38 SD) (Table 2.5). Mean nighttime surfacing time for the turtles tracked at night was 0:11:19 (+/- 0:16:54 SD), and mean nighttime dive duration was 0:04:59 (+/-0:00:48) (Table 2.5). Among individuals, there were significant differences in surfacing and dive times for both day and nighttime tracks (ANOVA; $p<0.0001$).

Among all track years, most turtles exhibited significantly directed movement throughout their entire track ($p<0.05$). This movement was often observed to be influenced by tidal flow. Among all turtles tracked, there were significant differences in daytime surface times between rehabilitated turtles and wild-caught turtles (ANOVA,

Table 2.5 Summary of day and night respiratory behavior (hh:mm:ss) from radio tracking data, 2004 (Turtle #170 not tracked at night).

Track ID	Time	Mean Surface Time	SD-Surface	Mean Dive Time	SD-Dive	Range: Surf. Time	Range: Dive Time
147	**Day**	0:03:47	0:07:06	0:10:53	0:15:13	Min: 0:00:06 Max: 0:37:06	Min: 0:00:06 Max:1:08:13
170	**Day**	0:00:57	0:01:14	0:06:08	0:11:44	Min: 0:00:06 Max: 0:05:06	Min: 0:00:06 Max: 1:00:18
195	**Day**	0:01:19	0:01:37	0:02:45	0:02:17	Min: 0:00:06 Max:0:08:08	Min: 0:00:12 Max: 0:10:59
141	**Day**	0:00:08	0:00:33	0:00:10	0:01:51	Min: 0:00:06 Max: 0:01:40	Min: 0:00:06 Max: 0:13:56
TOTAL-All Turtles		**0:01:33**	**0:01:34**	**0:04:59**	**0:04:38**		

Turtle #	Time	Mean Surface Time	SD-Surface	Mean Dive Time	SD-Dive	Range Surf. Time	Range: Dive Time
147	**Night**	0:30:48	0:28:00	0:05:10	0:01:07	Min: 0:00:06 Max: 1:19:56	Min: 0:04:18 Max: 0:07:43
195	**Night**	0:02:23	0:05:23	0:04:06	0:05:46	Min: 0:00:06 Max: 0:30:15	Min: 0:00:06 Max: 0:32:40
141	**Night**	0:00:45	0:01:07	0:05:41	0:07:34	Min: 0:00:06 Max: 0:05:11	Min: 0:00:09 Max: 0:28:10
TOTAL-All Turtles		**0:11:19**	**0:16:54**	**0:04:59**	**0:00:48**		

p<0.0001), however, no differences were found in the dive times among rehabilitated turtles and wild-caught turtles (ANOVA, p>0.05).

Satellite Track Data:

One juvenile loggerhead was tracked via satellite telemetry in 2001, and one Kemp's ridley received a satellite tag in addition to radio/sonic tags in 2002. Seven satellite tags were deployed in 2003, three on juvenile Kemp's ridleys and four on juvenile loggerheads. Two of the loggerheads and both Kemp's ridleys were also radio-tracked. Two juvenile loggerheads received satellite tags in 2004, and five loggerheads, including one adult male, were satellite-tracked in 2005 (Table 2.1). Four satellite tags were still transmitting as of January 31, 2006. One of these tags has been transmitting since the middle of July, 2003. The remaining four active tags were deployed in 2005 (Tables 2.1 and 2.6). The majority (53.5%) of ARGOS location classes received from deployed tags were classes A (18.8%) or B (34.7%) (Table 2.6). Track duration ranged from eight days post-deployment, to more than 930 days (Tables 2.1 and 2.6).

Among the Kemp's ridleys tracked, mean minimum travel speeds ranged between 1.6 km/hr (+/- 2.7 km/hr SD) and 3.0 km/hr (+/- 3.1 km/hr SD). On average, these turtles were found in depths ranging between 2.5 m (+/- 3.2 m SD) to 15.4 (+/- 14.0 m SD), with a maximum depth up to 109 m. Average distance from shore ranged from 0.4 km (+/- 0.6 km SD) to 15.4 km (+/- 20.4 km SD) (Table 2.7). All but one of these turtles remained in the Chesapeake Bay for the duration of their track. Two of these turtles exhibited fidelity to their foraging sites in either the upper York River, or the Mobjack Bay and near Smith Island. The York River turtle was tracked during a seasonal drought that resulted in

Table 2.6 ARGOS location code distribution from satellite track data, 2001-2005

Track ID	Release Date	Track Duration (days)	ARGOS Location Code 3	2	1	0	A	B
01234	9/13/2001	40	0	0	0	8	9	6
192	6/4/2002	40	1	3	4	12	38	134
10401	6/18/2003	78	1	3	3	2	33	101
137	7/15/2003	927+	26	82	193	171	154	250
205	7/17/2003	15	0	1	4	3	5	5
138*	7/31/2003	8	1	1	1	2	3	3
168*	8/14/2003	338	2	7	22	26	54	86
41335	10/22/2003	36	0	1	3	1	5	4
41336	10/22/2003	15	0	2	12	11	15	19
10378	6/10/2004	371	22	26	21	16	30	32
10692	11/16/2004	458	58	136	116	58	43	49
10693	6/17/2005	212+	0	2	18	14	24	94
10401b	6/17/2005	225	1	2	17	26	44	61
11993	8/30/2005	220	9	13	16	6	24	38
11585	8/30/2005	247+	2	3	5	5	12	30
10378b**	11/1/2005	123+	18	17	16	12	18	32
Total			**141**	**299**	**451**	**373**	**511**	**944**

*Flipper tags not applied; PIT tags only

**Turtle confirmed as mature adult (male)

Table 2.7 Summary statistics derived in STAT (Coyne and Godley 2005) from satellite movement data, 2001 to 2005.

Track ID	Release Date	Mean Depth (m)	Depth Range (m)	Distance from Shore (m)	Distance Range (m)	Mean Speed (km/hr)	Speed Range (km/hr)	Mean Bearing (º)
01234	9/13/2001	28.4 (+/- 9.9 SD)	1.1 to 48.7	33.3 (+/- 37.4 SD)	0 to 183.0	3.6 (+/- 3.1 SD)	0 to 11.3	184 (+/- 96 SD)
192*	6/4/2002	6.3 (+/- 5.4 SD)	0 to 31.9	3.1 (+/- 3.2 SD)	0 to 13.0	3.0 (+/- 3.0 SD)	0 to 12.0	177 (+/- 103 SD)
10401*	6/15/2003	2.5 (+/- 3.2 SD)	0.2 to 11.6	0.4 (+/- 0.6 SD)	0 to 2.0	1.6 (+/- 2.7 SD)	0 to 9.9	108 (+/- 94 SD)
137	7/15/2003	3857.5 (+/- 1675.1 SD)	0 to 5461.9	461.6 (+/- 265.2 SD)	0 to 980.0	3.8 (+/- 3.8 SD)	0 to 14.0	155 (+/- 89 SD)
205	7/17/2003	56.5 (+/- 281.6 SD)	0 to 1880.4	7.7 (+/- 13.5SD)	0 to 90	2.9 (+/- 4.2 SD)	0 to 14.4	101 (+/- 91 SD)
138*	7/31/2003	6.3 (+/- 4.7 SD)	0 to 13.7	4.4 (+/- 3.2 SD)	0 to 11.0	1.6 (+/- 2.9 SD)	0 to 9.7	105 (+/- 117 SD)
168*	8/14/2003	15.4 (+/- 14.0 SD)	0 to 109.3	15.4 (+/- 20.4 SD)	0 to 170.0	2.3 (+/- 3.1 SD)	0 to 10.9	147 (+/- 85 SD)
41335	10/22/2003	19.1 (+/- 6.5 SD)	2.4 to 39.5	27.2 (+/- 30.8 SD)	0 to 185.0	4.2 (+/- 3.6 SD)	0.2 to 13.5	101 (+/- 110 SD)
41336	10/22/2003	25.3 (+/- 18.0 SD)	0 to 129.7	32.2 (+/- 20.0 SD)	0 to 72.0	3.1 (+/- 13.2 SD)	0 to 13.2	136 (+/- 98 SD)
10378	6/10/2004	26.9 (+/- 9.1 SD)	0.1 to 63.4	30.8 +/- (21.9 SD)	0 to 163.0	2.6 (+/- 2.8 SD)	0 to 10.8	145 (+/- 83 SD)
10692	11/16/2004	4650.0 (+/- 1400.5 SD)	5.0 to 5674.4	337.1 (+/- 250.5 SD)	1.0 to 939.0	3.0 (+/- 2.6 SD)	0 to 11.9	162 (+/- 94 SD)
10693	6/17/2005	19.1 (+/- 12.1 SD)	0.1 to 62.4	19.4 (+/- 38.4 SD)	0 to 293.0	3.7 (+/- 3.0 SD)	0 to 12.3	138 (+/- 86 SD)
10401b	6/17/2005	24.5 (+/- 13.6 SD)	0.1 to 71.0	25.0 (+/- 24.0 SD)	0 to 99.0	3.8 (+/- 2.9 SD)	0 to 11.4	143 (+/- 84 SD)
11993	8/30/2005	21.7 (+/- 19.5 SD)	0.7 to 97.3	13.9 (+/- 18.5 SD)	0 to 118	3.3 (+/- 3.1 SD)	0.04 to 11.5	144 (+/- 86 SD)
11585	8/30/2005	15.7 (+/- 11.2 SD)	0.1 to 31.1	11.7 (+/- 12.6 SD)	0 to 58.0	2.3 (+/1 2.5 SD)	0.06 to 9.7	161 (+/- 3.0 SD)
10378b**	11/1/2005	1139.0 (+/- 1561.9 SD)	0.12 to 4869.0	95.3 (+/- 122.8 SD)	0 to 572	3.2 (+/- 3.2 SD)	0 to 14.3	152 (+/- 84 SD)

* Kemp's ridley sea turtle

** Mature adult male loggerhead

higher than average salinities and blue crab (*Callinectes sapidus*) abundances in the upper York River. One Kemp's exhibited significantly directed movement south, traveling along the Atlantic coastline to southeast Florida before transmissions ceased along the coast of southeast Florida. AVHRR sea temperature data were only available for two of these tracks and these turtles were found to remain within temperatures ranging between 15.8º C and 30.4º C (Table 2.8).

Mean travel speeds for the loggerheads tracked by satellite ranged between 2.3 km/hr (+/- 2.5 km/hr SD) and 4.2 km/hr (+/- 3.6 km/hr). Tracks ranged within mean depths of 15.7 m (+/- 11.2 m SD) to 4650.0 m (+/- 1400.5 m SD), and turtles remained, on average, between 11.7 km (+/- 12.6 km SD) to 337.1 (+/- 250.5 km SD) from the nearest shore (Table 2.7). Five of these turtles spent time within the Chesapeake Bay post-release and six remained with Virginia waters south to Cape Hatteras. One turtle established post-release foraging habitat off of the Eastern Shore of Virginia and Maryland. Seven turtles established over-wintering habitat south of Cape Hatteras, between the North Carolina shoreline and the outer continental shelf and Gulf Stream. Two turtles over-wintering south of Cape Hatteras connected with the Gulf Stream, following it to the northern Mid-Atlantic where they remained for up to two years. Two turtles, one juvenile Kemp's ridley and an adult male loggerhead, were observed to travel along the Atlantic coast as far south as Georgia or Florida immediately post-release. The male loggerhead traveled as far as Georgia before entering the Gulf Stream and returning to waters offshore of Virginia. All turtles were found to remain within mean surface water temperatures ranging between 19.1º C and 26.2º C (Table 2.8). With the exception of the adult male loggerhead and one juvenile Kemp's ridley, most turtles remained in

Table 2.8 Mean SST and ranges derived in STAT (Coyne and Godley 2005) from satellite movement data, 2001 to 2005.

Track ID	Release Date	Mean Temperature (°C)	Temperature Range (°C)
01234	9/13/2001	n/a	n/a
192*	6/4/2002	n/a	n/a
10401*	6/15/2003	25.7 (+/- 1.0 SD)	24.2 to 27.6
137	7/15/2003	20.2 (+/- 3.5 SD)	6.9 to 28.5
205	7/17/2003	26.2 (+/- 0.1 SD)	25.9 to 25.7
138*	7/31/2003	25.8 (+/- 0.1 SD)	25.9 to 25.7
168*	8/14/2003	23.7 (+/- 3.4 SD)	15.8 to 30.4
41335	10/22/2003	19.7 (+/- 2.6 SD)	16.3 to 26.9
41336	10/22/2003	19.1 (+/- 2.6 SD)	16.3 to 26.9
10378	6/10/2004	19.5 (+/- 4.0 SD)	9.01 to 26.8
10692	11/16/2004	22.3 (+/- 3.8 SD)	13.1 to 29.0
10693	6/17/2005	22.3 (+/- 4.1 SD)	15.7 to 29.3
10401b	6/17/2005	23.0 (+/- 3.8 SD)	14.3 to 28.7
11993	8/30/2005	22.0 (+/- 3.0 SD)	15.6 to 27.2
11585	8/30/2005	22.7 (+/- 2.6 SD)	18.7 to 26.4
10378b**	11/1/2005	20.0 (+/- 2.9 SD)	14.5 to 25.0

* Kemp's ridley sea turtle
** Mature adult male loggerhead

Virginia or North Carolina's waters during all or a significant portion of their track. Among the turtles satellite tracked in 2005, the average percent time turtles spent at the surface ranged between 4.1 % (+/- 3.9% SD) to 7.6% (+/- 5.3% SD) for turtles that remained in waters between the Chesapeake Bay, Virginia and Cape Hatteras, North Carolina. One turtle (#10378b) immediately migrated south upon release, only to follow the Gulf Stream north again late December. This turtle spent an average of 9.5% (+/- 8.5% SD) at the surface. Among all turtles tracked in 2005, maximum surface times per 24-hour period ranged as high as 50.6%.

Details of each individual track are listed below. Turtles were obtained from cooperative pound net fishermen in the western Chesapeake Bay (Potomac River or Newpoint Comfort) or relocation trawlers unless otherwise noted as a rehabilitated animal. All rehabilitated turtles were obtained from the Virginia Aquarium and Stranding Program.

2001: Satellite Tag ID# 0123

Loggerhead (juvenile)

Turtle #01234 (XXF779) was originally captured by relocation trawler in the lower Chesapeake Bay near Thimble Shoals (36.958N; -76.047W). This turtle was released on September 13, 2001 approximately 6.5 km offshore of Virginia Beach. Transmissions from the satellite tag lasted only 40 days. Throughout the entire track period, the turtle remained offshore of the Outer Banks, between the Virginia/North Carolina border and Cape Hatteras (Figure 2.1), but did not exhibit significant site fidelity to this area. This turtle also did not exhibit a significantly directed movement

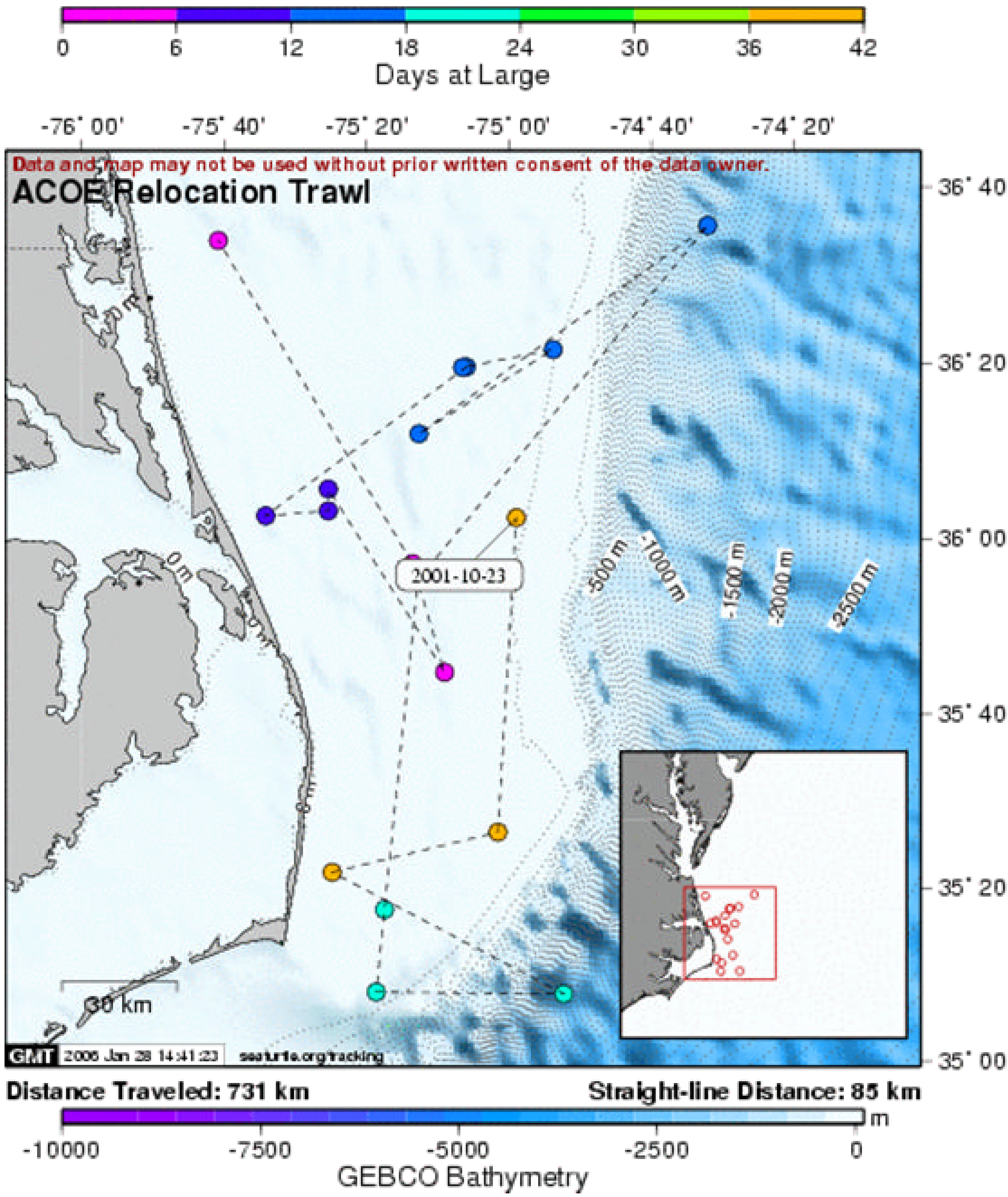


Figure 2.1 Satellite tracks of juvenile loggerhead (Turtle #01234), September 13 to October 23, 2001.

pattern. Turtle #01234's tracks ranged within depths of 1.1 m to 48.7 m, with a mean depth of 28.4 m (+/- 9.9 SD). This turtle ranged up to 183.0 km from the nearest shoreline, averaging a distance of 33.3 km (+/- 37.4 SD) offshore. Mean speed between locations was 3.6 km/hr (+/- 3.1 SD) and mean bearing was 184º (+/- 96º SD; rounded to the nearest degree) (Table 2.2). No temperature data were available for this track.

2002: Radio/Sonic Tag ID #198

Loggerhead (juvenile)

Turtle #198 (XXF794) was released May 23, 2002 in 9.4 m of water in the York River Entrance Channel near the mouth of the York River. The turtle was released on an ebb tide and swam with the current, along the York River Channel, adjacent to Poquoson Flats (Figure 2.2). With the change in tide after sunset, the turtle remained within the flats until track was broken. Tracking was aborted approximately eight hours after release due to high seas and winds. Follow-up tracking the next two days for this turtle was unsuccessful. At the time of release, surface temperatures were 18.3º C, and bottom temperatures were 17.9º C (Figure 2). This turtle was tracked with an H antenna, which proved inadequate for receiving consistent surfacing data, therefore respiratory behavior could not be quantified.

2002: Radio/Sonic Tag ID #199

Loggerhead (juvenile, cold-stun rehabilitated turtle)

Turtle #199 originally stranded in early January 2002 on Virginia Beach due to cold-stunning. After rehabilitation, Turtle #199 was released May 28, 2002 within the

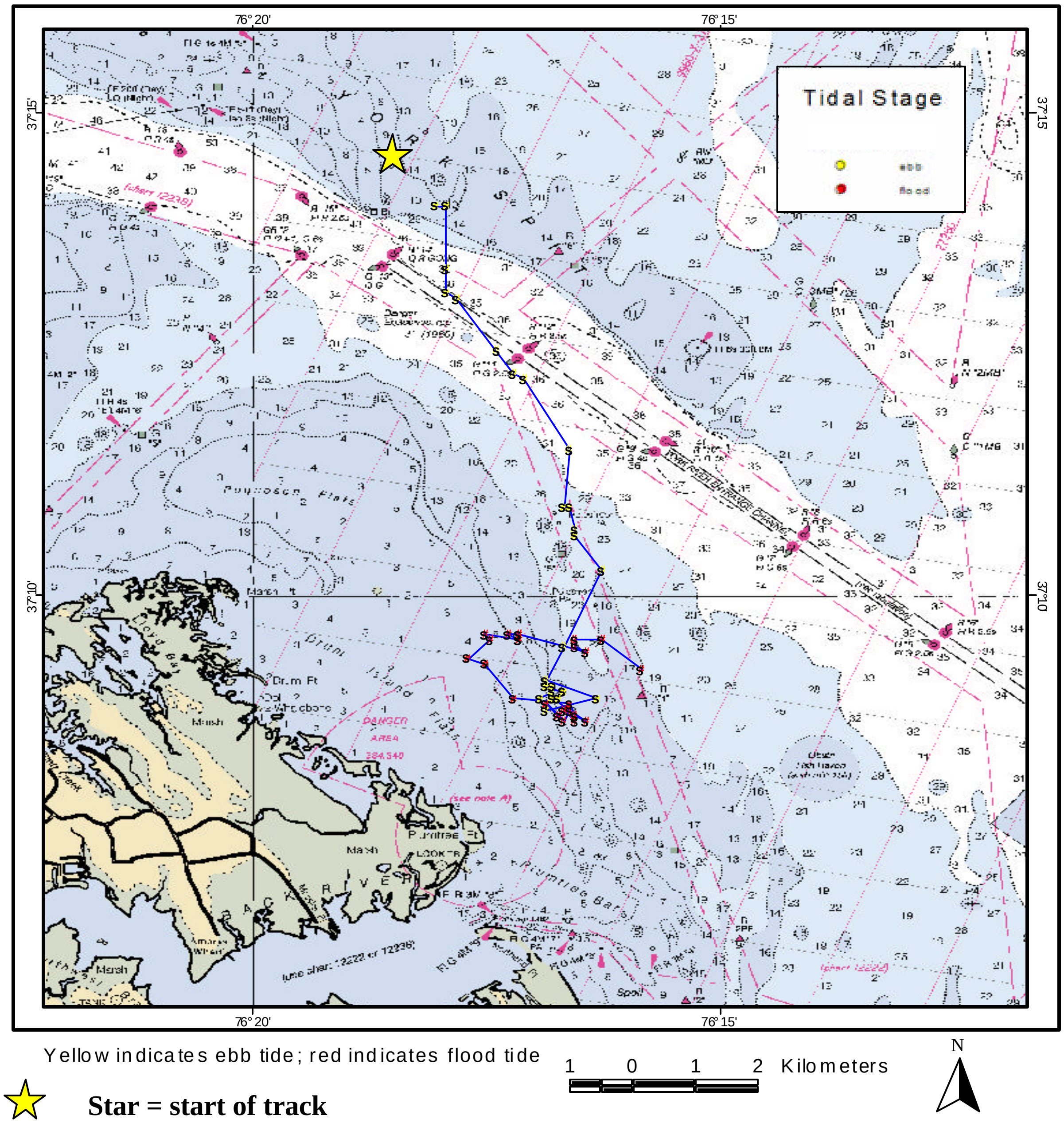


Figure 2.2 Turtle #198 tracked from the mouth of the York River, May 23, 2002. NOAA Chart 12221_1.

Chesapeake Channel on the ocean side of the CBBT into 9.8 m of water. This turtle swam in a large circuit that, after approximately 10 hours of tracking, brought it back in the same vicinity of its release location (Figure 2.3). Track was broken due to high seas and winds after approximately 8.5 hours. When last observed, the turtle was heading towards the CBBT and into the Bay. This turtle did not exhibit significantly directed movement, however, this is most likely due to a travel path that appeared to have been influenced by tidal direction (Figure 2.3).

When Turtle #199 was released, surface temperatures were approximately 22.5º C, with bottom temperatures of 19.1º C. The mean time spent at the surface was 32 seconds (+/- 0:00:51 SD) during the day and 57 seconds (+/- 0:00:39 SD) at night. Mean dive time was 0:06:57 (+/- 0:07:32 SD) during the day and 0:04:15 (+/-0:02:52 SD) at night (Table 2.2). During both day and night, minimum surface times were six seconds (or one transmission from the radio tag). Maximum transmissions were 0:06:00 during the day and 0:01:50 at night. Minimum dive times were 14 seconds during the day, 15 seconds at night. Maximum dive times were 0:40:23 during the day and 0:08:00 at night (Table 2.2). Peak surfacing times were associated with sunset. This turtle was only tracked for a few hours after sunset, so the sample size for nighttime respiratory behavior is small. The percent time this turtle spent at the surface, based on the ratio of surface to submergence times was 7.7% (Table 2.3).

2002: Radio/Sonic Tag ID #192; Satellite Tag #01234

Kemp's ridley (large juvenile)

Turtle #192 (XXF767) was released June 4, 2002 in 7.3 m of water on the ocean side of the CBBT, mouth if the Bay. Shortly after release, seas picked up to 1-1.5 m and

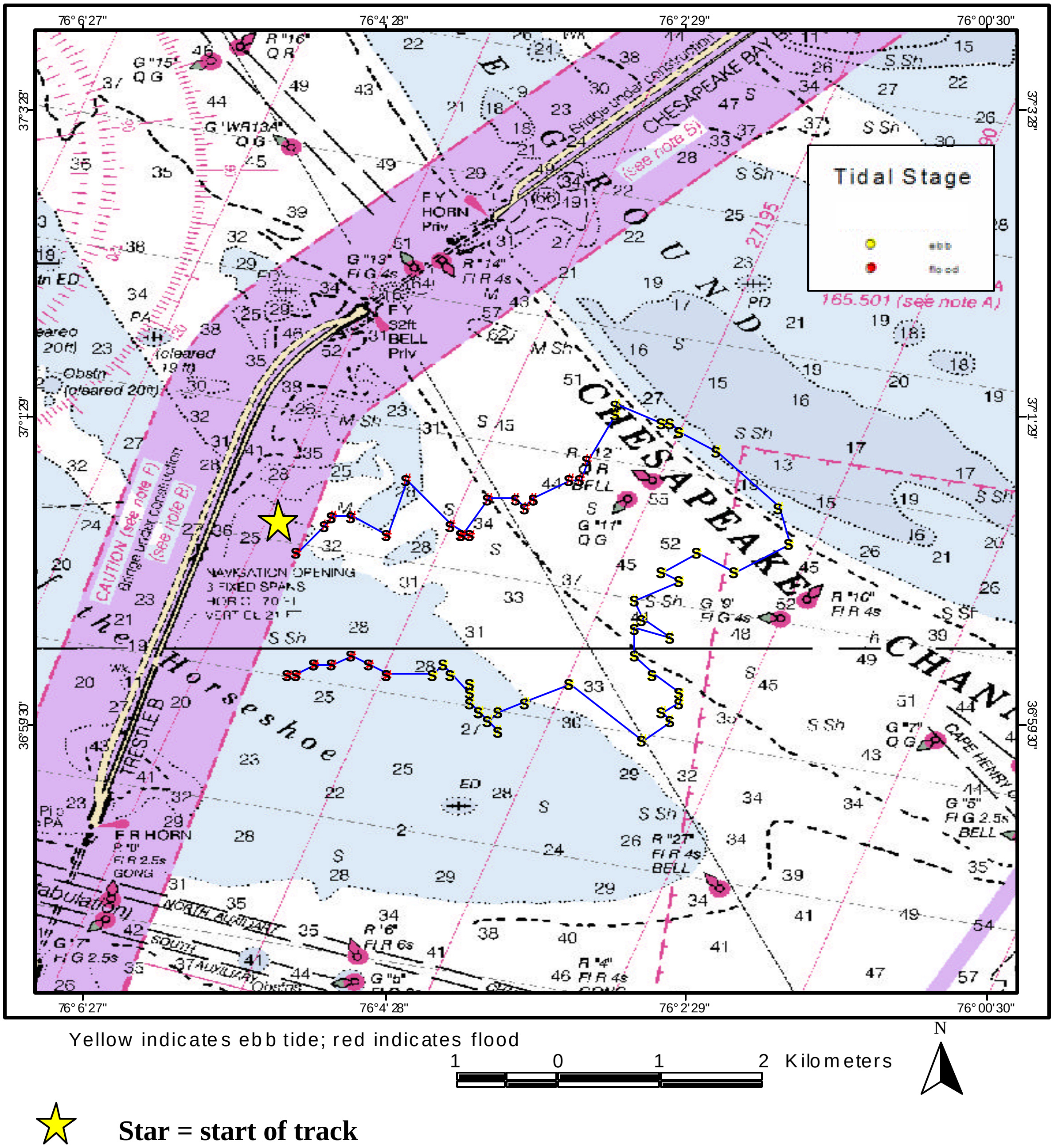


Figure 2.3 Turtle #199 tracked at the mouth of the Chesapeake Bay, May 28, 2002. NOAA Chart 12221_1.

approximately two hours after release, track was broken with turtle in order to secure a calm anchorage for radio monitoring in the lee of the CBBT near the Thimble Shoal channel. The turtle was picked up by radio receiver three hours later, indicating that the turtle was slowly moving up the shipping channel and through the CBBT channel opening, against an ebbing tide. Surfacing events were monitored continuously for approximately three hours until weather and tidal conditions required that the tracking trip be aborted. The long-term movements of this turtle were monitored remotely via satellite transmitter. The week following release, the turtle swam northwest to Mobjack Bay where it remained until mid-July, foraging along the shoreline near the mouths of the Ware, North and Severn rivers (Figure 2.4). Mid-July through the end of August when transmissions ceased, this turtle remained in the center of the Chesapeake Bay adjacent to Smith and South Marsh Islands (Figure 2.4).

At the time this turtle was released, surface temperatures were 22.1º C, and bottom temperatures were 20.0º C. No nighttime respiratory data are available for this turtle due to the shortened sampling period. Mean surface time during the day was 0:01:26 (+/-0:01:49 SD), and mean daytime dive time was 0:03:08 (+/-0:03:05 SD), with an increase in surfacing events observed during the time that the turtle was tracked passing through the CBBT. Minimum surface and dive times were six and ten seconds respectively; maximum surface and dive times were 0:07:34 and 0:12:47 (Table 2.2). Maximum surfacing time occurred while this turtle was passing through the CBBT. The percent time this turtle spent at the surface, based on the ratio of surface to submergence times was 45.7%, however the turtle was inconsistently tracked over an 8-hour period (Table 2.3).

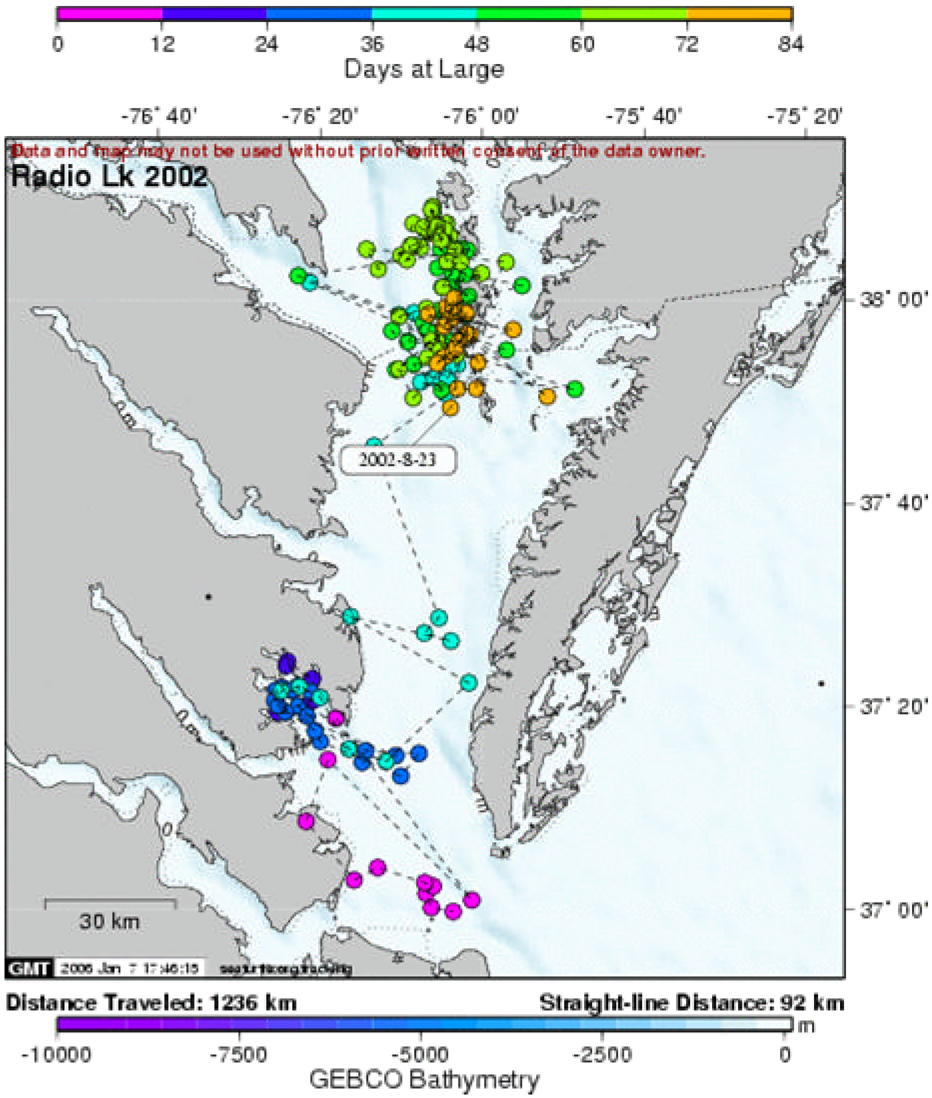


Figure 2.4 Satellite movements of Kemp's ridley June 4 to August 23, 2002

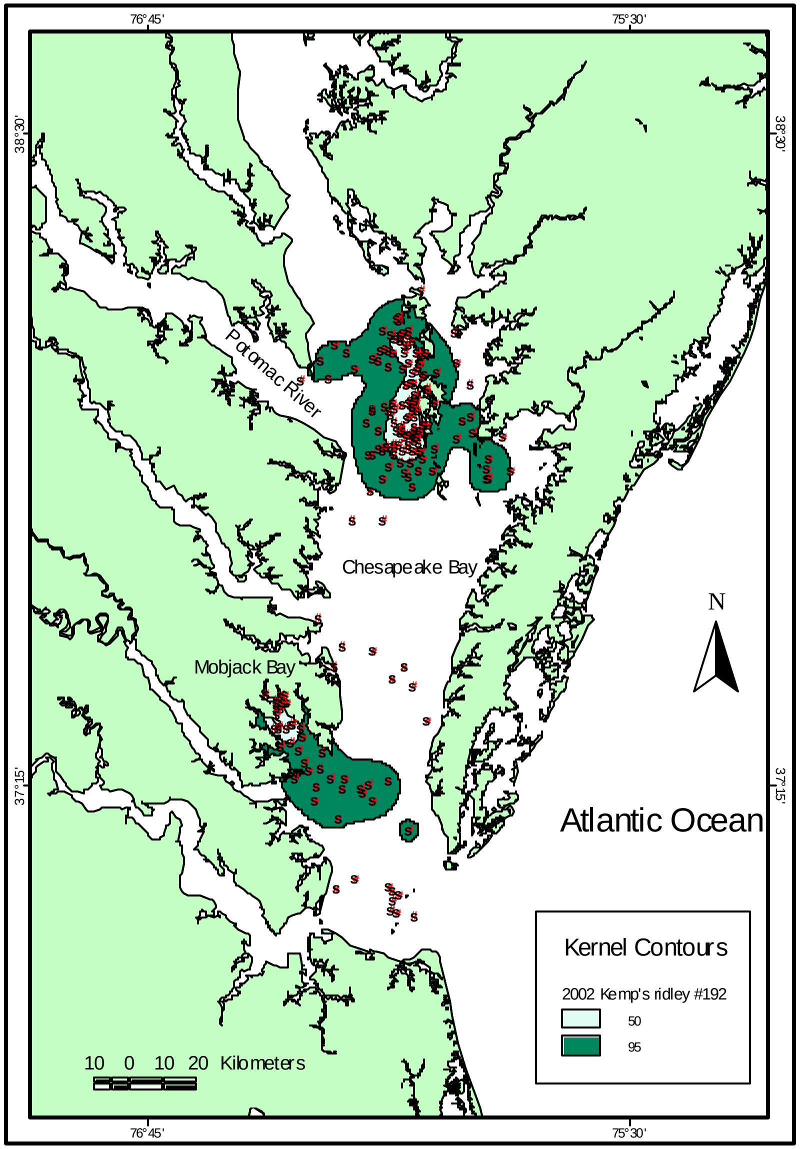


Figure 2.5 50% and 95% home range Kernels for Kemp's ridley #192 tracked June 4 to August 23, 2002

The observed track for this turtle was more constrained than random movements and it exhibited fidelity to both the Mobjack Bay early in its track, and the region near the center of the Chesapeake Bay adjacent to Smith and South Marsh Islands ($p<0.01$; $r^2=0.01$). There was no significant travel direction associated with this track. Mean travel speed was 3.0 km/hr (+/- 3.0 km/hr SD). This turtle ranged up to 13.0 km from shore, averaging 34.1 km (+/- 3.2 km SD) from the nearest shoreline. Mean depth associated with the turtle's locations was 6.3 m (+/- 5.4 m SD) (Table 2.7). Mean bearings between locations was 177º (+/- 103º SD). Kernel home range analysis of indicated that the primary home range for this turtle was adjacent to Smith Island near the mouth of the Potomac River, with a secondary home range found within Mobjack Bay near the mouth of the North River. Kernel analyses of each concentrated (50%) home range resulted in an area of 296.0 km^2 for the primary home range and an area of 131.6 km^2 for the secondary home range. The area within which this turtle was likely to be found (95% probability Kernel contour) included an area spanning 2,660.8 km^2, representing 1,652.3 km^2 within the primary range and 1,008.5 km^2 within the secondary range (Figure 2.5).

2002: Radio/Sonic Tag ID #142

Loggerhead (juvenile, cold-stun rehabilitated turtle)

Turtle #142 (XXT523) stranded on Virginia Beach early January 2002 due to cold-stunning. After rehabilitation, this turtle was released June 11, 2002 south of the Chesapeake Channel and just north of the Thimble Shoals Channel on the ocean side of the CBBT. The turtle was released into 7.3 m of water on an ebb tide. Post-release, it swam southeast within the Thimble Shoals Channel, past Cape Henry, then almost directly south later in the day with a flood tide (Figure 2.6). The track was broken due to high seas and winds after 12 hours. The turtle was last observed east of Rudee Inlet, heading slightly offshore and to the southeast (Figure 2.6).

This turtle exhibited significantly directed movement (z=27.0; n=85; r=0.64) throughout her entire track, with a mean bearing of 130º (+/- 54º SD). On release, sea surface temperatures were 22.8º C. Bottom temperatures ranged between 20.9º and 21.0º C. The mean time spent at the surface was 23 seconds (+/- 0:00:23 SD) during the day and 53 seconds (+/- 0:00:35 SD) at night. Mean dive time was 0:03:01 (+/- 0:02:41 SD) during the day and 0:04:30 (+/-0:02:33 SD) at night. During both the day and night, minimum surface times were six seconds (or one transmission from the radio tag); maximum transmissions were 0:02:15 during the day, 0:02:28 at night. Minimum dive times were 14 seconds during the day, eight seconds at night. Maximum dive times were 0:16:33 during the day and 0:11:55 at night (Table 2.2). The longest surfacing events for Turtle #142 occurred approximately ten minutes prior to, and after sunset. This turtle was only tracked for a few hours after sunset, so the sample size for nighttime respiratory behavior is small. During the 12-hour track, this turtle spent 12.7% of its time at the surface (Table 2.3).

2002: Radio/Sonic Tag ID #165

Loggerhead (juvenile)

Turtle #165 (XXF775) was released June 17, 2002 just south of the Chesapeake Channel on the ocean side of the CBBT into 8.5 m of water. This turtle was released with

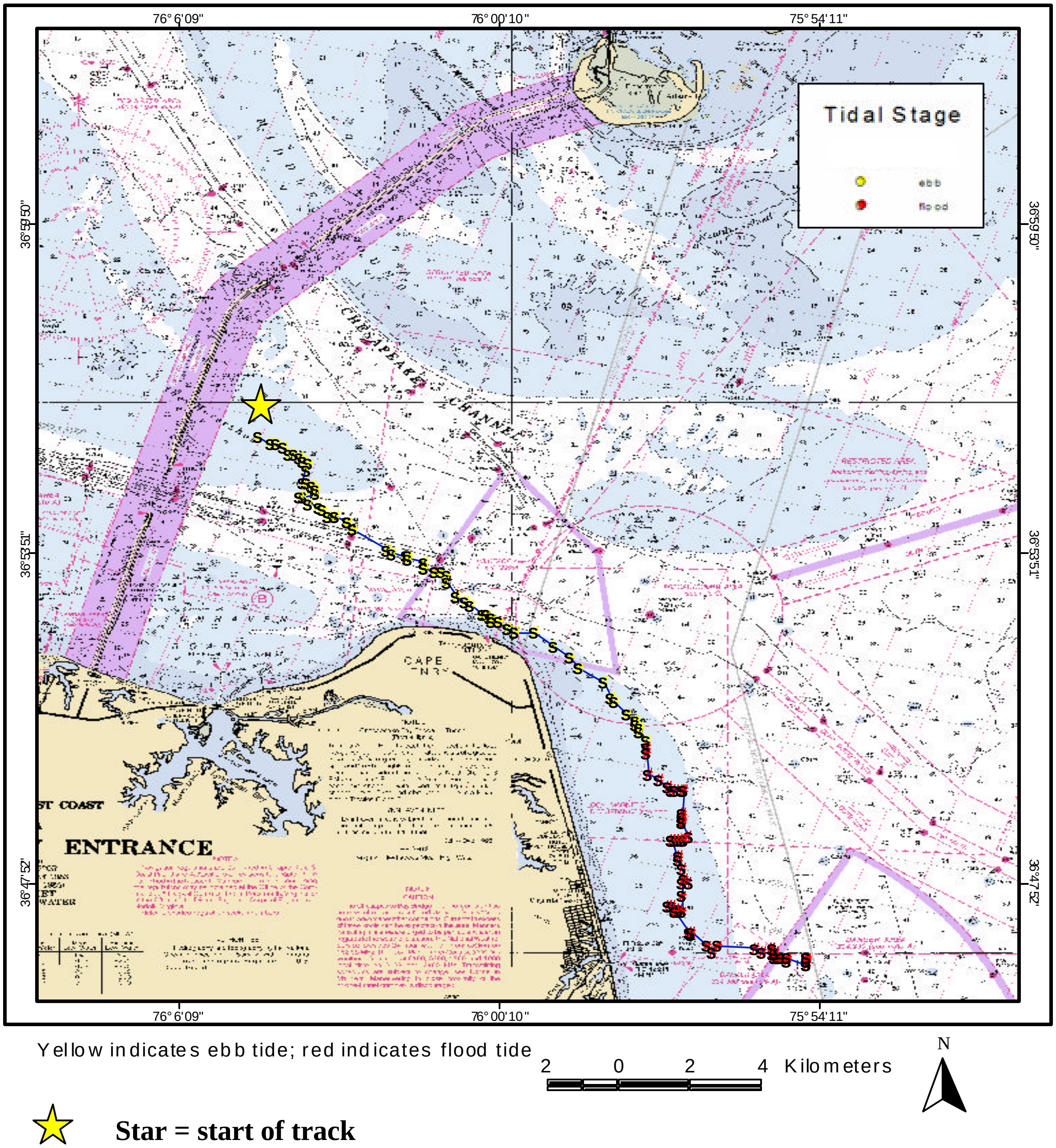


Figure 2.6 Turtle #142 tracked at the mouth of the Chesapeake Bay, June 11, 2002. NOAA Chart 12221_1.

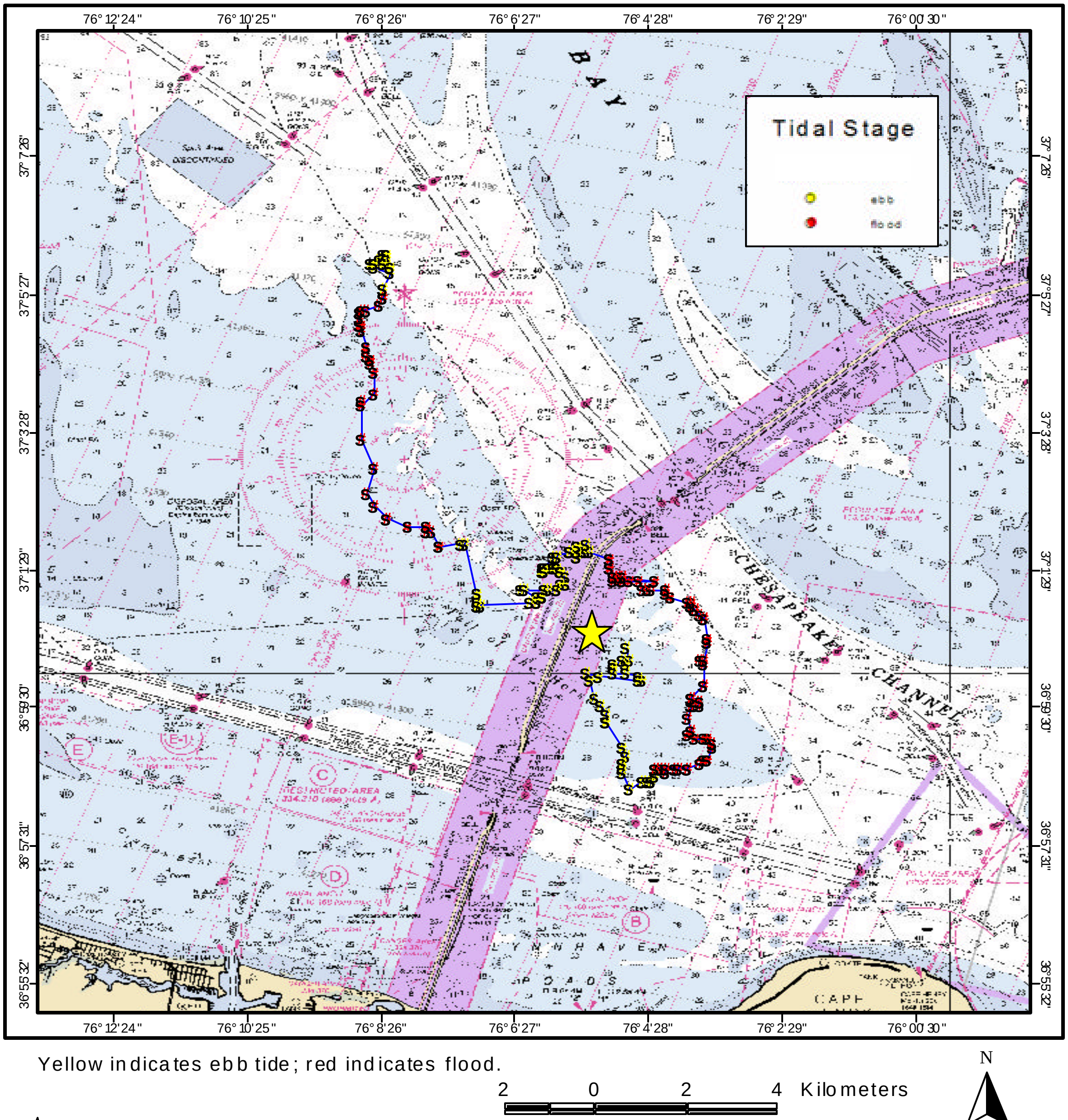
an ebb tide and swam south until the tide turned, after which it swam north along the Chesapeake Channel, under the CBBT and into the Bay. Once under the CBBT, with the tide ebbing, the turtle swam southeast and east until the tide flooded again. After which the turtle moved northward again (Figure 2.7). Track was broken on June 18, 24 hours after release of the turtle.

This turtle exhibited significantly directed movement (z=6.1; n=133; r=0.24) throughout her entire track, particularly with the flood tide (Figure 2.7). A mean bearing of 322º (+/- 96º SD) was observed. At the time of release, surface temperatures were approximately 23.2º C, and bottom temperatures were 22.9º C. The mean time spent at the surface was 24 seconds (+/- 0:00:30) during the day and 54 seconds (+/- 0:01:12) at night. Mean dive time was 0:03:17 (+/- 0:04:14) during the day and 0:05:30 (+/-0:08:10) at night. During both the day and night, minimum surface times were six seconds (or one transmission from the radio tag) and maximum transmissions were 0:04:44 during the day, 0:07:50 at night. Minimum dive times were six seconds during the day and night. Maximum dive times were 0:26:05 during the day and 0:28:15 at night (Table 2.2). Peak surfacing events occurred when the turtle passed under the CBBT, and15 to 20 minutes prior to during and after sunrise (Figure 2.8). This turtle spent 12.2% of its track time at the surface (Table 2.3).

2002: Radio/Sonic Tag ID #167

Loggerhead (juvenile)

Turtle #167 (XXF771) was released June 24, 2002 just north of Thimble Shoals Channel on the ocean side of the CBBT (Figure 2.9). It was released into 7.6 m of water



Star = start of track

Figure 2.7 Turtle #165 tracked at the mouth of the Chesapeake Bay, June 17-18, 2002. NOAA Chart 12221_1.

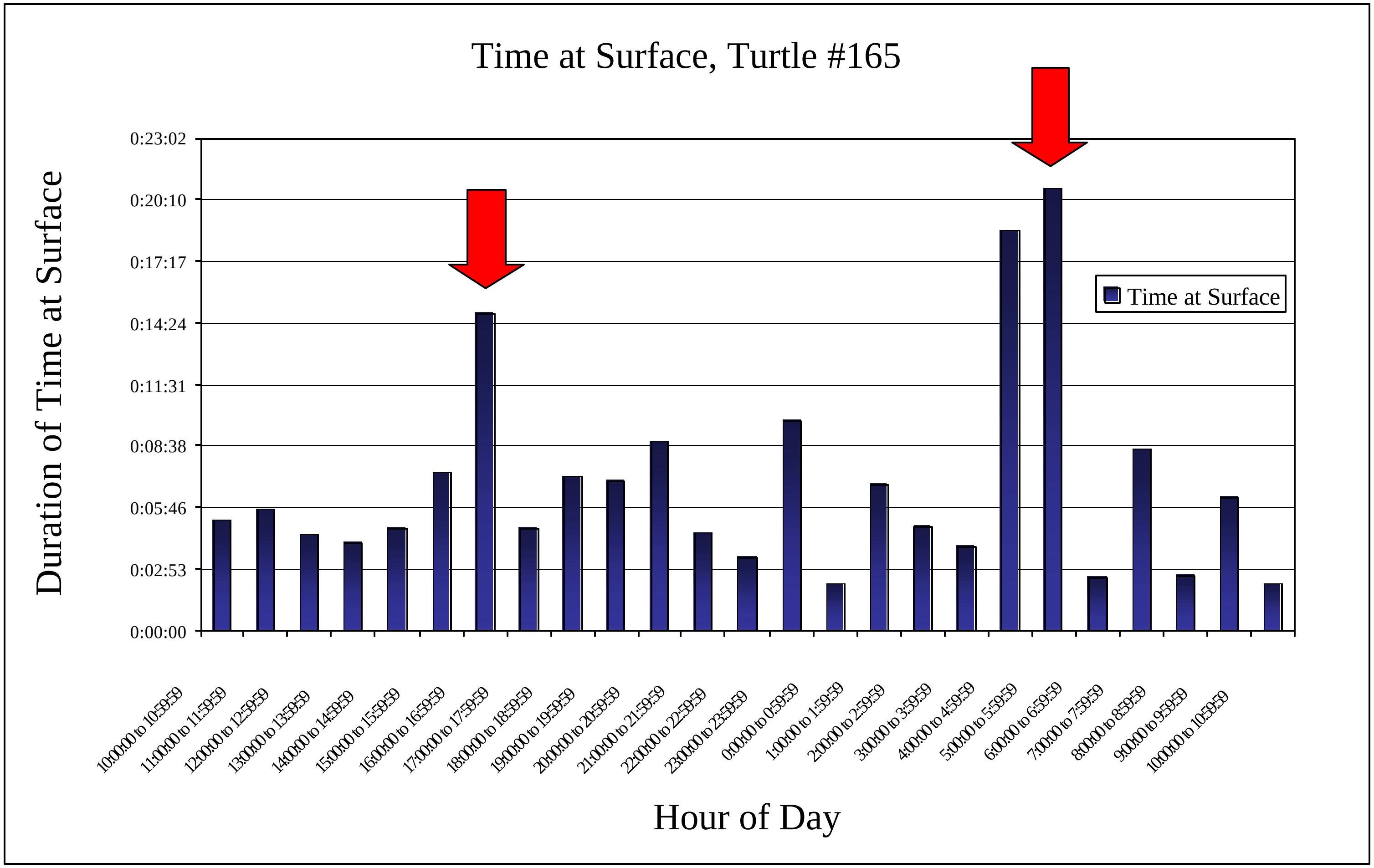
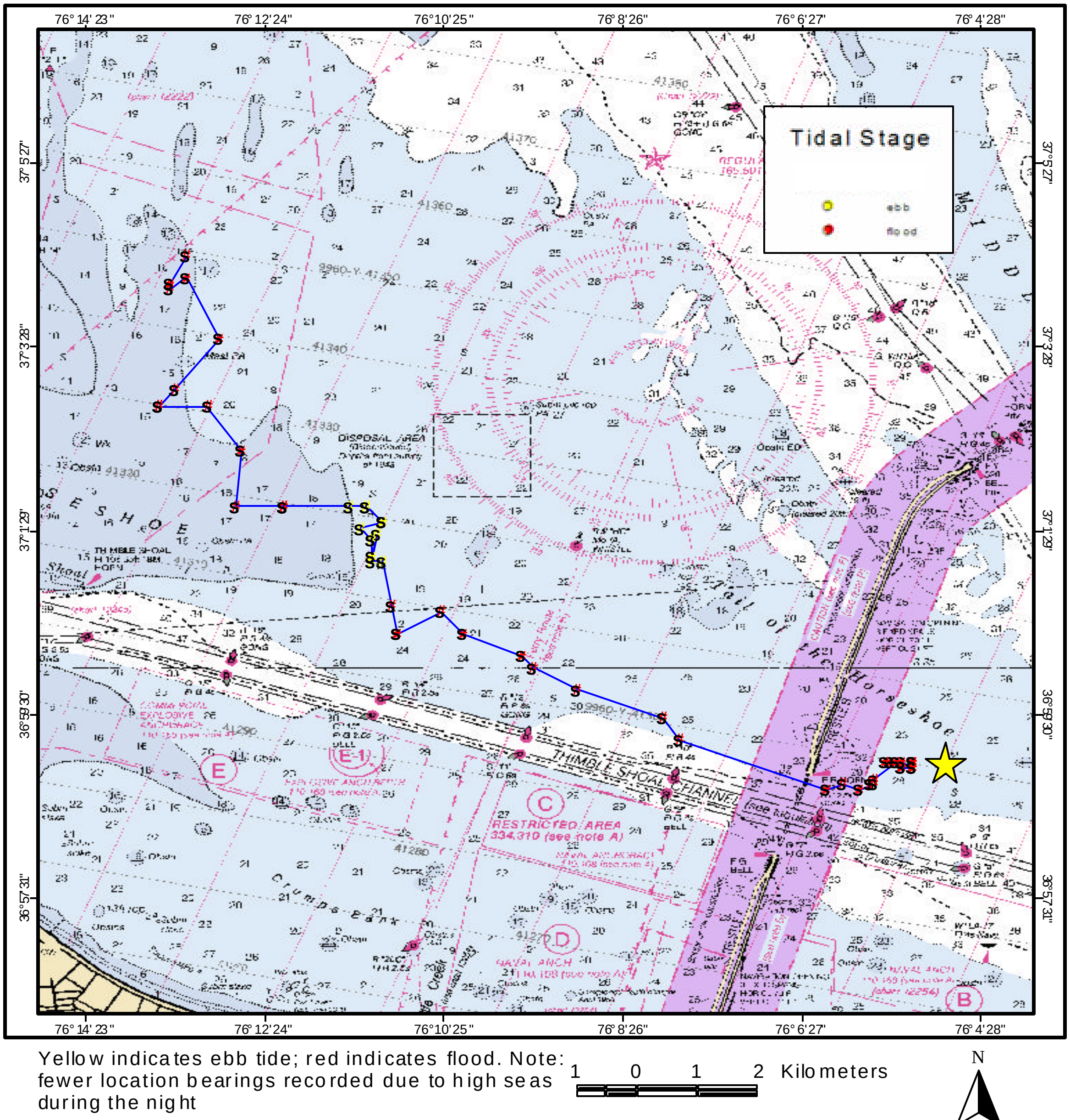


Figure 2.8 Turtle #165 Surfacing times, June 17-18, 2002. First red arrow indicates turtle passing under CBBT, second indicates hour of sunrise.



☆ **Star = start of track**

Figure 2.9 Turtle #167 tracked from the mouth of the York River, June 24-25, 2002. NOAA Chart 12221_1**.**

with a flood tide. This turtle immediately swam east under the CBBT along the northern edge of the Channel (Figure 2.9). During the nighttime hours and an ebb tide, the turtle remained relatively stationary until the tide changed and morning arrived, after which it continued swimming north to northeast (Figure 2.9). Track was broken on June 25, 18 hours after release of the turtle.

This turtle exhibited significantly directed movement ($z=5.0$; $n=34$; $r=0.41$) throughout her entire track, particularly with the flood tide (Figure 2.9). A mean bearing of 316º (+/- 77º SD) was recorded. When Turtle # 167 was released, surface temperatures were 25.4º C, and bottom temperatures were 24.8º C. The mean time spent at the surface was 29 seconds (+/- 0:00:39) during the day and 56 seconds (+/- 0:00:55) at night. Mean dive time was 0:06:50 (+/- 0:08:27) during the day and 0:08:33 (+/-0:07:40) at night. During both the day and night, minimum surface times were six seconds (or one transmission from the radio tag) and maximum transmissions were 0:03:12 during the day, 0:05:23 at night. Minimum dive times were six seconds during the day and night. Maximum dive times were 0:39:31 during the day and 0:29:39 at night (Table 2.2). Peak surfacing events occurred within 15 to 20 minutes of sunrise (Figure 2.10). This turtle spent 7.1% of its time at the surface (Table 2.3).

Radio/Sonic Tag ID #211

Loggerhead (adult)

Turtle #211 (SSB919) was released on July 16, 2002. Ultrasound tests of this turtle confirmed its sex as female. This turtle's weight and size prohibited safe transfer to and from the tracking vessel for an in-water release, thus was released from the VIMS

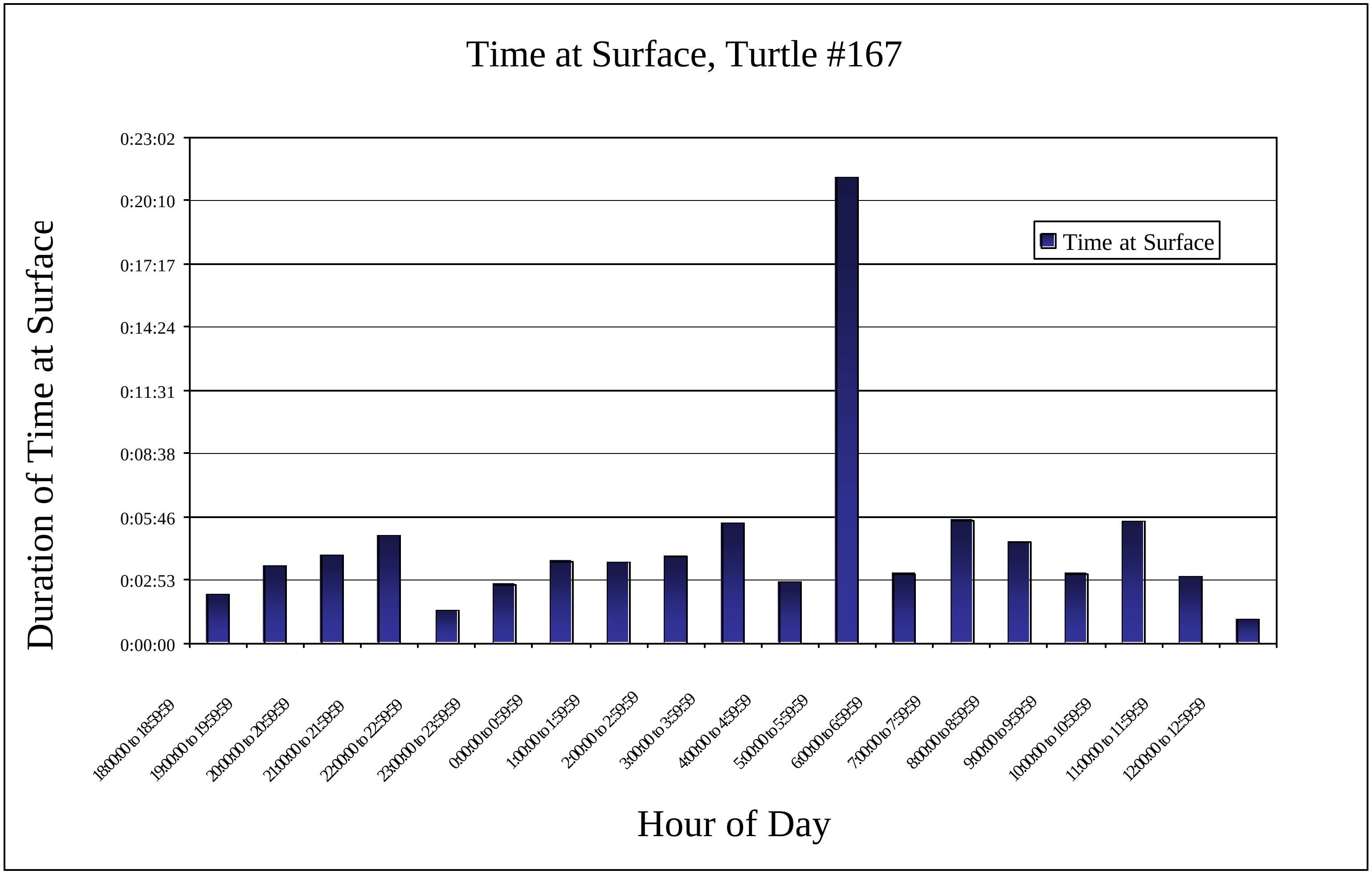


Figure 2.10 Turtle #167 Surfacing times, June 24-25, 2002.

beach upriver from the Coleman Bridge in the York River. This turtle initially swam with the ebbing tide under the Coleman Bridge until the tide turned and she swam with the flooding tide back under the Bridge towards the US Naval Weapons Station (Figure 2.11). When the tide turned again, she followed the ebbing tide out under the Bridge a third time, along the York River Channel. With the nighttime flood tide, she remained in the middle of the River, within the Channel until the tide changed again in the early morning and she followed it down river. Track was broken July 17, 24 hours post-release. The turtle was last seen swimming against a flood tide towards the mouth of the York River. This turtle was recaptured in the mouth of the Potomac River ten days later in the same pound net she was captured in originally. She was captured one more time within the same pound net late summer.

This turtle exhibited significantly directed movement (z=11.3; n=180; r=0.32) throughout her entire track (Figure 2.9). She maintained a mean bearing of 94º (+/- 87º SD). At the time of release, surface temperatures were 25.4º C, and bottom temperatures were 26.6º C near the VIMS beach adjacent to the Coleman Bridge. These temperatures increased with depth (25.0º C to 27.3º C), unlike all other profiles taken in 2002. The mean time spent at the surface was 8 seconds (+/- 0:00:07) during the day and 19 seconds (+/- 0:00:31) at night. Mean dive time was 0:04:53 (+/- 0:05:46) during the day and 0:09:55 (+/-0:09:00) at night. During both the day and night, minimum surface times were six seconds (or one transmission from the radio tag) and maximum transmissions were 0:01:17 during the day, 0:03:07 at night. Minimum dive times were six seconds during the day, seven seconds at night. Maximum dive times were 0:38:05 during the day and 0:32:49 at night (Table 2.2). The longest period this turtle spent at the surface during

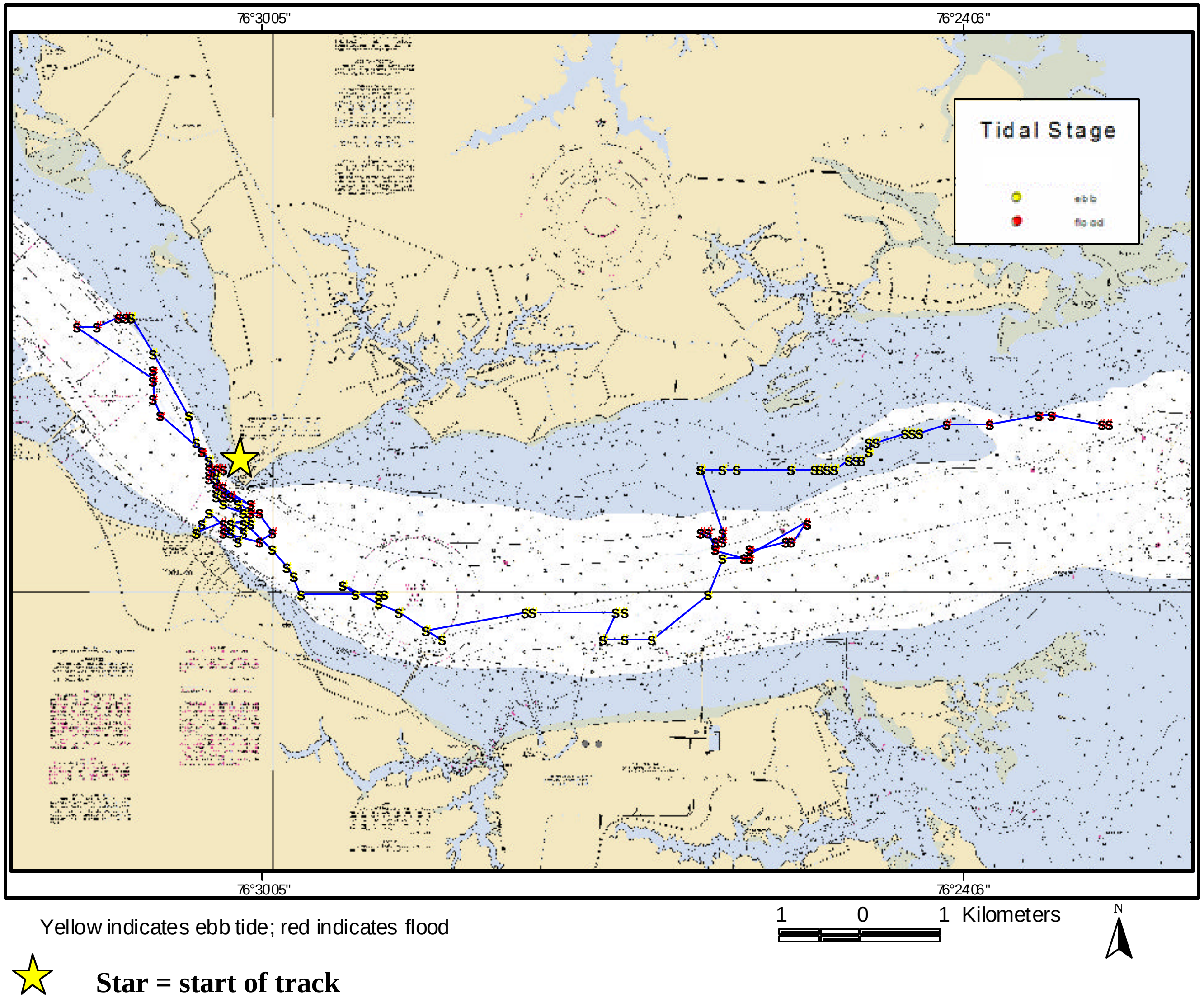


Figure 2.11 Turtle #211 tracked from VIMS to the mouth of the York River, July 16- 17, 2002. NOAA Chart 12241_1.

the day was at sunset (0:01:17). The percent time this turtle spent at the surface, based on the ratio of surface to submergence times was 2.7% (Table 2.3).

2003: Satellite Tag ID #10401

Kemp's ridley (juvenile):

Turtle #10401 (XXN292) was released on June 18, 2003 from the VIMS beach in the York River. The first few days post-release, the turtle remained in the vicinity of the VIMS beach and the Coleman Bridge before moving upriver. For the duration of its track, this turtle remained in the upper York River between the Poropotank River and West Point at the junction of the Mattaponi and Pamunkey Rivers (Figure 2.12). There was no significant travel direction associated with this turtle's track, however, movement vectors corresponded with prevailing tidal currents in the River. Mean travel speed was 1.6 km/hr (+/- 2.7 km/hr SD). This turtle ranged up to 2.0 km from shore, averaging 0.4 km (+/- 0.6 km SD) from the nearest shoreline. Mean depth associated with the turtle's locations was 2.5 m (+/- 3.2 m SD) (Table 2.7). Mean bearing was 251º (+/- 156º SD) and mean temperature associated with this track was 25.7° C (+/- 1.0 C° SD) (Table 2.8). The standard deviation of the mean bearing reflected the opposing vectors associated with the tidal currents in the York River. The turtle's movements were constrained by the shape of the York River and despite remaining within a relatively discrete region of the upper York, movements up and down river with the tides resulted in statistically insignificant fidelity to any particular region.

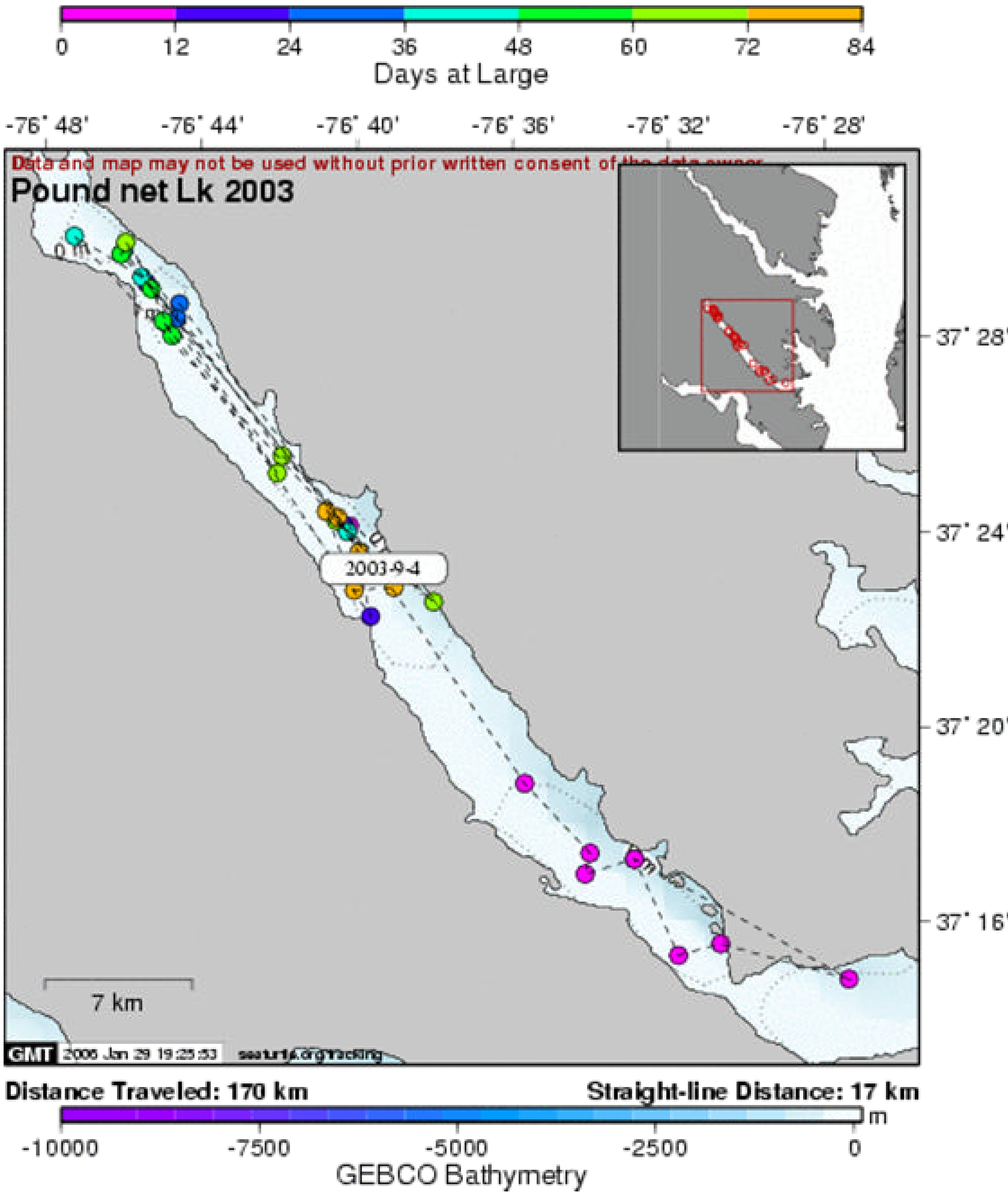


Figure 2.12 Satellite movements of Kemp's ridley in the York River, June 18 to September 9, 2003.

2003: Radio/Sonic Tag ID #197

Kemp's ridley (juvenile):

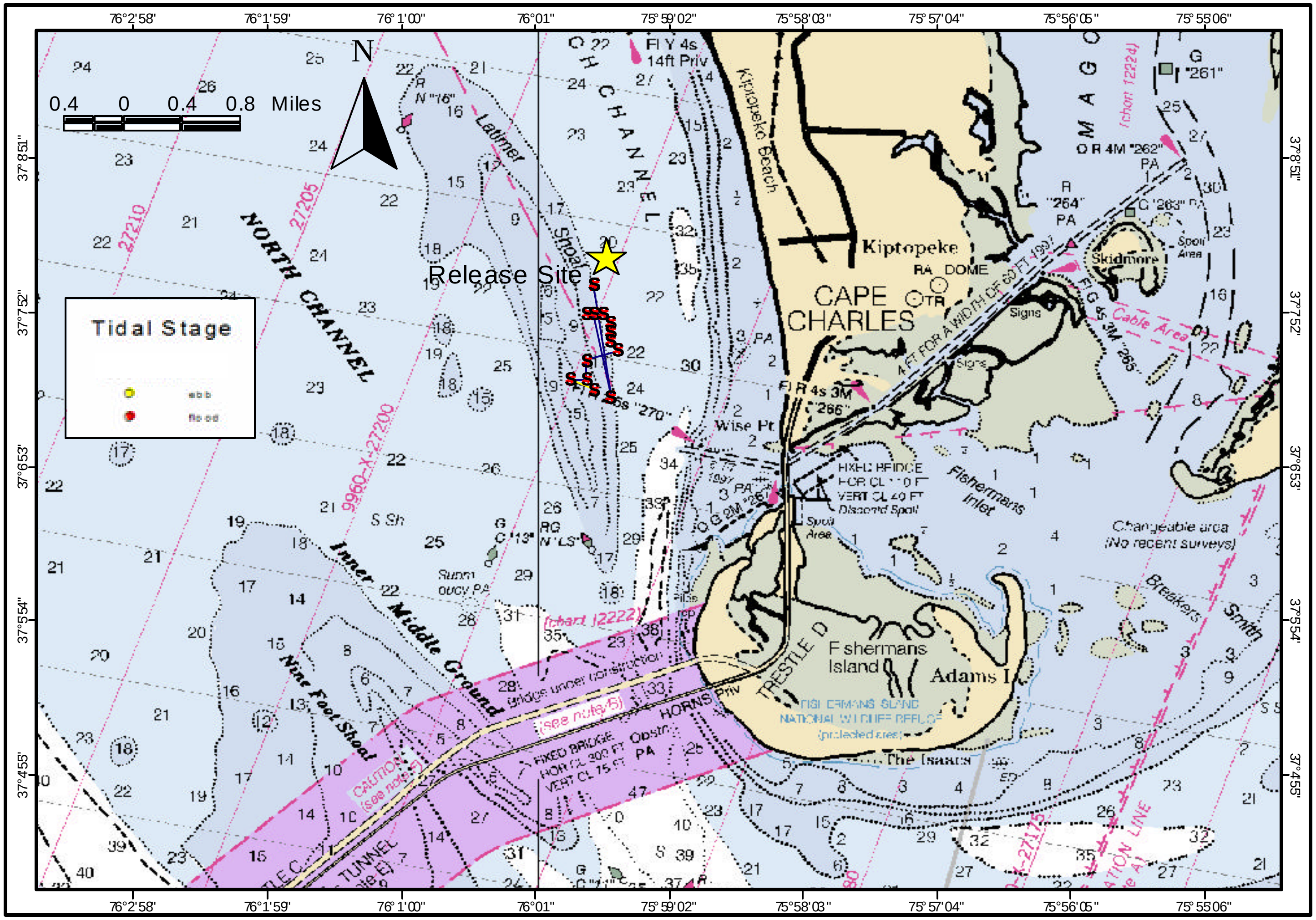
Turtle #197 was released June 16, 2003 in 6.1 m of water on the eastern Bay side of the CBBT. The turtle was released on a flood tide in one-foot seas off of Latimer Shoals. For the duration of the track, the turtle remained within approximately one mile of its release site (Figure 2.13). Tracking was aborted approximately four hours after release due to sustained high seas and winds. The turtle was consistently tracked for two of those four hours. Follow-up tracking for this turtle was unsuccessful.

At the time of release, surface temperatures were 20.8º C, and bottom temperatures were 19.3º C. The mean surfacing time for this turtle was 0:00:09 (+/- 0:00:05 SD). The mean dive period was 0:01:42 (+/- 0:01:39). Minimum surfacing time was 0:00:06; maximum surfacing time was 0:00:24. Minimum dive time was 0:00:06; maximum dive time was 0:09:27. During the successful two hour track post-release, this turtle's radio signal could be heard (indicating that it was within the top meter of water) 7.2% of the time tracked (Table 2.3).

2003: Radio/Sonic Tag #137; Satellite Tag #11583

Loggerhead (juvenile):

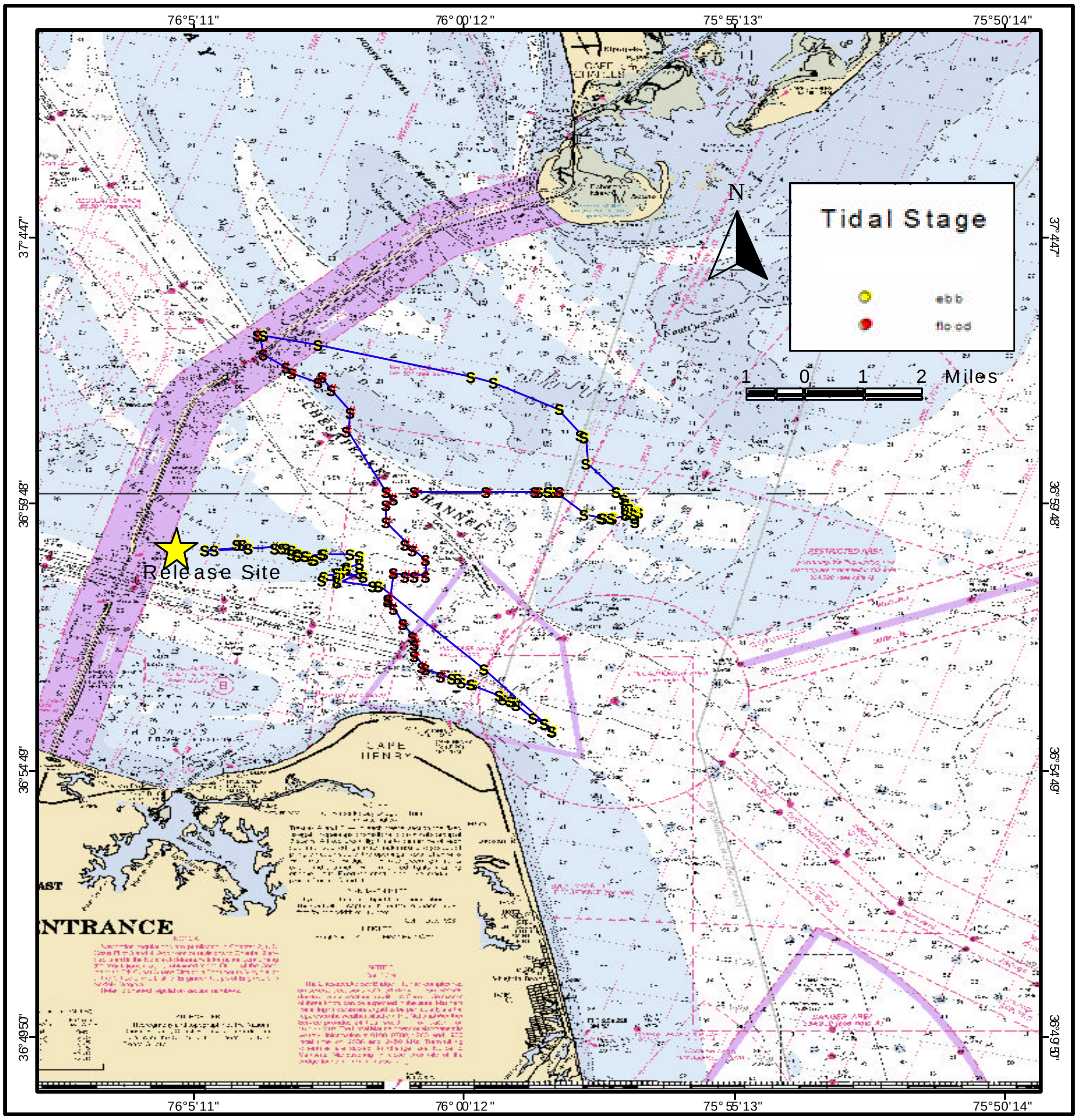
Turtle #137 (XXF731) was released July 15, 2003 within the Chesapeake Channel on the ocean side of the CBBT. The turtle was released into 9.8 m of water. This turtle initially swam southeast towards Cape Henry with the ebb tide. Once the tide changed, the turtle swam north northwest through the Chesapeake Channel with the flooding tide (Figure 2.14), only to head southwest again with the subsequent ebb tide. When last



Yellow indicates ebb tide; red indicates flood tide

☆ **Star = start of track**

Figure 2.13 Post-release movements of turtle #197 radio tracked in the mouth of the Chesapeake Bay for 4-hours June16-17, 2003. NOAA Chart 12221_1.



Yellow indicates ebb tide; red indicates flood tide

☆ **Star = start of track**

Figure 2.14 Post-release movements of turtle #137 radio tracked in the mouth of the Chesapeake Bay for 24-hours July 15 to 16, 2003. NOAA Chart 12221_1**.**

observed after a 24-hour track, the turtle was heading back towards the CBBT via the Chesapeake Channel with the flood tide. These movements, corresponding to the direction in tidal flow, did not result in statistically significant directional movement.

When Turtle #137 was released, surface temperatures were 23.9º C, and bottom temperatures were 18.2º C. After sunset and with the rise of the (close-to) full moon, this turtle spent almost the entire nighttime hours within the first meter or two of water. The mean time spent at the surface was 46 seconds (SD +/- 0:04:02) during the day and 0:13:50 (+/- 0:38:41) at night. Mean dive time was 0:05:42 (+/- 0:08:47) during the day and 0:05:31 (+/-0:04:56) at night (Table 2.4). During both the day and night, minimum surface times were six seconds (or one transmission from the radio tag) and maximum length of transmission was 0:42:45 during the day, 2:40:45 at night. Minimum dive times were 6 seconds during the day and night; maximum dive times were 0:44:31 during the day and 0:16:28 at night (Table 2.4). During the 13-hour track, this turtle's radio signal could be heard (indicating that it was within the top meter of water) 36.45% of the time (Table 2.3).

Based on acoustic data, the average depth this turtle could be found was 5.67 meters (+/- 3.28) (Figure 2.15), however reception of acoustic data was limited during the night due to high seas limiting the range of acoustic tag reception. As a result, the prolonged nighttime surfacing event for this turtle is not reflected in the acoustic depth average. The average temperature was 18.8º C (+/-2.28), with the majority of the acoustic temperature data ranging between 16º C and 19º C (Figure 2.16).

The satellite tracks of this turtle have provided over two and a half years of data. As of January 31, 2006, this turtle's satellite tag is still transmitting. After its release and

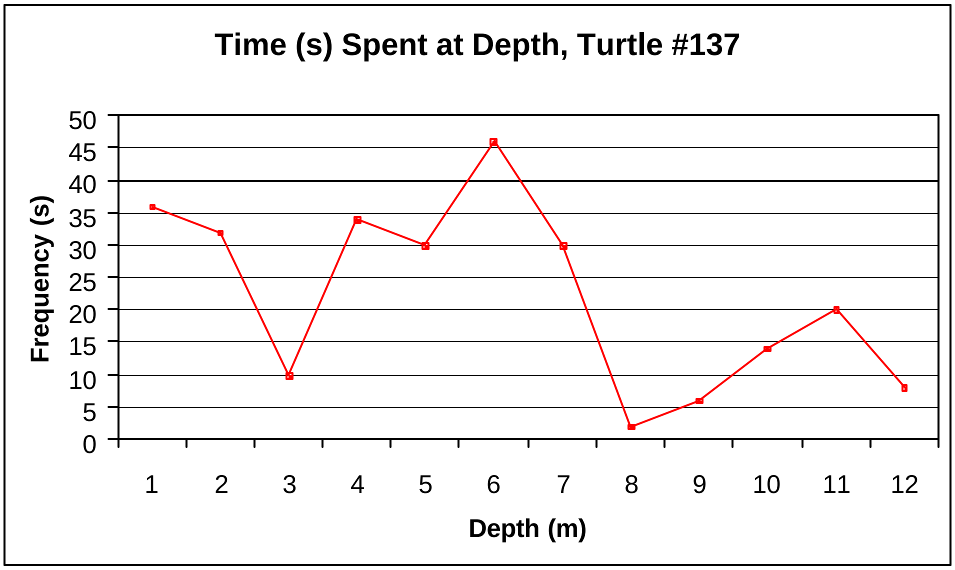


Figure 2.15 Frequency of time spent at different depths for turtle #137 (total track).

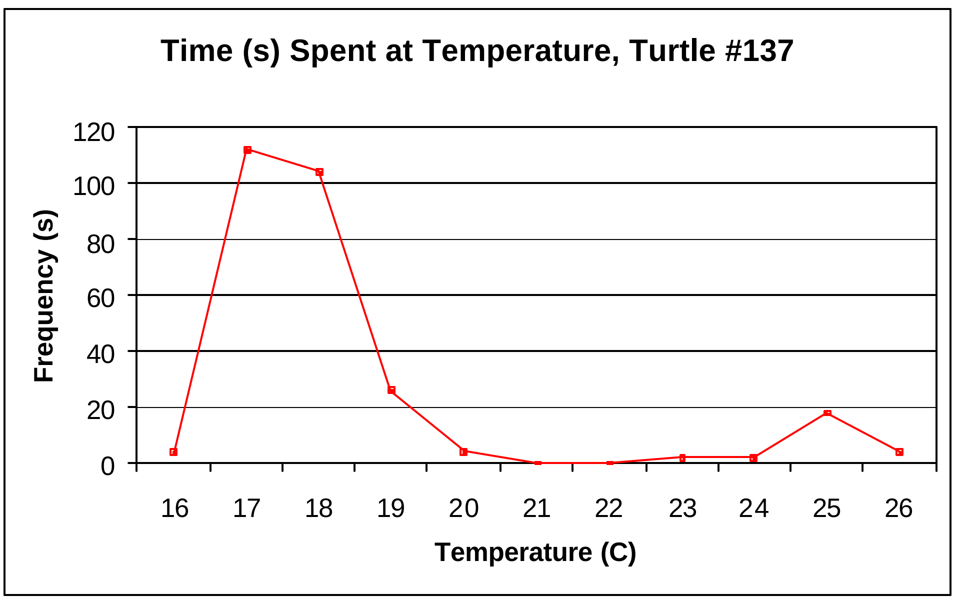


Figure 2.16 Frequency of time spent at different temperatures for turtle #137 (total track).

subsequent radio/acoustic track, this turtle established residency near the mouth of the Potomac River in the upper Virginia portion of the Chesapeake Bay. This turtle exhibited significant fidelity to this region ($p<0.002$; $r^2= 0.02$) (Figure 2.17). Kernel home range analysis indicates that the primary foraging home range for this turtle occurred in the waters south of Smith Point and the Potomac River along the western shore of the Chesapeake Bay, represented by the 50% Kernel probability contour (Figure 2.18). The 50% Kernel represented an area of 87.1 square kilometers. The area within which this turtle was likely to be found (95% probability Kernel contour) included an area spanning 1,042.0 square kilometers (Figure 2.18).

The first week in October 2003 the turtle swam out of the Bay mouth, remaining just offshore of the lower Eastern Shore until the first week in November when it began its southern migration to its over-wintering habitat off of the North Carolina coast. The turtle over-wintered south of Cape Hatteras, offshore near the edge of the continental shelf and in the western edge of the Gulf Stream. Site fidelity tests indicated significant fidelity to this habitat ($p<0.04$; $r^2=0.04$). Mid-March, 2004, the turtle swam north with the Gulf Stream, remaining with current as it continued towards the north-Atlantic. The turtle has remained in the north Atlantic gyre south of the Grand Banks for approximately two years (Figures 2.19 and 2.21).

Satellite telemetry locations overlaid on AVHRR SST datasets from the NOAA NESDIS archives indicate that the turtle remained within a SST range of 11º C to 28º C and a mean SST of 20.0º C (+/- 3.5º C SD) (Figure 2.20). Sea surface temperatures during the turtle's migration to its over-wintering habitat were between 15º C and 20º C. Mean travel speed has been 3.8 km/hr (+/- 3.8 km/hr SD). This turtle has ranged up to

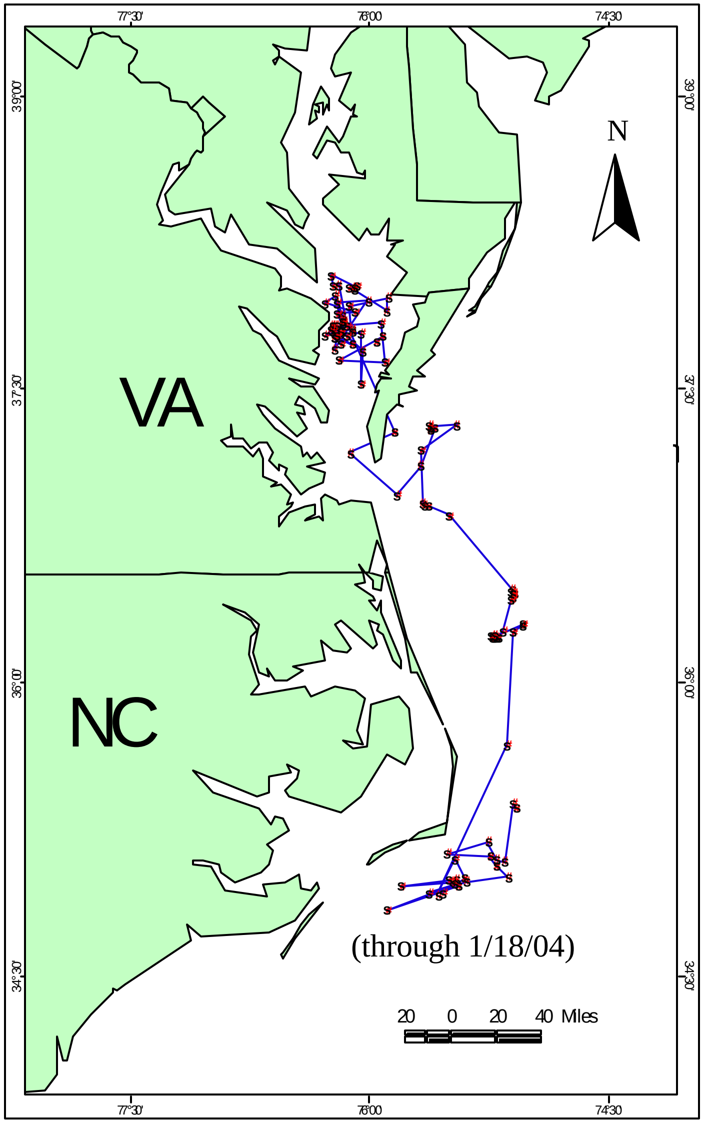


Figure 2.17 Initial satellite tracks of turtle #137 from July 15, 2003 to January 18, 2004.

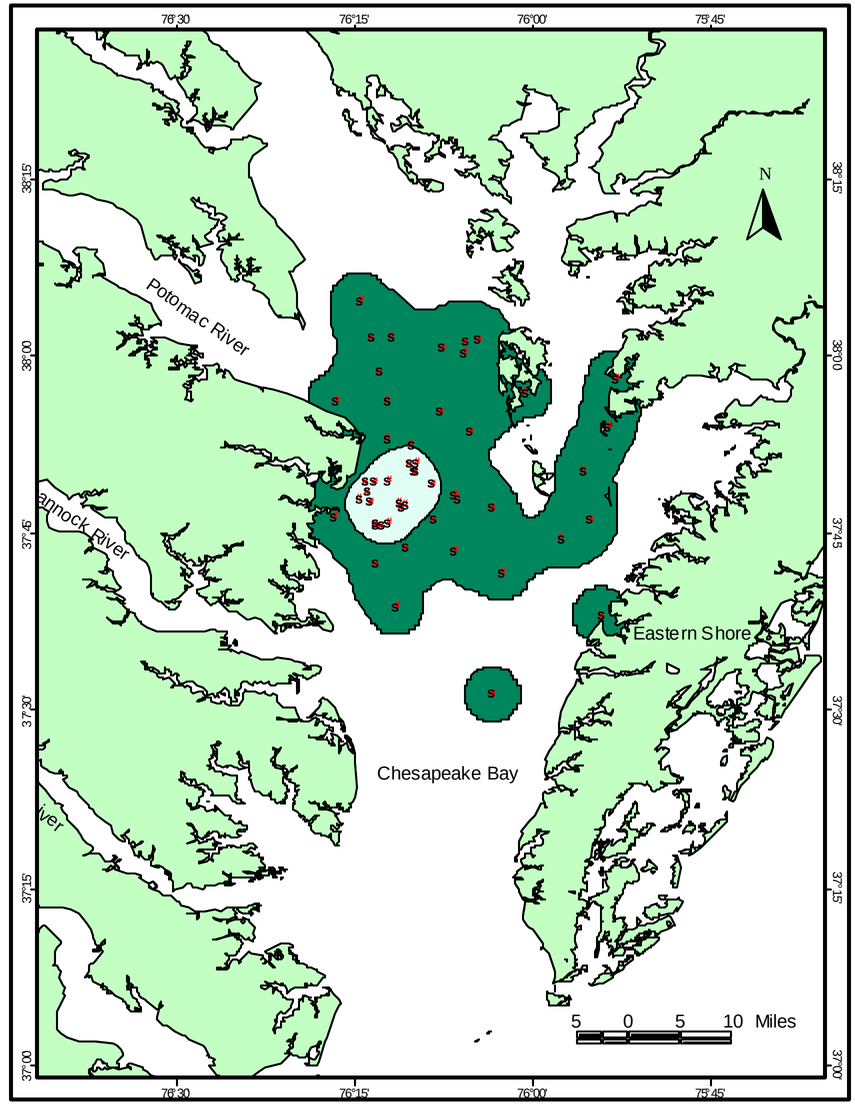


Figure 2.18 Kernel home range analysis of turtle #137's satellite tracks while resident in the Chesapeake Bay July 15 to the first week in October, 2003.

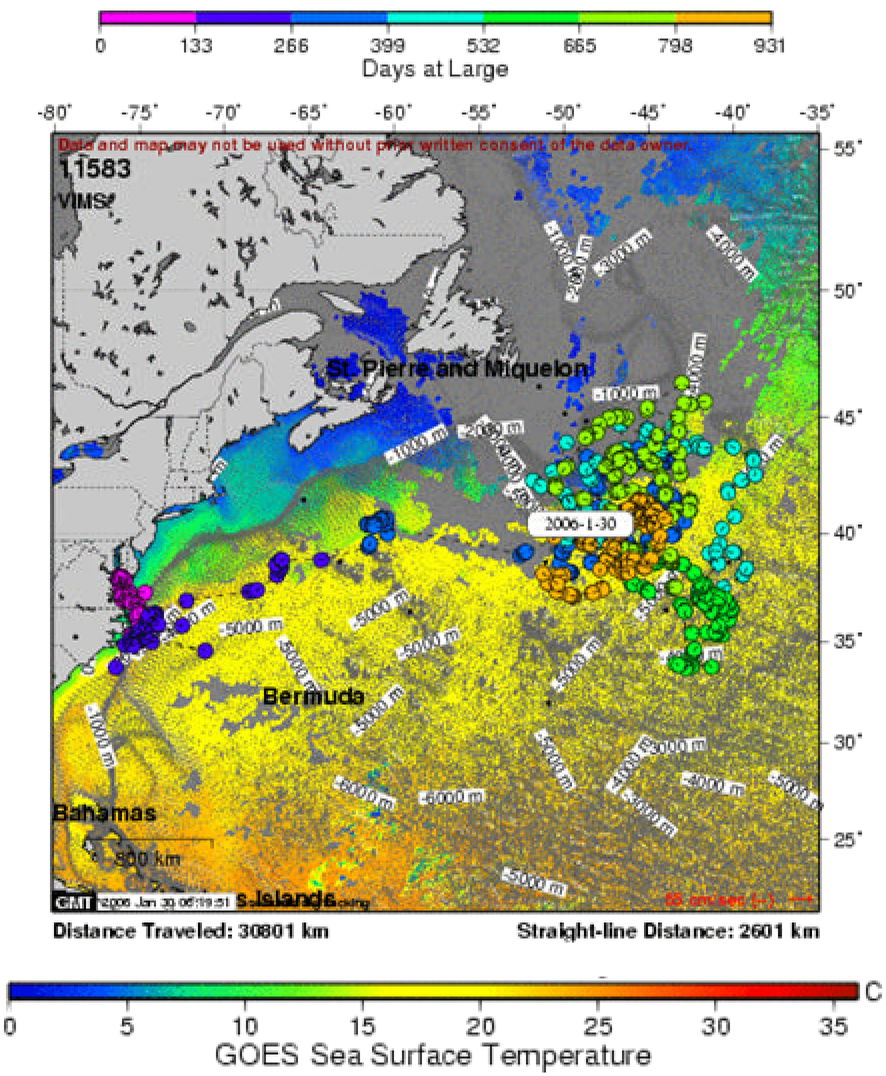


Figure 2.19 Satellite tracks of turtle #137 from July 15, 2003 to January 30, 2006.

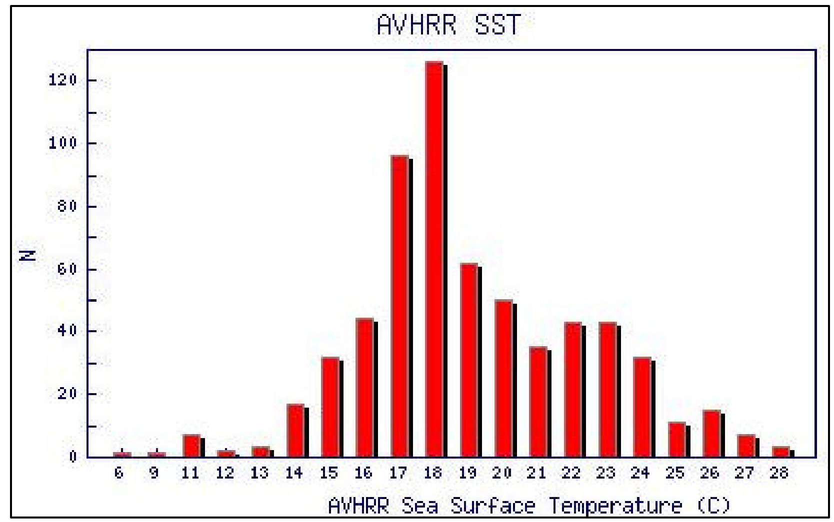


Figure 2.20 Frequency (N) of satellite telemetry locations for turtle # 137 associated with AVHRR SST. Generated in STAT (Coyne and Godley 2005).

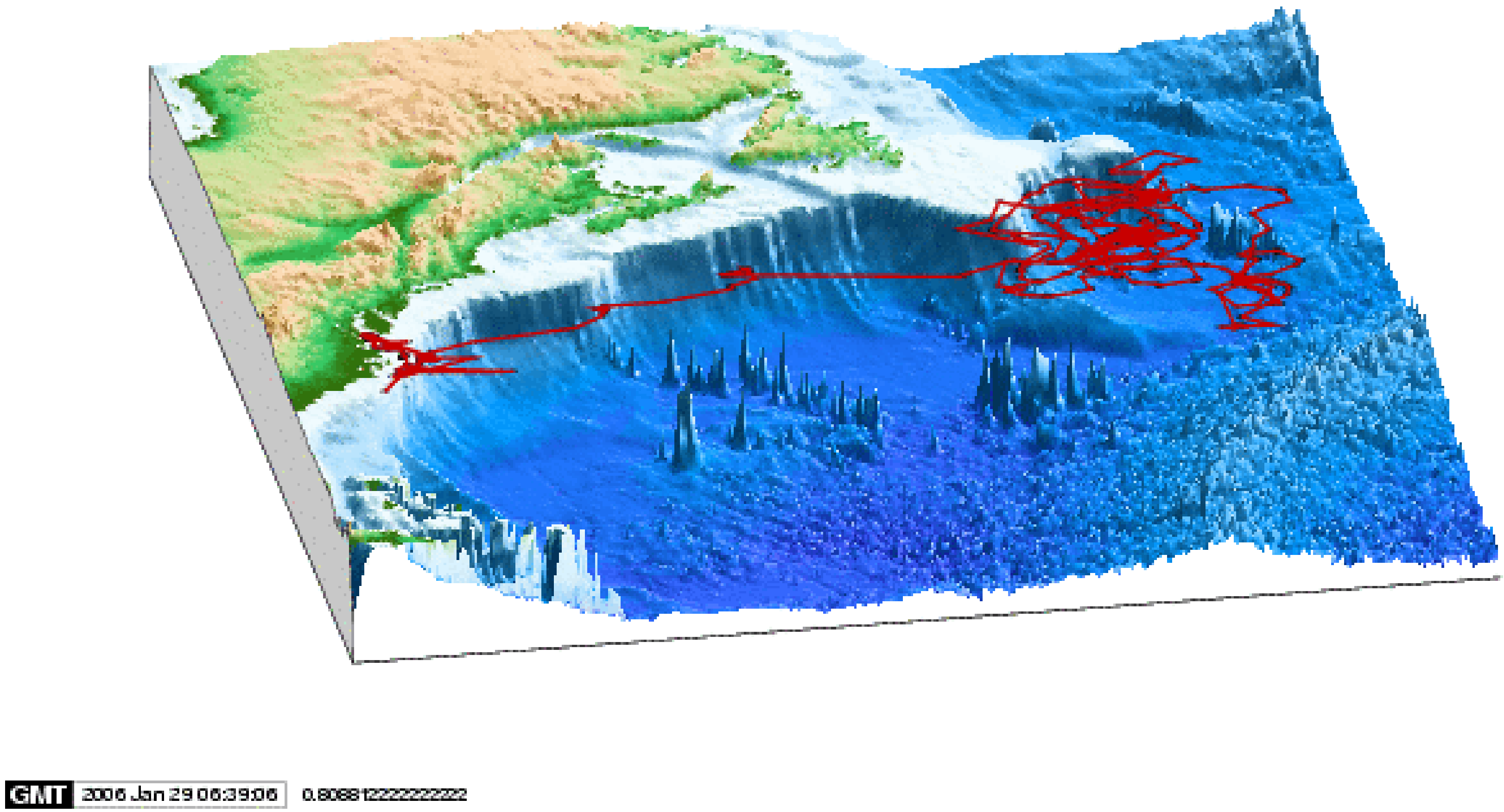


Figure 2.21 Satellite tracks of turtle #137 plotted on three-dimensional bathymetric contour layer generated in STAT (Coyne and Godley 2005).

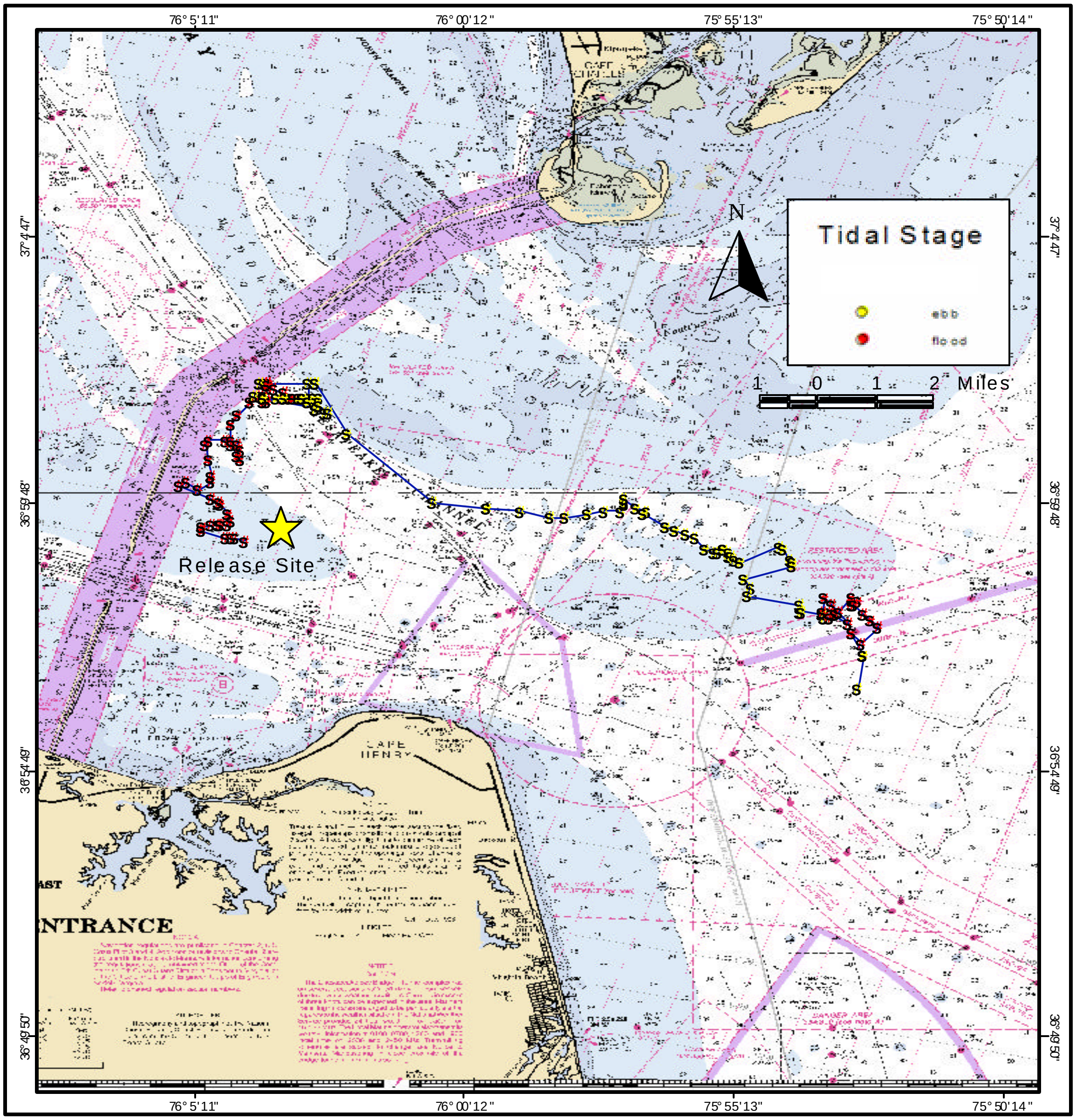
980.0 km from shore, averaging 461.6 km (+/- 265.2 km SD) from the nearest shoreline. Mean depth associated with the turtle's locations has been 3857.5 m (+/- 1675.1 m SD) (Table 2.7).

2003: Radio/Sonic Tag #205; Satellite Tag #11993

Loggerhead (juvenile, cold-stun rehabilitated turtle)

In early December 2005, Turtle #205 (XXT517) was found stranded from cold-stunning near Barnstable MA. This turtle was rehabilitated at the New England Aquarium and Virginia Aquarium and Stranding program prior to release on July 17, 2003. The turtle was released in 7.6 m of water on the ocean side of the CBBT, in the mouth if the Chesapeake Bay. From the point of release, the turtle swam north into the Chesapeake Bay Channel, parallel to and just east of the CBBT as the tide flooded (Figure 2.22). With the change in tide, the turtle moved with the ebb flow eastward to the Chesapeake Bay Light Tower where it remained through the night hours. The track was broken after 13 hours due to heavy fog and a high level of shipping traffic. At the time this turtle was released, surface temperatures were 23.7º C, and bottom temperatures were 21.6º C. At the Chesapeake Bay Light Tower, surface temperatures were 24.5º C, however, bottom temperatures were 11.7º C (data courtesy of the VIMS Longline Survey).

This turtle exhibited significantly directed movement ($z=11.7$; $n=153$; $r=0.3$) during its radio/acoustic track. Mean surface time during the day was 0:00:28 (+/- 0:00:29), and mean daytime dive time was 0:03:57 (+/-0:4:06). Minimum daytime surface and dive times were six seconds; maximum daytime surface and dive times were 0:02:00 and 0:23:34 respectively (Table 2.4). Mean nighttime surface time was 0:01:01



Yellow indicates ebb tide; red indicates flood tide

☆ **Star = start of track**

Figure 2.22 Post-release movements of turtle #205 radio tracked in the mouth of the Chesapeake Bay for 13-hours July 17 to 18, 2003. NOAA Chart 12221_1.

(+/-0:00:45); mean nighttime dive duration was 0:06:19 (+/-0:05:26). Minimum nighttime surface and dive times were six and eleven seconds respectively; maximum daytime surface and dive times were 0:02:45 and 0:20:56 (Table 2.4). During the 24-hour track, this turtle remained within the top meter of water 13.46% of the time (Table 2.3).

This turtle spent a significant period of track time within the shipping channels outside of the Bay mouth. As a result, the acoustic track had to be broken frequently to make way for military and commercial traffic. Sample size of depth data was minimal. The mean temperature recorded by the acoustic tag was 17.4º C (+/-0.89º C SD). Unfortunately, the long-term movements of this turtle could only be monitored remotely for approximately two weeks post-release due to failure of the satellite tag. The few days following release, the turtle remained in the entrance of the Chesapeake Bay, near the Chesapeake Bay Light Tower, after which it traveled south along the Outer Banks and Cape Hatteras. The last transmissions were received on July 30, 2003 offshore of Cape Hatteras (Figure 2.23). This track did not result in significant site fidelity or significance in travel direction. During its two-week track, the turtle remained within a SST range of 24º C to 29º C and a mean SST of 26.2º C (+/- 0.1º C SD) (Figure 2.24). Mean travel speed was 2.9 km/hr (+/- 4.2 km/hr SD). This turtle ranged up to 90.0 km from shore, averaging 7.7.6 km (+/- 13.5 km SD), and mean depth associated with the turtle's locations was 56.5 m (+/- 281.6 m SD) (Table 2.7).

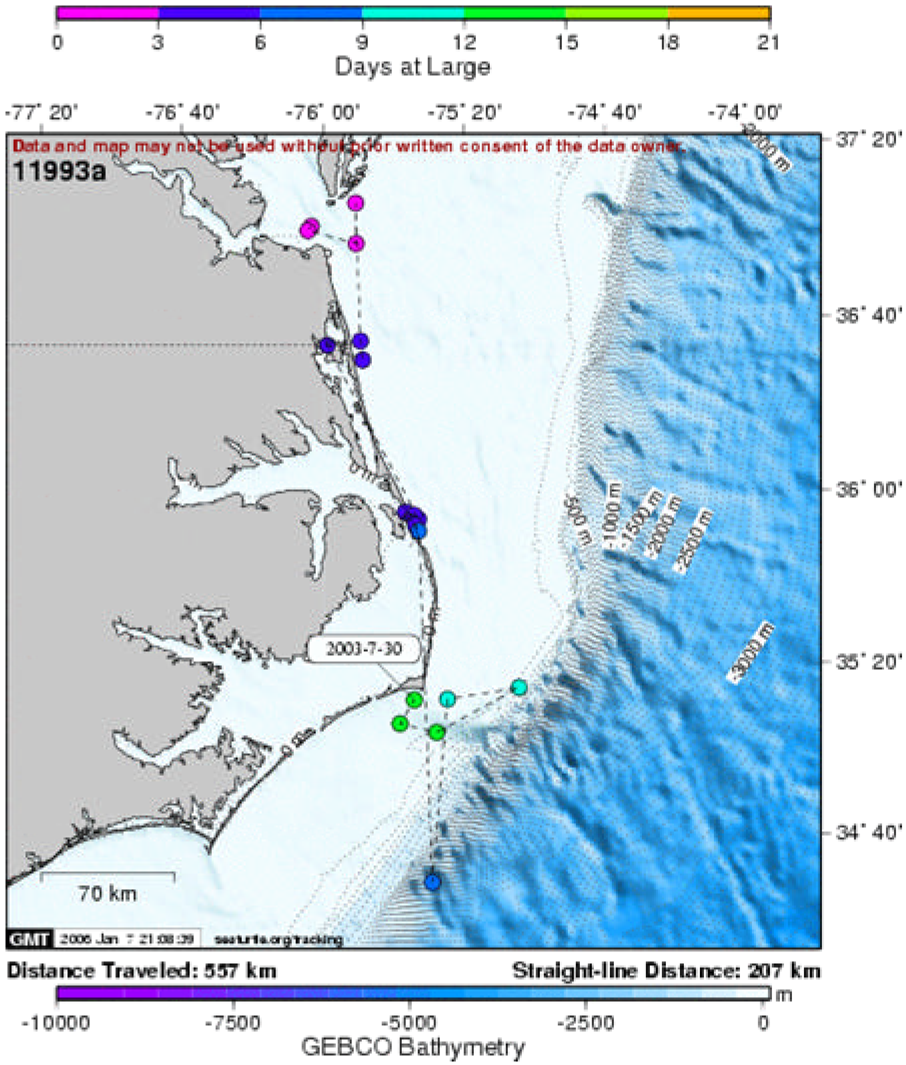


Figure 2.23 Satellite tracks of turtle #205 from July 17 to 30, 2003.

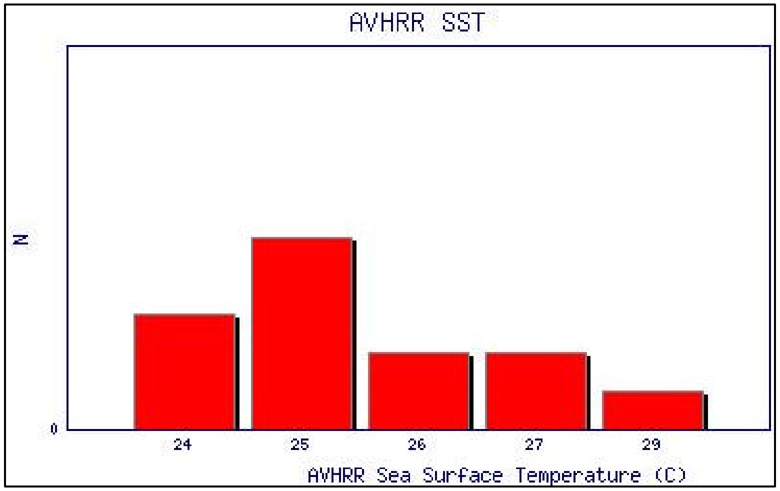
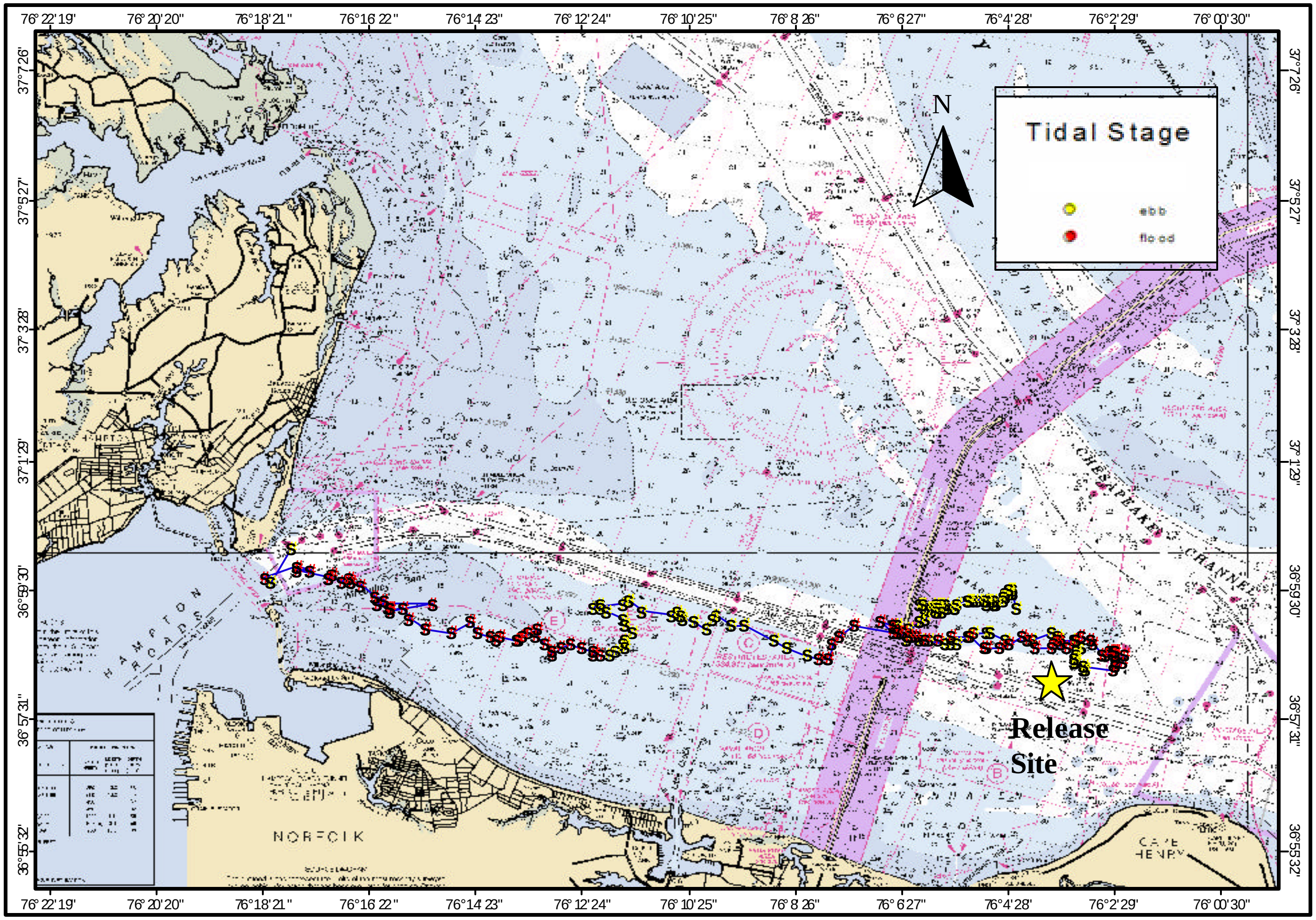


Figure 2.24 Frequency (N) of satellite telemetry locations for turtle #205 associated with AVHRR SST. Generated in STAT (Coyne and Godley 2005).

2003: Radio/Sonic Tag #138; Satellite Tag #11585

Kemp's ridley (juvenile, rehabilitated turtle)

Turtle #138 was hooked in its left front flipper by a fisherman off of the Little Island Fishing Pier in Virginia Beach. After rehabilitation, this turtle was released on July 31, 2003 south of the Chesapeake Channel and just north of the Thimble Shoals Channel on the ocean side of the CBBT. The turtle was released in 7.9 m of water. Turtle #138 was released on an ebb tide and initially moved with the tidal flow during the first two tidal periods, remaining just east of the CBBT and along the northern edge of the Thimble Shoals Channel and finally moving in to the Chesapeake Bay towards the end of the first flood tide (Figure 2.25). With the change back to ebb, the turtle exhibited directed movement (z=24.6; n=104; r=0.5) against the tide approximately due west, remaining on this course through the remainder of the 24-hour track. The turtle was last observed near the northern edge of the James River mouth. At the time of release, sea surface temperatures were approximately 22.6º C and bottom temperatures were 18.2º C. The mean time spent at the surface during the day was 54 seconds (+/- 0:00:52) and 00:01:14 (+/- 0:00:55) at night. Mean dive time was 0:03:44 (+/- 0:03:23) during the day and 0:08:37 (+/-0:04:08) at night (Table 2.4). During both the day and night, minimum surface times were six and seven seconds respectively, and maximum transmissions were 0:04:41 during the day, 0:06:22 at night. Minimum dive times were eight seconds during the day, 0:01:40 at night. Maximum dive times were 0:15:23 during the day and 0:23:29 at night (Table 2.4). This turtle spent 16.5% of its track time at the surface (Table 2.3). Based on acoustic data, the average depth this turtle could be found was 5.53 meters (+/- 3.03). The turtle spent more time in deeper waters (6 to 8 m) during the day than at night



1 0 1 Miles

Yellow indicates ebb tide; red indicates flood tide

☆ **Star = start of track**

Figure 2.25 Post-release movements of turtle #138 radio tracked in the mouth of the Chesapeake Bay for 24-hours July 31 to August 1, 2003. NOAA Chart 12221_1**.**

(4 to 6 m) (Figure 2.26). The average temperature where the turtle was found was 21.42º C (+/-2.27º C SD), reflecting the time the turtle spent in the warmer surface layer of water (Figure 2.27). The majority of the acoustic temperature data ranged between 16º C and 26º C, with a nighttime preference for temperatures between 23º C and 25º C (Figure 2.27).

The satellite tag attached to this turtle ceased transmitting after approximately one week due to probable tag failure. The recorded location for this turtle was in the mouth of the York River on August 8, 2003 (Figure 2.28). This track did not result in significant site fidelity or significance in travel direction. During its one-week track, the turtle remained within a SST range of 22º C to 25º C and a mean SST of 25.8º C (+/- 0.1º C SD) (Figure 2.29). Mean travel speed was 1.6 km/hr (+/- 2.9 km/hr SD). This turtle ranged up to 11.0 km from shore, averaging 4.4 km (+/- 3.2 km SD), and mean depth associated with the turtle's locations was 6.3 m (+/- 4.7 m SD) (Table 2.7).

2003: Radio/Sonic Tag #168

Kemp's ridley (juvenile, cold-stun rehabilitated turtle)

Turtle #168 originally stranded outside of Barstable, MA in November 2000 due to cold stunning. At the time of stranding, this turtle was approximately 27 cm curved carapace length (CCL). After initial treatment at the New England Aquarium, Turtle #168 was transferred to the Columbus Zoo for long-term rehabilitation. In 2003, this turtle was transferred to the Virginia Aquarium and Stranding Program's facilities in Virginia Beach, Virginia. Turtle #168 was released August 14, 2003 just south of the Chesapeake Channel on the ocean side of the CBBT (Figure 2.30). At this time, Turtle #168 grew to

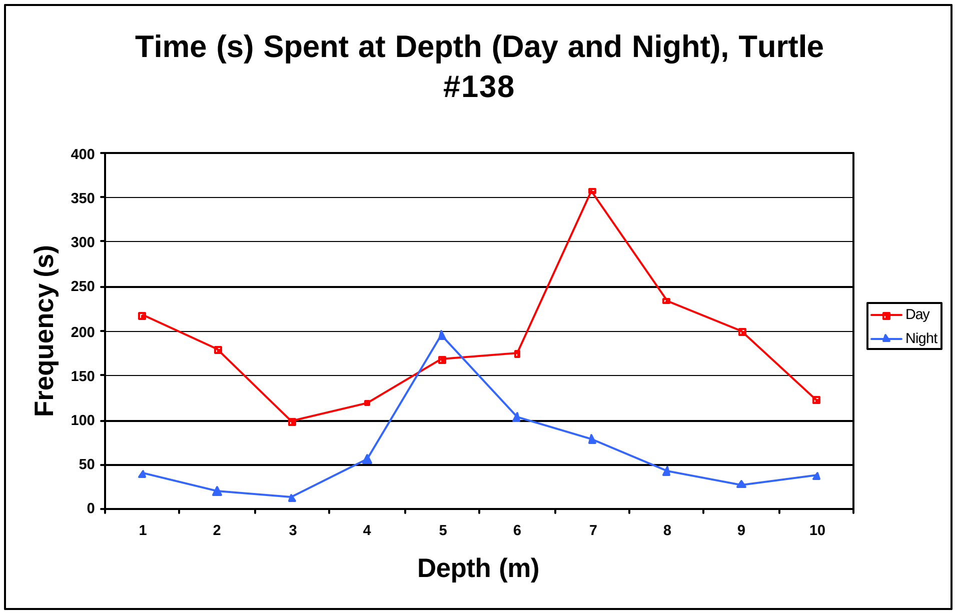


Figure 2.26 Frequency of time spent at different depths for turtle #138 (total track).

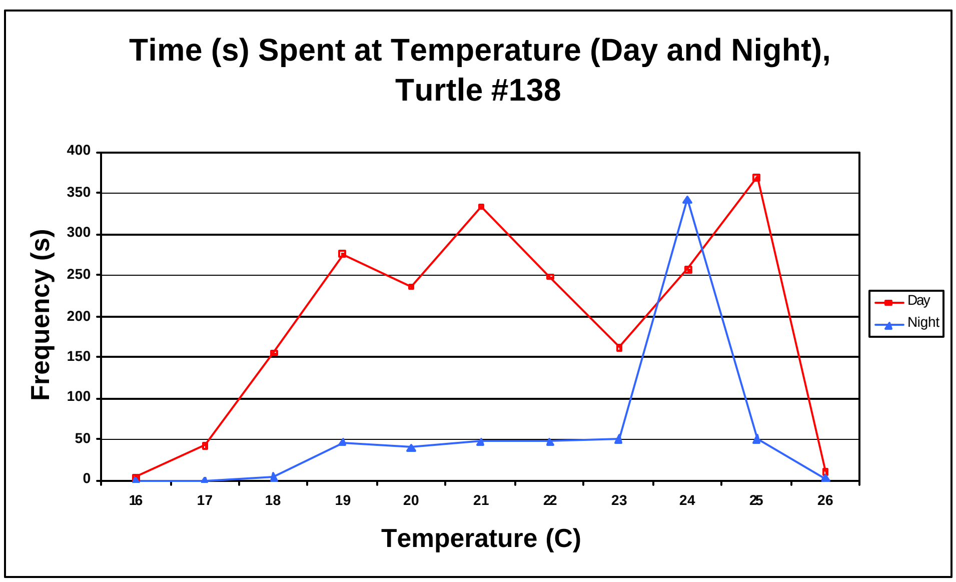


Figure 2.27 Frequency of time spent at different temperatures for turtle #138 (total track).

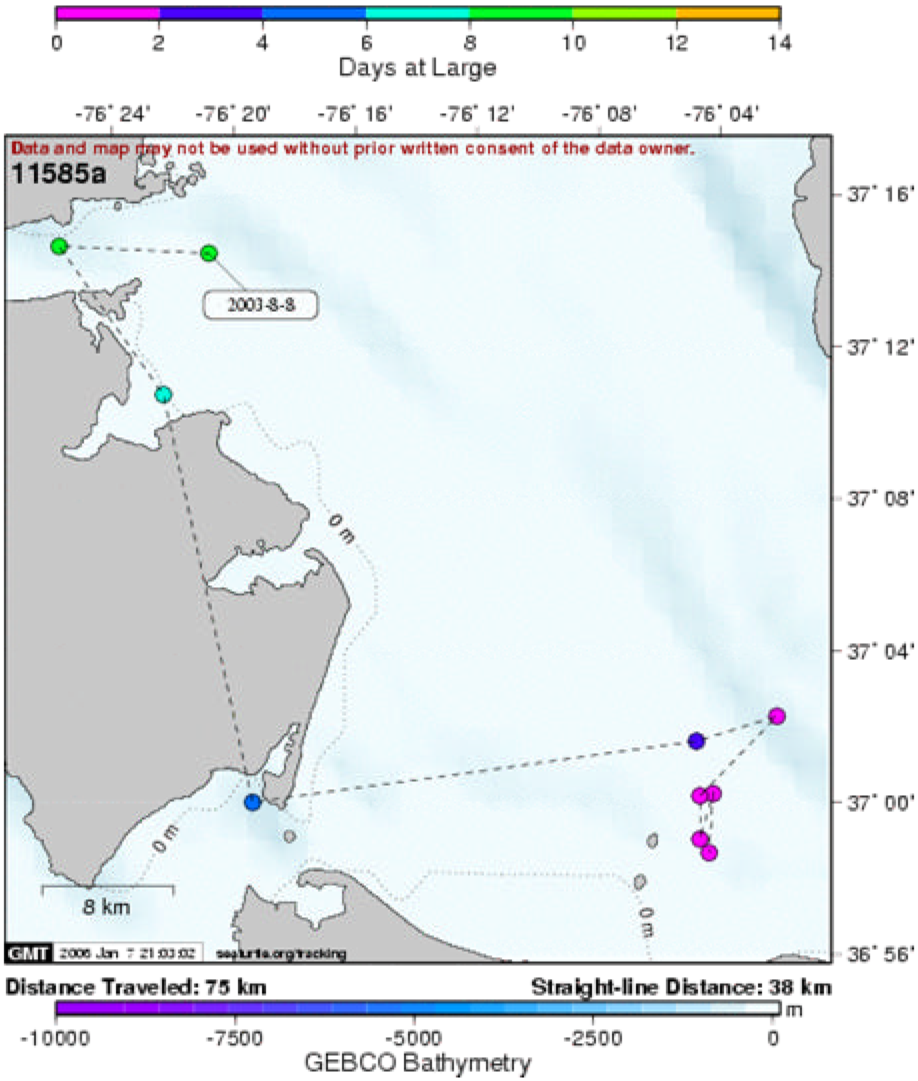


Figure 2.28 Satellite tracks of turtle #138 from July 31 to August 8, 2004.

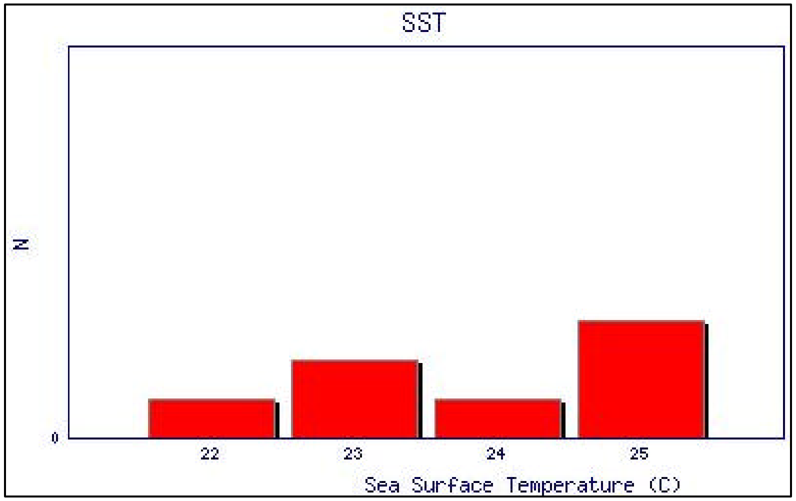
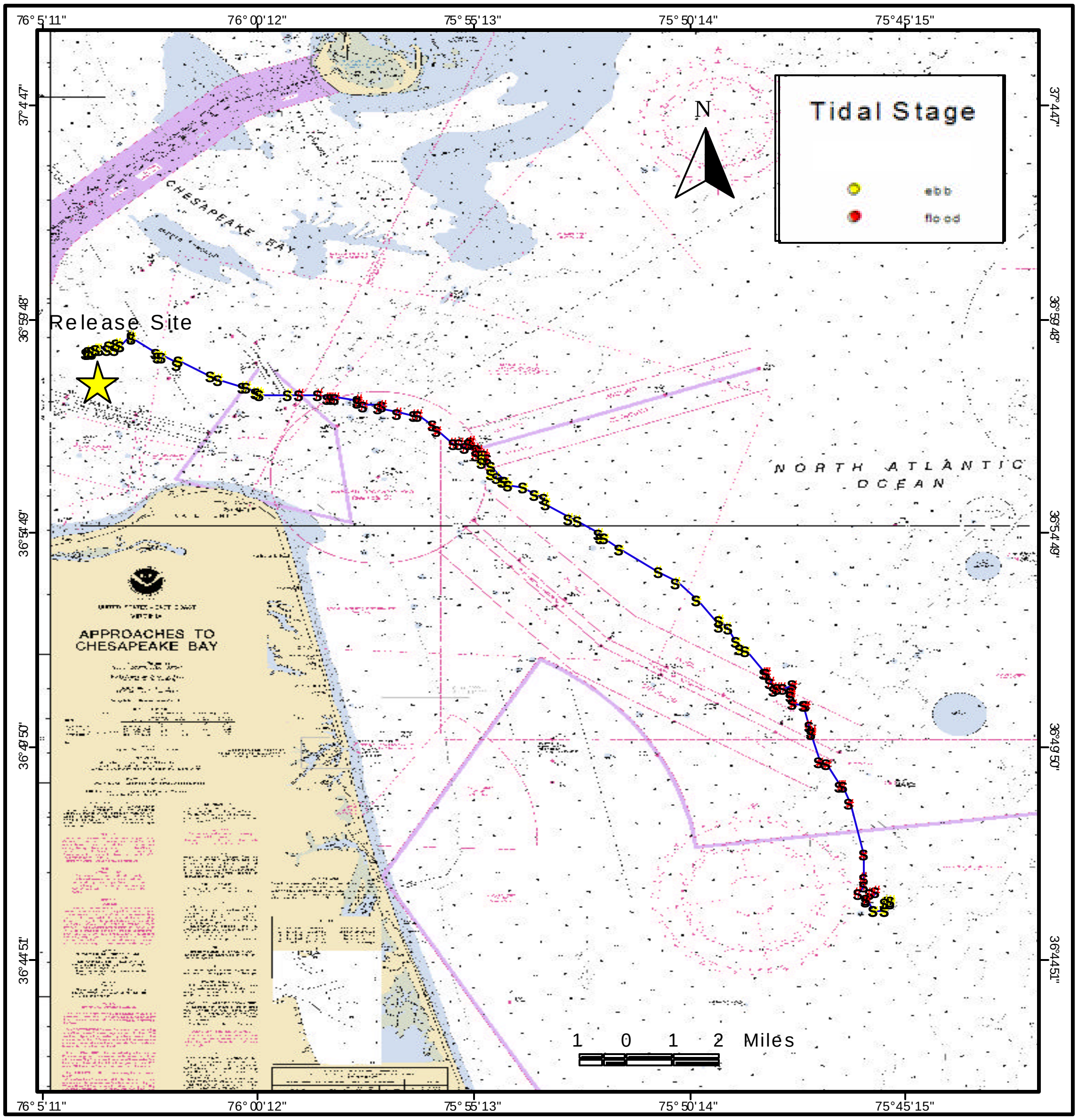


Figure 2.29 Frequency (N) of satellite telemetry locations for turtle #138 associated with AVHRR SST. Generated in STAT (Coyne and Godley 2005).



Yellow indicates ebb tide; red indicates flood tide

Star = start of track

Figure 2.30 Post-release movements of turtle #168 radio tracked in the mouth of the Chesapeake Bay for 24-hours August 14 to 15, 2003. NOAA Chart 12221_1**.**

50 cm CCL. The turtle was released into 7.6 m of water on an ebb tide. Upon release, the turtle exhibited directed movement (z=45.8; n=137; r^2=0.6), with and against the prevailing tidal flow, east and southeast out of the Bay mouth then south parallel to the Virginia Beach shoreline (Figure 2.30). After a 24-hour track, the turtle was last observed due east of Rudee Inlet.

At the release location, surface temperatures were 24.4º C, and bottom temperatures were 19.8º C. However, as the turtle moved south along the oceanfront, vertical sea temperature profiles became more stratified due to a coastal upwelling event. Towards the end of the track, surface temperatures were approximately 21.9º C and bottom temperatures were 10.4º C The mean time spent at the surface was 0:07:32 (+/- 0:11:26) during the day and 0:12:03 (+/- 0:03:21) at night. Mean dive time was 0:05:10 (+/- 0:06:20) during the day and 0:18:01 (+/-0:07:34) at night (Table 2.4). During the day and night, minimum surface times were five seconds and 0:06:34 respectively. Maximum duration of transmissions was 1:09:44 during the day, 0:18:11 at night. Minimum dive times were five and six seconds during the day and night. Maximum dive times were 0:23:00 during the day and 0:23:46 at night (Table 2.4). This turtle spent 49.19% of its time at the surface (Table 2.3).

Acoustic data indicated that the average depth this turtle could be found was 6.0 m (+/- 5.82m SD). Unlike Turtle #138, this turtle spent more time in deeper waters (11 to 15 m) during the night than during the day (7 to 8 m) (Figure 2.31). This may be an artifact of the turtle's movement into deeper shipping channels at night. The average temperature along the turtle's dive path was 19.9º C (+/-5.82º C SD). For the last two-thirds of this turtle's track, it was located in an area of coastal upwelling with a 19º C

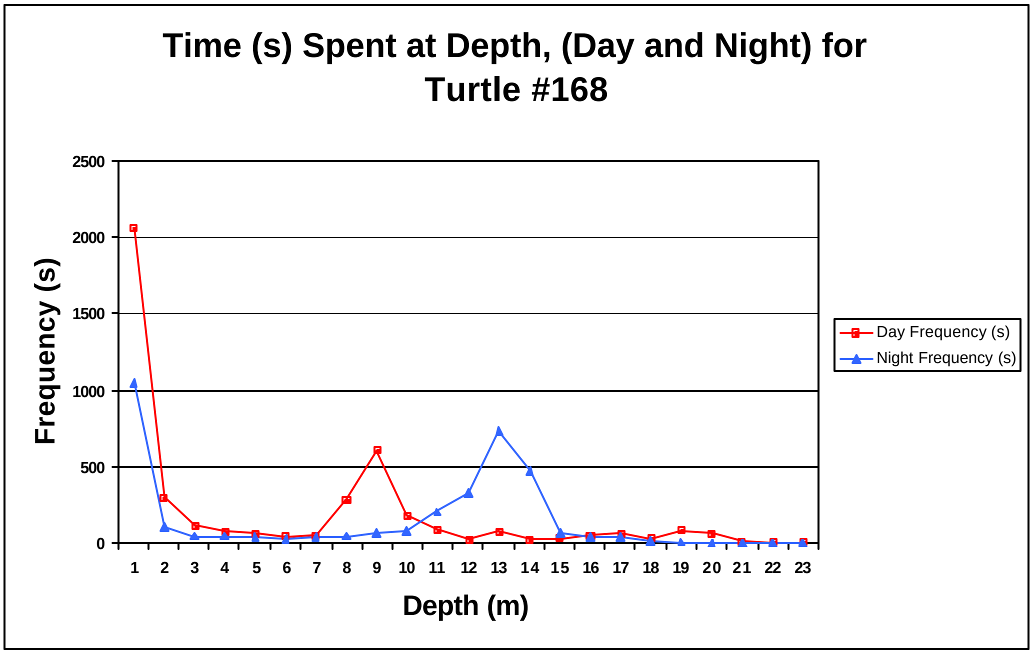


Figure 2.31 Frequency of time spent at different depths for turtle # 168, day vs. night.

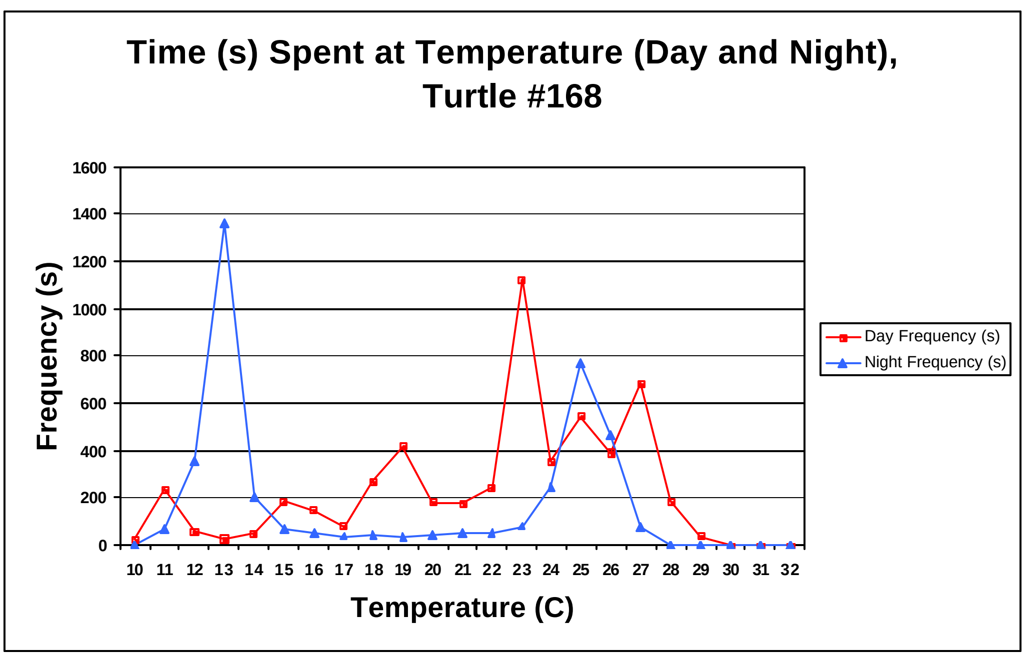


Figure 2.32 Frequency of time spent at different temperatures for turtle # 168, day vs. night.

thermocline occurring three meters below the surface of the water column. The acoustic temperature data ranged between 10º C and 32º C, though the higher end of this range may in part be due to the sonic tag being exposed to air and sunlight. During the night, the turtle spent the majority of its time either within the top three meters of surface waters in temperatures ranging between 23º and 26º C, or within the bottom few meters in temperatures ranging between 11º C and 15º C (Figure 2.32).

The satellite track of this animal continued through July 4, 2004. Immediately post-release, this turtle exhibited directed movement (z=12.4; n=123; r=0.3) south along the Atlantic coastline until approximately mid-January 2004 when it reached the waters off of central Florida where it remained until July 2004 (Figure 2.33). Mean SST for this track was 23.7° C (+/- 3.4° C SD) and SSTs ranged between 15° C and 30° C (Table 2.8 and Figure 2.34). Mean travel speed was 2.3 km/hr (+/- 3.1 km/hr SD) and the turtle remained an average 15.4 km (+/- 20.4 km SD) from shore during its entire migration south (Table 2.7). Average depths encountered by the turtle were 15.4 m (+/- 14.0 km SD), ranging up to 109.0 m (Table 2.7). Average direction of travel was 147° (+/- 85° SD).

2003: Satellite Tag #41335

Loggerhead (juvenile, rehabilitated turtle)

In August 2003, Turtle #41335 (XXT526) stranded off of Virginia's Eastern Shore. This turtle was discovered floating and unable to dive. Turtle #41335 was released after rehabilitation on October 22, 2003 from Back Bay National Wildlife Refuge. For the first week after release, the turtle remained off of the southern Virginia coastline,

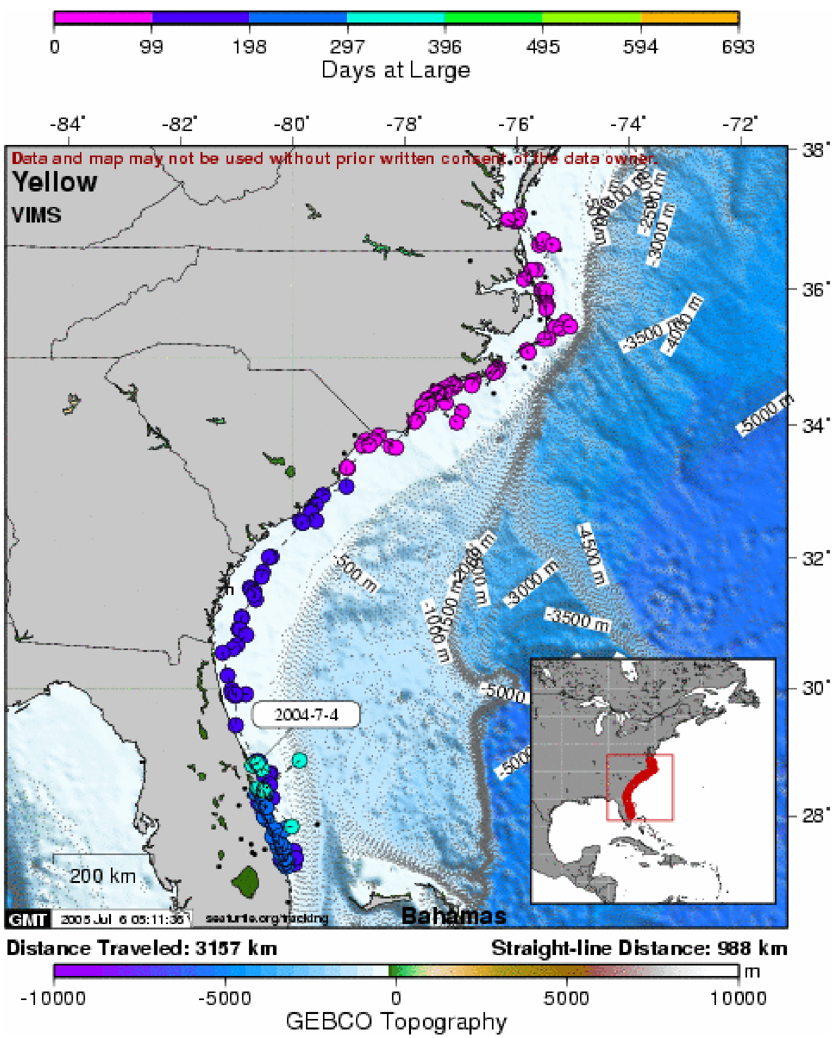


Figure 2.33 Satellite tracks of turtle #168 from August 18, 2003 to July 4, 2004.

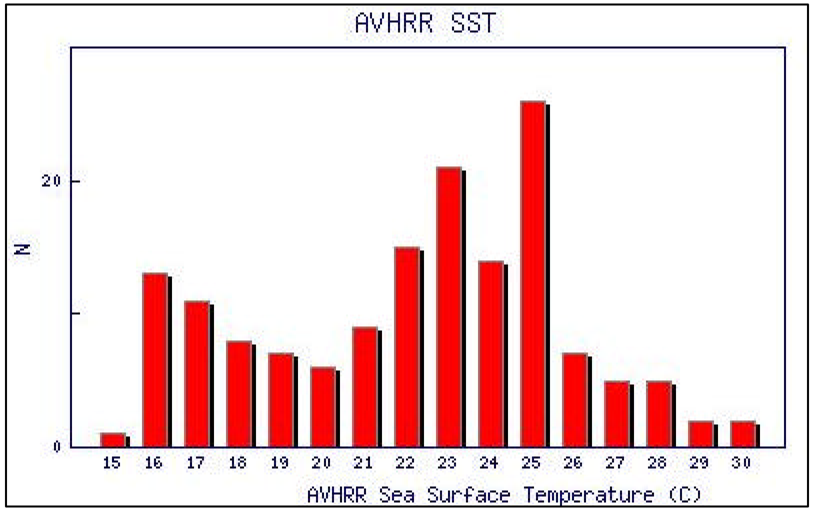


Figure 2.34 Frequency (N) of satellite telemetry locations for turtle #168 associated with AVHRR SST. Generated in STAT (Coyne and Godley 2005).

\moving south off of the northern North Carolina coast by the first week in November (Figure 2.35). Tests for site fidelity and significance of movement were inconclusive. The satellite tag ceased transmitting by November 6, 2003. During its two-week track, the turtle remained within a SST range of 18º C to 21º (Figure 2.36). The majority of movement occurred within waters with depths averaging 19.1 m (+/- 6.5 m SD) (Table 2.7). This turtle ranged up to 185 km from shore, averaging 27.2 km +/- 30.8 km SD) (Table 2.7).

2003: Satellite Tag #41336

Loggerhead (juvenile):

Turtle #41335 (QQN709) was previously flipper tagged and released after rehabilitation in 2001 by the National Marine Fisheries Service and Topsail Marine Turtle Hospital in North Carolina after stranding due to difficulty diving. This turtle was recaptured in Virginia's waters in early October, 2003 by relocation trawler operating in the vicinity of the Thimble Shoals Dredge Operations. The turtle was transferred to the Virginia Marine Science Museum for observation, after which it was released with a satellite tag on October 22, 2003 from Back Bay National Wildlife Refuge. Initially, the turtle moved just south of the Virginia/North Carolina border, then north, to an area due east of the Chesapeake Bay mouth and southern Eastern Shore. By mid-November, the turtle started moving south, eventually making its way to Cape Hatteras by late November, when the tag ceased transmitting (Figure 2.37). Tests for site fidelity and direction of movement were not significant. During the four and a half week track, the turtle remained within a SST range of 16º C to 25º C, with a concentration of movement

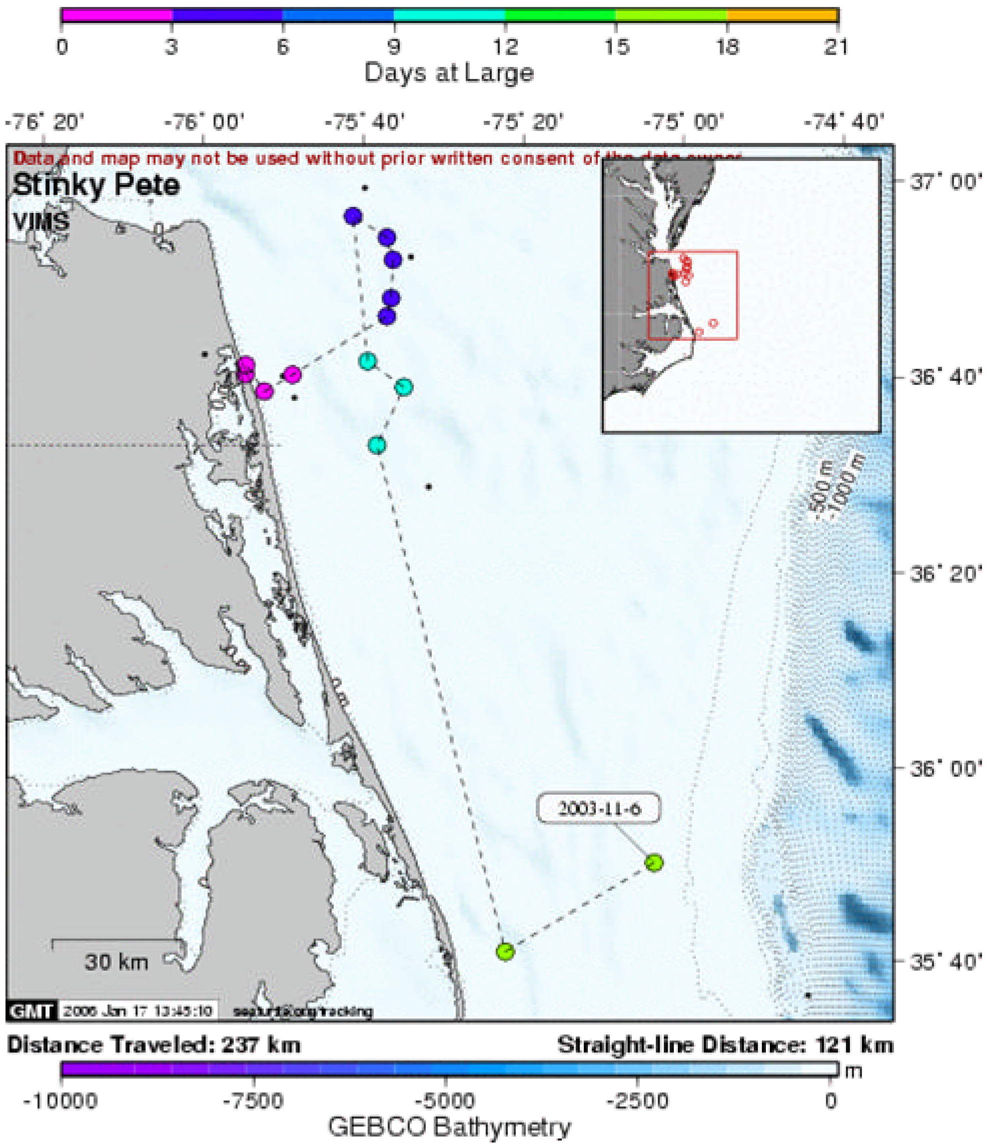


Figure 2.35 Satellite tracks of turtle #41135 from October 22 to November 6, 2003

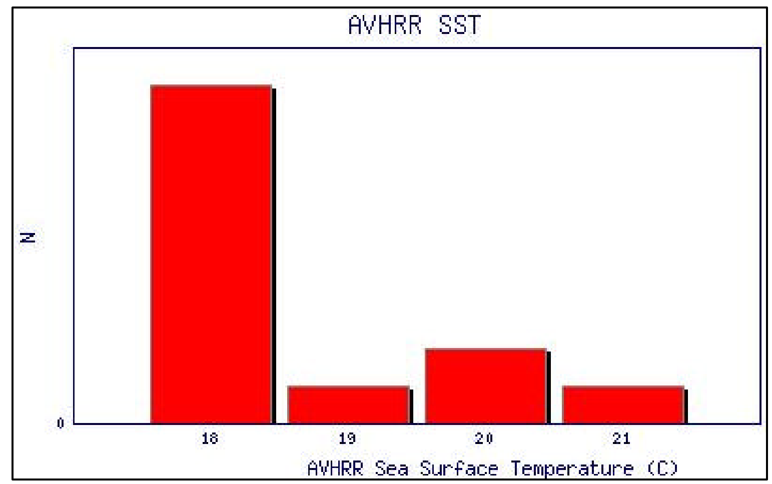


Figure 2.36 Frequency (N) of satellite telemetry locations for turtle #41335 associated with AVHRR SST. Generated in STAT (Coyne and Godley 2005).

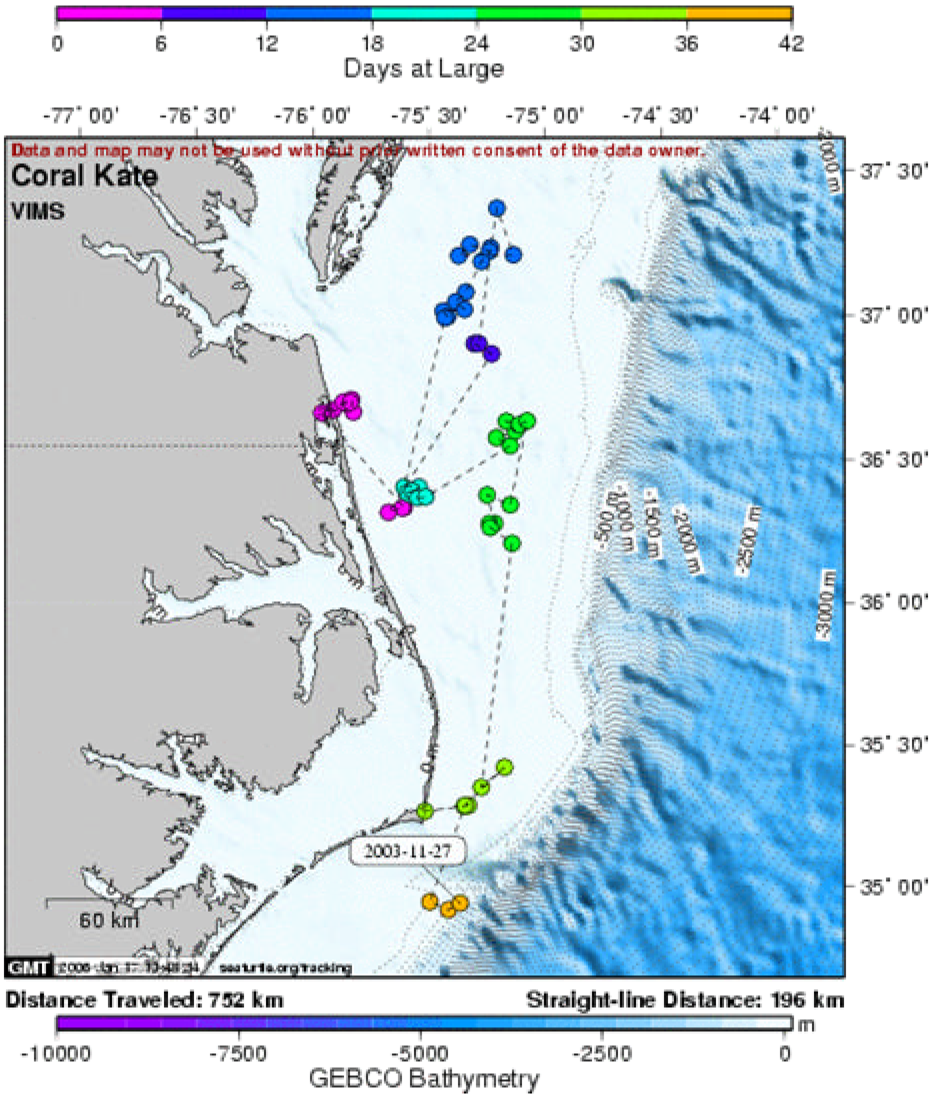


Figure 2.37 Satellite tracks of turtle #41136 from October 22 to November 27, 2003.

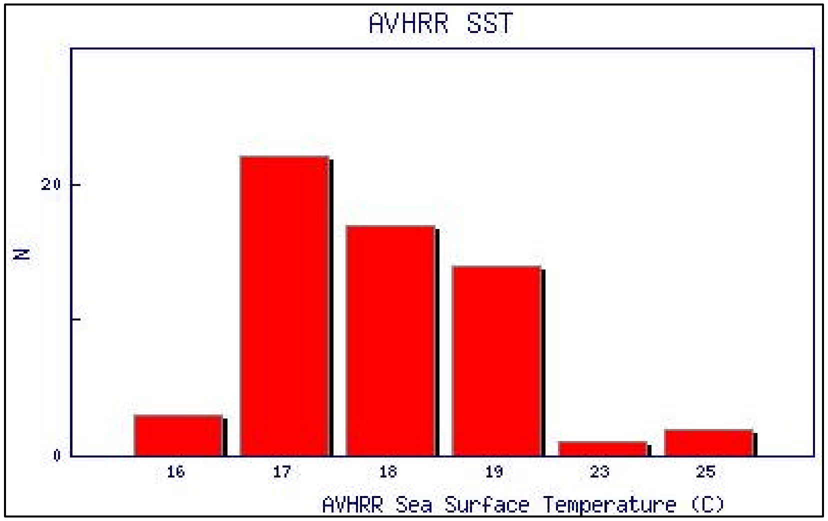


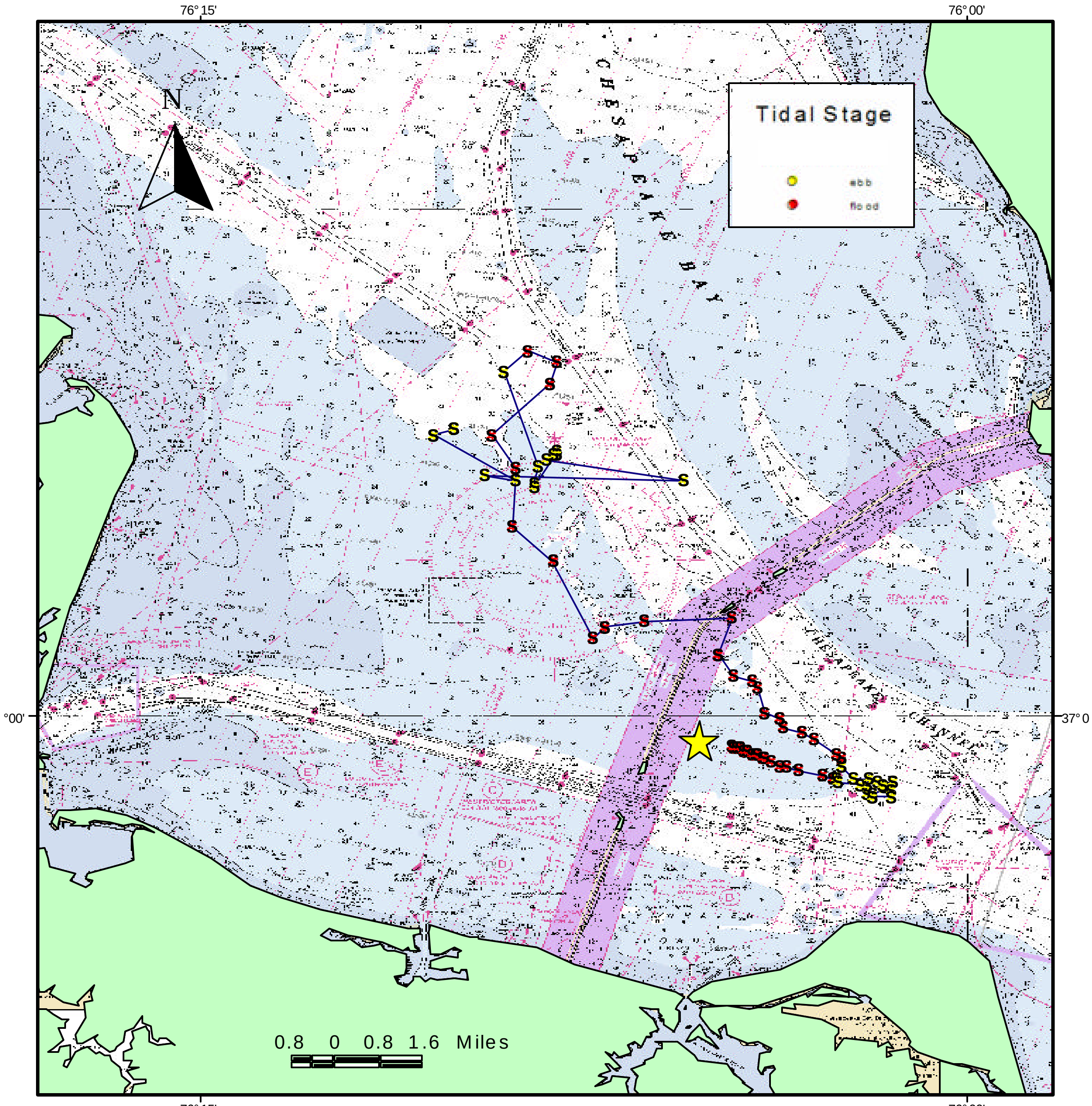
Figure 2.38 Frequency (N) of satellite telemetry locations for turtle #41336 associated with AVHRR SST. Generated in STAT (Coyne and Godley 2005).

within 17º C to 19º C (Figure 2.38). The majority of movement occurred within waters with depths averaging 19.1 m (+/- 6.5 m SD). This turtle ranged up to 72 km from shore, averaging 32.2 km +/- 20.0 km SD) (Table 2.7).

2004: Radio/Sonic Tag #147; Kemp's ridley (juvenile):

Turtle #147 (SSV626) was released June 3, 2004 in 7.9 m of water on the eastern side of the CBBT. The turtle was released on a flood tide in one-foot seas. The turtle initially swam east of its release location remaining in the Chesapeake Channel through the change of the next tidal cycle. On the following flood tide, it swam northwest into the Bay, remaining within or along the western edge of the Chesapeake Channel for the remainder of its track (Figure 2.39). This turtle was tracked for approximately twenty-four hours and did not exhibit a significant travel direction. This turtle spent 13.7% of its time at the surface (Table 2.3).

At the time of release, surface temperatures were approximately 21.9º C, and bottom temperatures were approximately 17.6º C. The mean daytime surfacing time for this turtle was 0:03:47 +/- 0:07:06 standard deviation (SD). The mean daytime dive period was 0:10:53 (+/- 0:15:13). The mean nighttime surfacing time for this turtle was 0:30:48 (+/- 0:28:00 SD) and the mean nighttime dive period was 0:05:10 (+/- 0:01:07 SD). Minimum daytime surfacing and dive times were 0:00:06; maximum daytime surfacing time was 0:37:06. Maximum daytime dive time was 1:08:13 (Table 2.5). During the successful twenty-four hour track, this turtle remained at the surface 13.7% of the time (Table 2.3). Based on acoustic data, the average depth this turtle could be found was 9.63 m (+/- 15.08 m SD) (Figure 2.40). The average temperature was 19.26º C (+/-



Yellow indicates ebb tide; red indicates flood tide

☆ **Star = start of track**

Figure 2.39 Post-release movements of turtle #147 radio tracked in the mouth of the Chesapeake Bay for 24-hours June 3-4, 2004. NOAA Chart 12221_1**.**

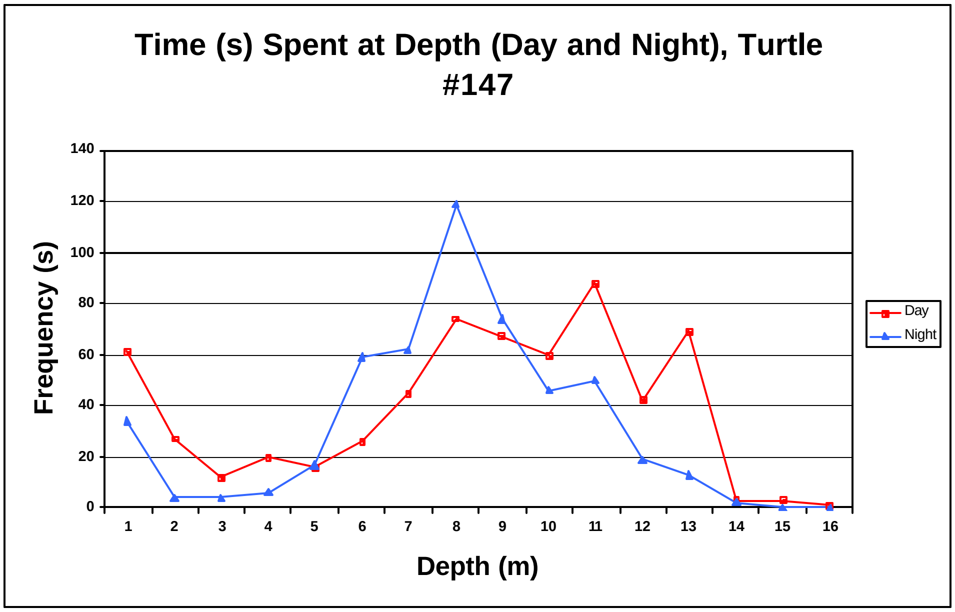


Figure 2.40 Frequency of time spent at different depths for turtle # 147, day vs. night

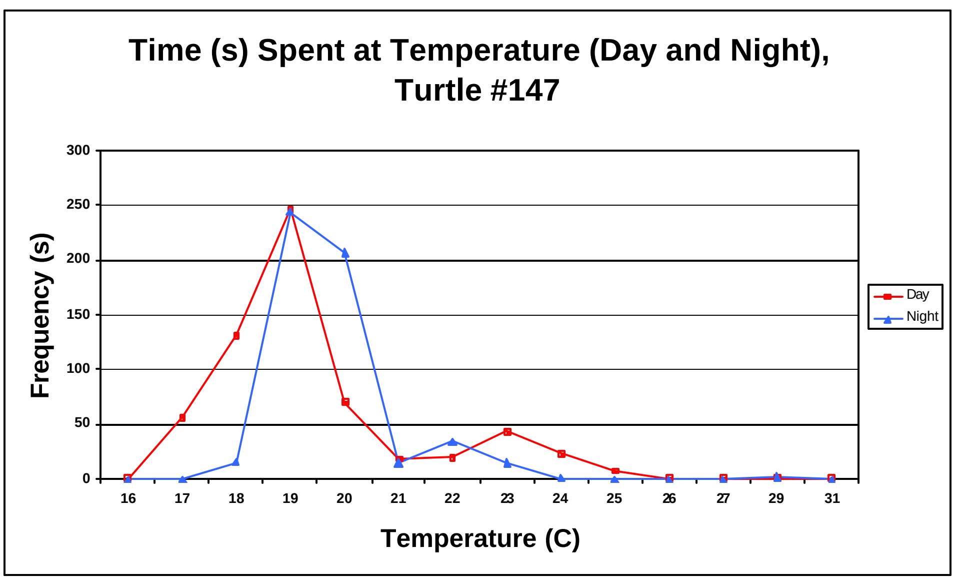


Figure 2.41 Frequency of time spent at different temperatures for turtle # 147, day vs. night.

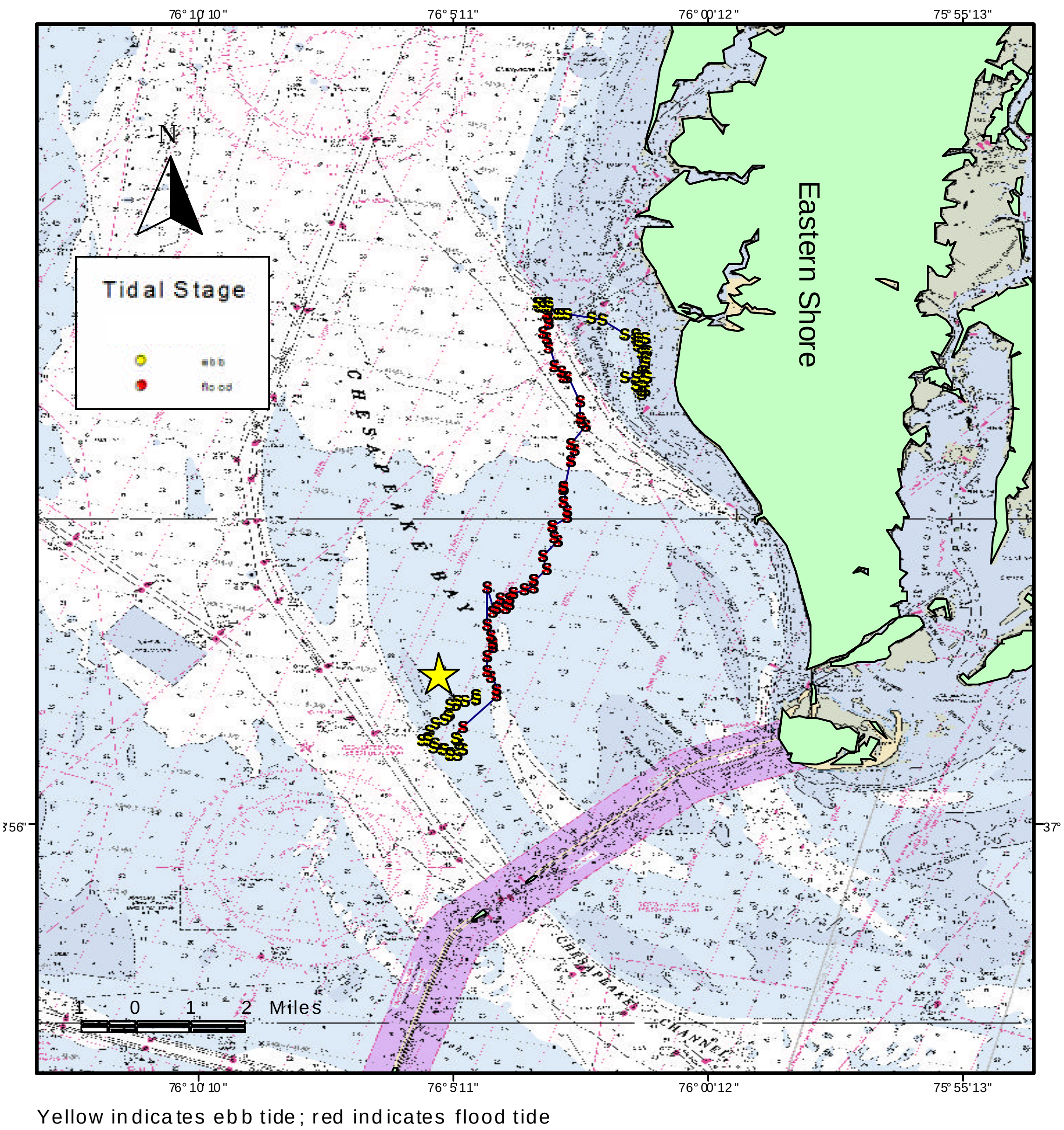
3.58º C SD) (Figure 2.41). Temperature and depth ranges varied little between day and nighttime hours.

2004: Radio/Sonic Tag #195

Kemp's ridley (juvenile):

Turtle #195 (XXF738) was released June 29, 2004 just to the east of the Chesapeake Channel, on the Bay side of the CBBT. The turtle was released inside the Bay due to higher seas generated by westerly winds on the ocean side of the CBBT. The turtle was released into 8.2 m of water in an ebb tide with zero to one-foot seas. This turtle remained on Middle Ground with the ebb tide, moving north and east into the Bay with the flood tide. This turtle remained close to shore near Cape Charles most of the night (Figure 242). With sunrise, a severe thunderstorm developed and the track was terminated after approximately 14 hours. This turtle exhibited directed movement (z=4.4; n=168; r=0.2), particularly with the flood tide, and spent 16.6% of its time at the surface (Table 2.3).

When Turtle #195 was released, surface temperatures were approximately 24.4º C, and bottom temperatures were approximately 23.1º C. The mean time spent at the surface was 0:01:19 (+/- 0:01:37 SD) during the day and 0:02:23 (+/- 0:05:23 SD) at night. Mean dive time was 0:02:45 (+/- 0:02:17) during the day and 0:04:06 (+/-0:05:46) at night (Table 2.5). During both the day and night, minimum surface times were six seconds (or one transmission from the radio tag); maximum length of transmissions was 0:08:08 during the day, 0:30:15 at night. Minimum dive times were 6 seconds during the day and 12 seconds at night; maximum dive times were 0:10:59 during the day and 0:32:40 at night (Table 2.5). Based on acoustic data, the average depth this turtle could be



Star = start of track

Figure 2.42 Post-release movements of turtle #195, radio tracked in the mouth of the Chesapeake Bay for 14-hours June 29-30, 2004. NOAA Chart 12221_1**.**

found was 5.18 m (+/- 7.99 m SD) and the average temperature was 24.1º C (+/-1.26º C SD).

2004: Radio/Sonic Tag #170

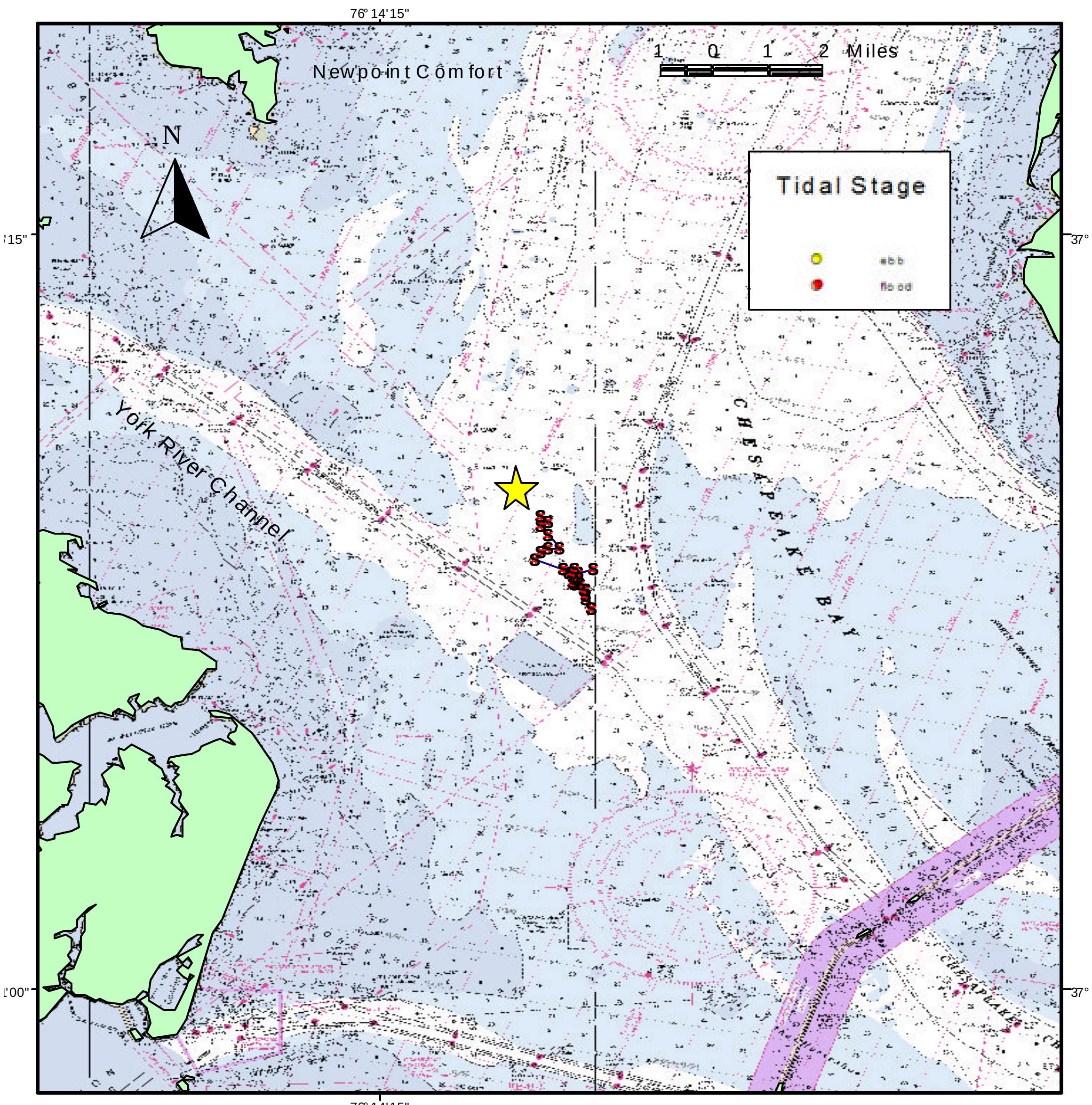
Kemp's ridley (juvenile)

Turtle #170 (XXF774) was released July 6, 2004 in 11.3 m of water on a flood tide between the York Spit Channel and York River Channel. This turtle was only successfully tracked for a total of four hours due to a very strong thunderstorm with 55+ miles an hour wind and five to six foot seas that formed late afternoon. Due to this storm, the VIMS vessels operations required that we return to dock. For the duration of this track, the turtle remained fairly close to its release location (Figure 2.43). At the time of release, surface temperatures were 26.8º C, and bottom temperatures were 22.6º C. Mean surface time during the day was 0:00:57 (+/-0:01:14), and mean daytime dive time was 0:06:08 (+/-0:11:44). Minimum daytime surface and dive times were six seconds; maximum daytime surface and dive times were 0:06:06 and 1:00:18 respectively (Table 2.5). During the 4-hour track, this turtle spent 59.8% of the time at the surface (Table 2.3). Based on acoustic data, the average depth this turtle could be found was 5.84 m (+/- 4.49 m SD) and the average temperature was 27.1º C (+/-2.70º C SD).

2004: Radio/Sonic Tag #141

Loggerhead (juvenile, rehabilitated turtle)

Turtle #141 ((XXT538) was found in June 2004 off of Northampton County on the Eastern Shore. At the time of stranding, this turtle was unable to dive. Turtle #141



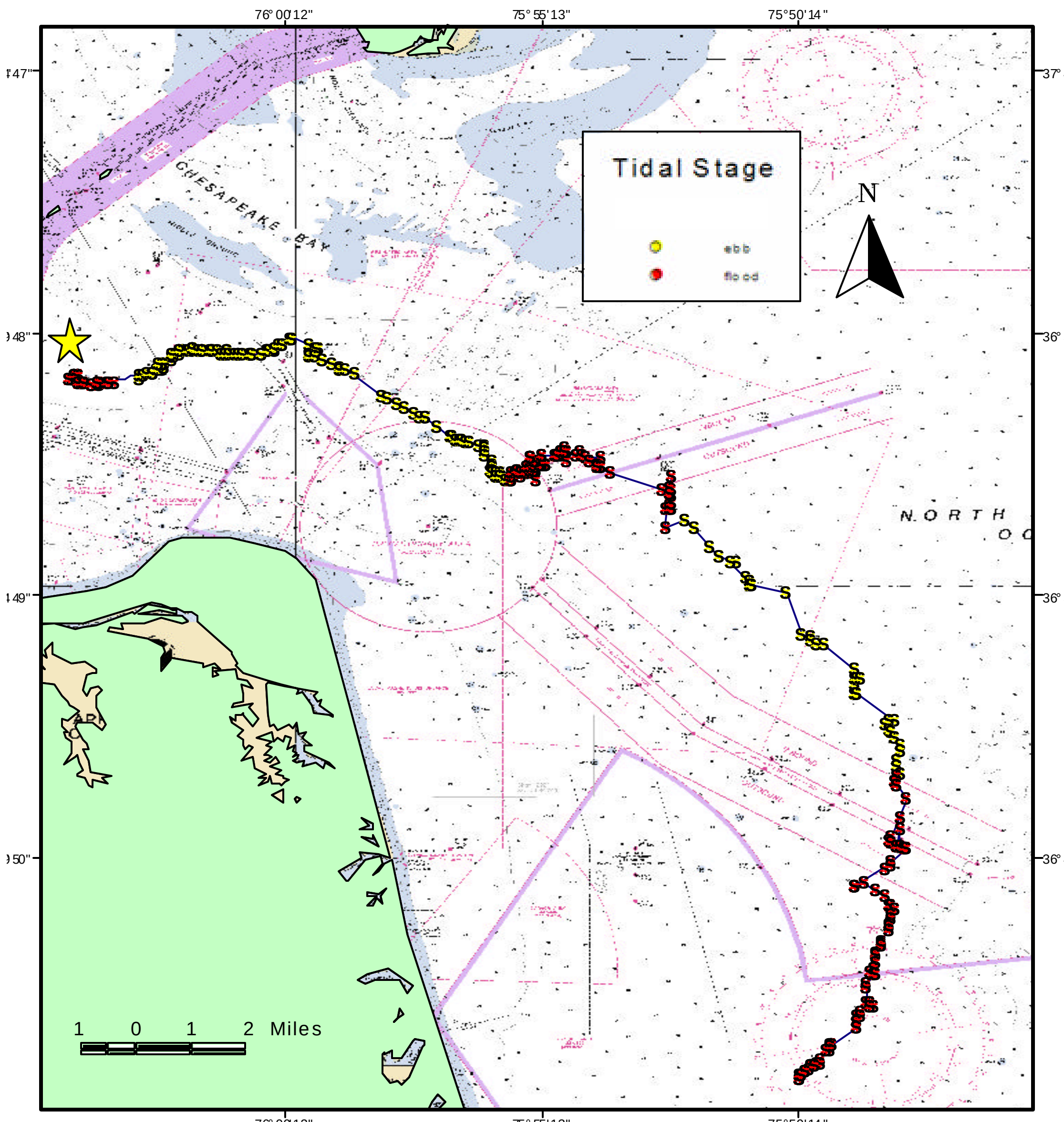
Yellow indicates ebb tide; red indicates flood tide

Star = start of track

Figure 2.43 Post-release movements of turtle #170, radio tracked off the York Spit and York River Channel for 4-hours July 6, 2004. NOAA Chart 12241_1.

was rehabilitated and released on July 21, 2004 south of the Chesapeake Channel and just north of the Thimble Shoals Channel on the ocean side of the CBBT. The turtle was released in 7.6 m of water on a flood tide. Turtle #141 initially headed eastward against the tidal flow (Figure 2.44). When the tides changed to ebb, the turtle moved with the current eastward towards the ocean and moved against the subsequent flood tide. Once clear of Cape Henry, the turtle continued its movements east and south along the coastline of Virginia Beach (Figure 2.44). This turtle exhibited directed movement exhibited directed movement (z=39.6; n=294; r=0.4) throughout its observed track and was tracked for a total of 24-hours. The turtle was last observed off of Virginia Beach heading south.

At the time of release, sea surface temperatures were approximately 27.3º C and bottom temperatures were 21.1º C. The mean time spent at the surface during the day was eight seconds (+/- 0:00:33) and 45 seconds (+/- 0:01:07 SD) at night. Mean dive time was ten seconds (+/- 0:01:51) during the day and 0:05:41 (+/-0:07:34) at night (Table 2.5). During both the day and night, minimum surface times were six seconds, and maximum surface times were 0:01:40 during the day, 0:05:11 at night. Minimum dive times were six seconds during the day, nine seconds at night. Maximum dive times were 0:13:56 during the day and 28:10 at night (Table 2.5). During the 24-hour track, this turtle spent 12.3% of its time within the upper meter of the water column (Table 2.3). Acoustic data indicated that the average depth of this track was 6.25 m (+/- 7.40 m SD) and the average temperature was 20.96º C (+/-5.38º C SD). This turtle spent a greater time in deeper, cooler waters at night versus the day, however, this may be due in part to the available depths associated with the turtle's locations (Figures 2.45 and 2.46).



Yellow indicates ebb tide; red indicates flood tide

☆ **Star = start of track**

Figure 2.44 Post-release movements of turtle #141, radio tracked in the mouth of the Chesapeake Bay for 24-hours July 21 to 22, 2003. NOAA Chart 12221_1.

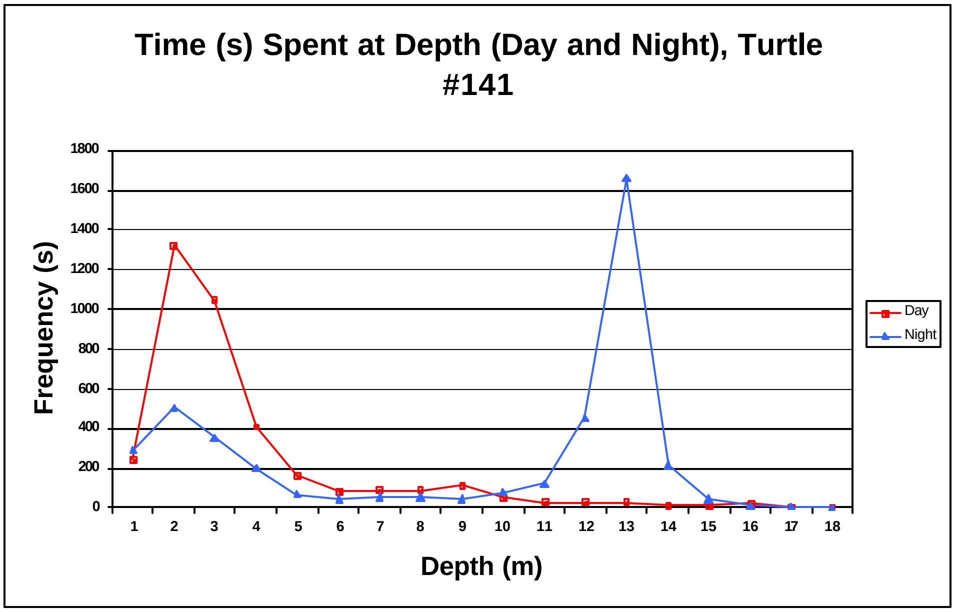


Figure 2.45 Frequency of time spent at different depths for turtle # 141, day vs. night.

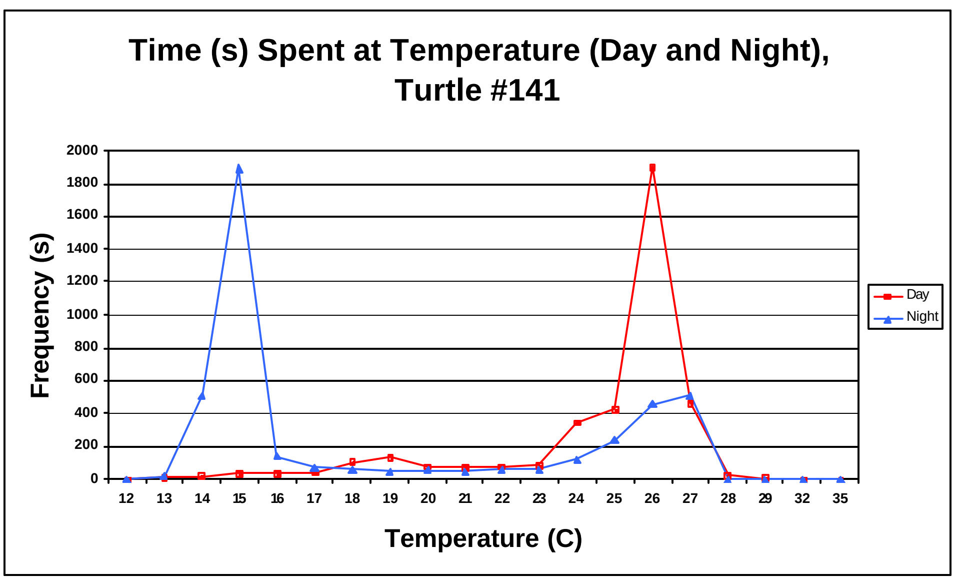


Figure 2.46 Frequency of time spent at different temperatures for turtle # 141, day vs. night.

2004: Satellite Tag #10378

Loggerhead (juvenile)

Turtle #10378 (XXF706) was released on June 10, 2004 from the VIMS beach in the York River. Locations for this turtle were not transmitted for almost two weeks post-release, perhaps due to infrequent surfacing events or short periods spend at the surface. Approximately two weeks post-release, the turtle was observed off of Chincoteague and Assateague along the ocean side of the Eastern Shore of Virginia and Maryland (Figure 2.47). The turtle remained in this area until the fall when temperatures dropped, after which it swam south to Cape Hatteras where it remained until the tag ceased transmitting May 19, 2005. Turtle #10378 established its winter habitat just south of Cape Hatteras, along the outer shelf area and just inside the western edge of the Gulf Stream (Figure 2.47). This turtle did not exhibit a significant travel direction, nor did it exhibit significant fidelity to a particular region, either off the Eastern Shore or in its winter habitat. The turtle remained within a SST range of 9º C to 26º C, averaging 19.5º C (+/- 4.0º C SD) (Figure 2.48; Table 2.8). Sea surface temperatures during the turtle's southern migration were between 15º C and 20º C. The majority of fall movement occurred within waters with depths ranging between 25 to 50 m and average depths along the track were 26.9 m (+/- 9.7 m SD). This turtle ranged up to 163 km from shore and traveled at an average speed of 2.6 km/hr (+/- 2.8 km/hr SD) (Table 2.7).

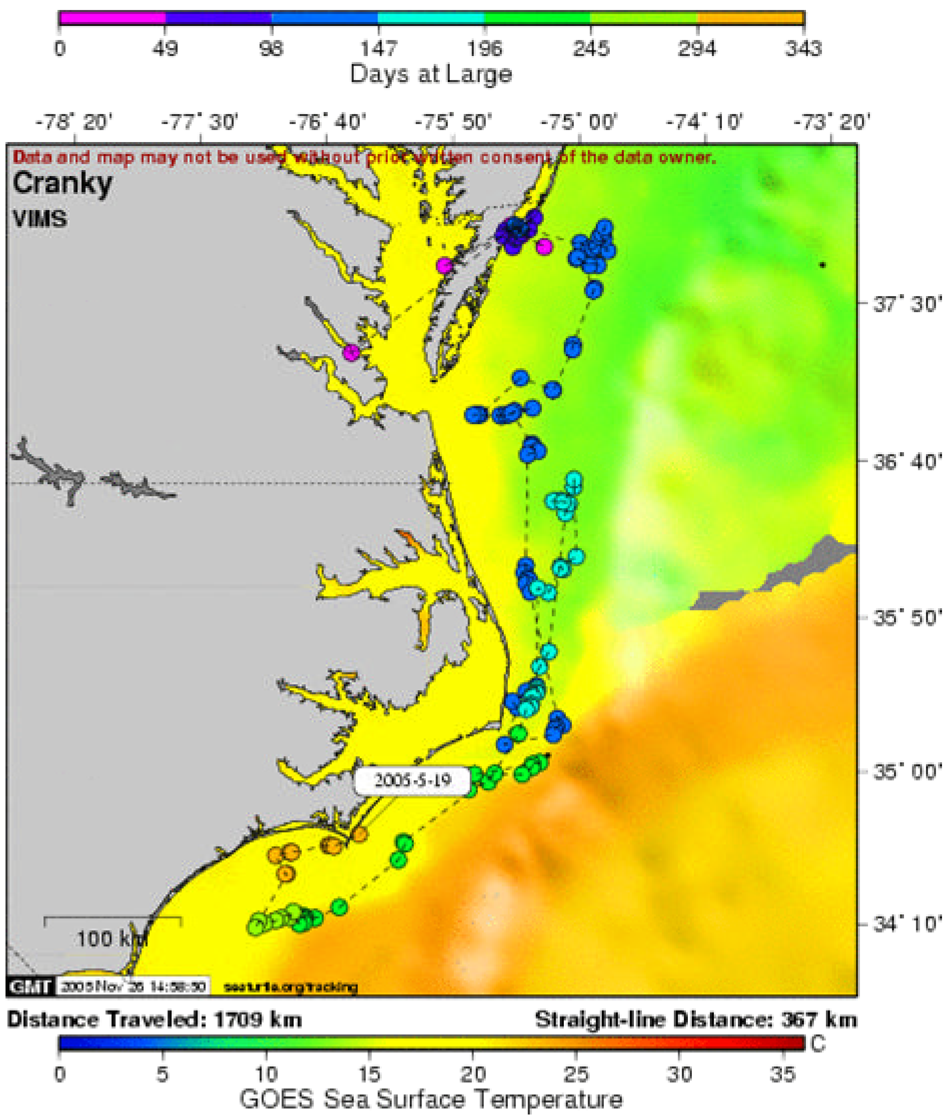


Figure 2.47 Satellite tracks of turtle #10378 from June 10, 2004 to May 19, 2005.

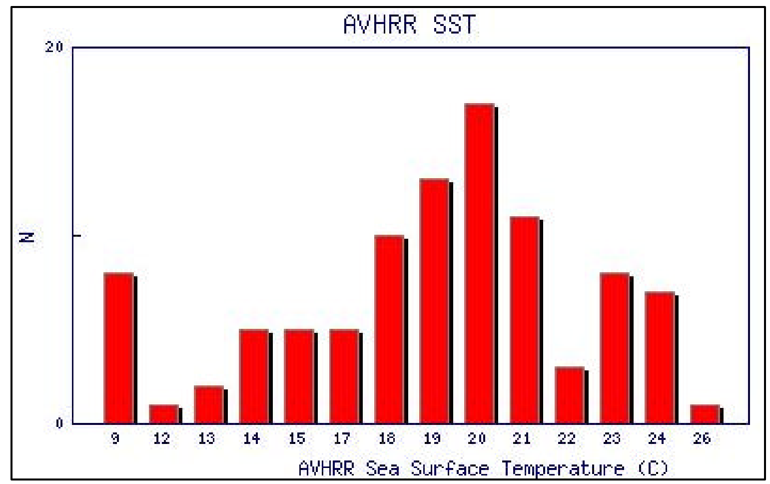


Figure 2.48 Frequency (N) of satellite telemetry locations for turtle #10378 associated with AVHRR SST. Generated in STAT (Coyne and Godley 2005).

2004: Satellite Tag #10692

Loggerhead (juvenile, rehabilitated turtle)

In July 2004, Turtle #10692 (XXT542) stranded near Deltaville, VA due to a head laceration. This turtle was rehabilitated and released on November 16, 2004 from Ocracoke Island in the Outer Banks, North Carolina. Shortly after release, turtle #10692 entered the Gulf Stream, following it to the north Atlantic just off the Grand Banks. The turtle appeared to swim in several large-scale circles within the north Atlantic gyre system before slowly heading in a westerly direction back towards the United States (Figure 2.49). The satellite transmitter remained active until early August, 2005. The turtle exhibited a significant direction of travel during the first leg of its track ($z=23.0$; $n=196$; $r=0.3$), out to the mid-Atlantic, and during its final leg back towards the United States ($z=12.1$; $n=158$; $r=0.3$). The turtle remained within a SST range of 14º C to 26º C, averaging 22.3º C (+/- 3.8º C SD) (Figure 2.50; Table 2.8). The majority of movement occurred within waters of depths ranging between 5 m and 5674.4m. Average depths along the track were 4650 m (+/- 1400.5 m SD). This turtle ranged up to 939.0 km from shore and traveled at an average speed of 3.0 km/hr (+/- 2.6 km/hr SD) (Table 2.7).

2005: Satellite Tag #10693

Loggerhead (juvenile, cold-stun rehabilitated turtle)

This turtle originally stranded in November 2004 due to cold-stunning near Norfolk, VA. Turtle #10693 (XXT552) was rehabilitated over the winter and released on June 17, 2005 from the mouth of the York River in the Chesapeake Bay. Post-release, the turtle moved north into the Maryland portion of the Chesapeake Bay were it remained

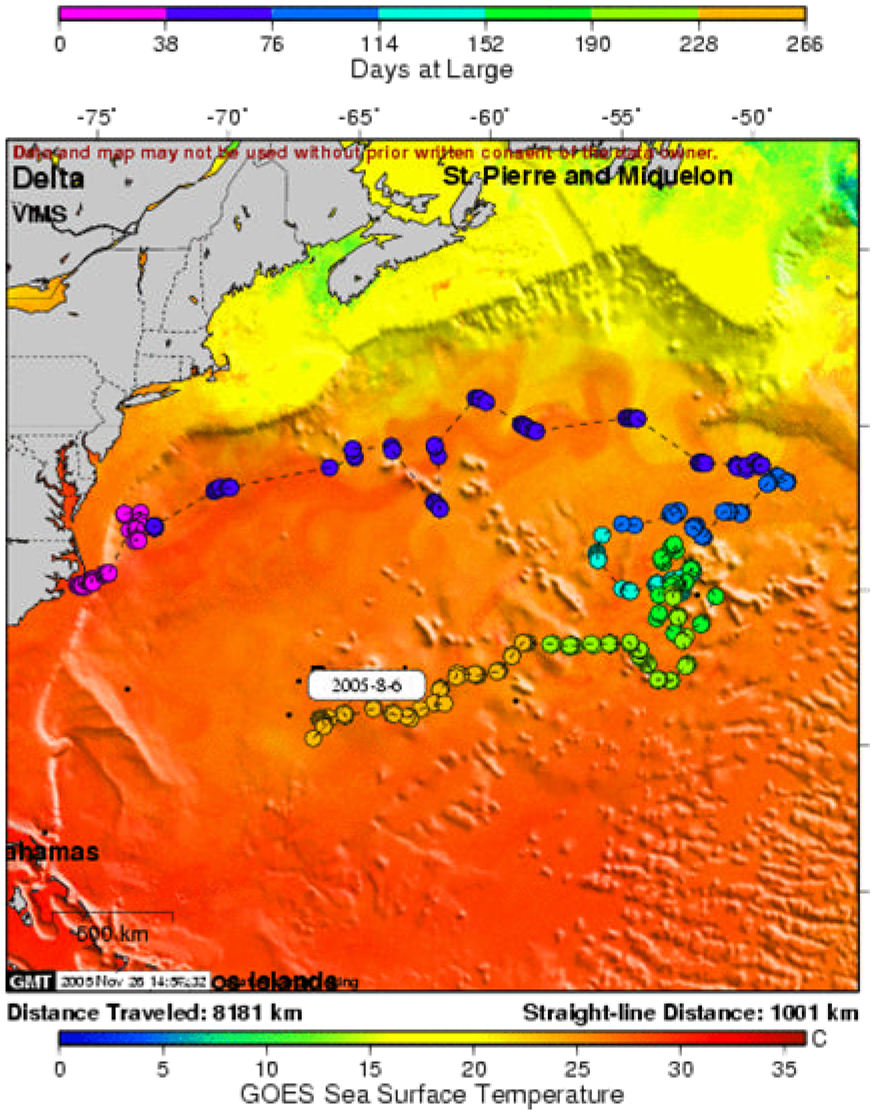


Figure 2.49 Satellite tracks of turtle #10692 from November 16, 2004 to August 6, 2005.

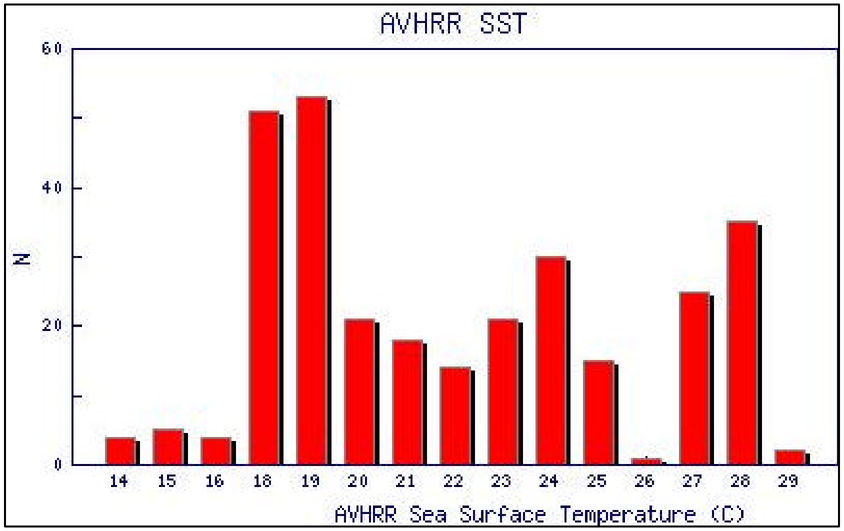


Figure 2.50 Frequency (N) of satellite telemetry locations for turtle #10692 associated with AVHRR SST. Generated in STAT (Coyne and Godley 2005).

until the third week in October 2005 when temperatures dropped between 20º and 21º C. With the drop in temperatures, the turtle moved south, out of the Bay, eventually moving south of Cape Hatteras, North Carolina where it remained between the Outer Banks and the continental shelf until transmissions ceased January 3, 2006 (Figure 2.51). Travel direction was statistically insignificant and the turtle did not establish statistically significant fidelity to any specific region. Throughout its track, the turtle average 11.7 km (+/- 12.6 km SD) from shore. Average swim speed was 3.7 km/hr (+/-3.0 km/hr SD) and mean depth associated with the travel path was 19.0 m (+/- 12.1 m SD) (Table 2.7). Temperatures ranged between 15º C and 28º C with a mean SST of 22.3º C (+/- 4.1º C SD) (Figure 2.52; Table 2.8). Average time at surface per 24-hour period was 01:49:21 (+/- 01:16:59 SD). On average the turtle spent 7.6% (+/- 5.3% SD) of its time at the surface, with a maximum surface time per 24-hour period of 50.6%.

The popup archival tag released from the turtle on June 21, 2005, four days after deployment. The tag popped off at 37.248N, -76.548W, near the mouth of the North River in the Mobjack Bay. Approximately 61% of the total data stream was successfully transmitted from the tag. Mean depth of all dives was 1.3 m (+/- 1.9 m SD) and ranged between 0 m and 10.8 m. This turtle spent 70.0% of its time within the top two meters of the water column during the four days the tag collected data (Figure 2.53). Mean temperature recorded during dives was 24.7° C (+/- 1.0° C SD), ranging between 17.8° C and 32.5° C. This turtle spent 81.4% of its time in temperatures between 24° and 25° C (Figure 2.54).

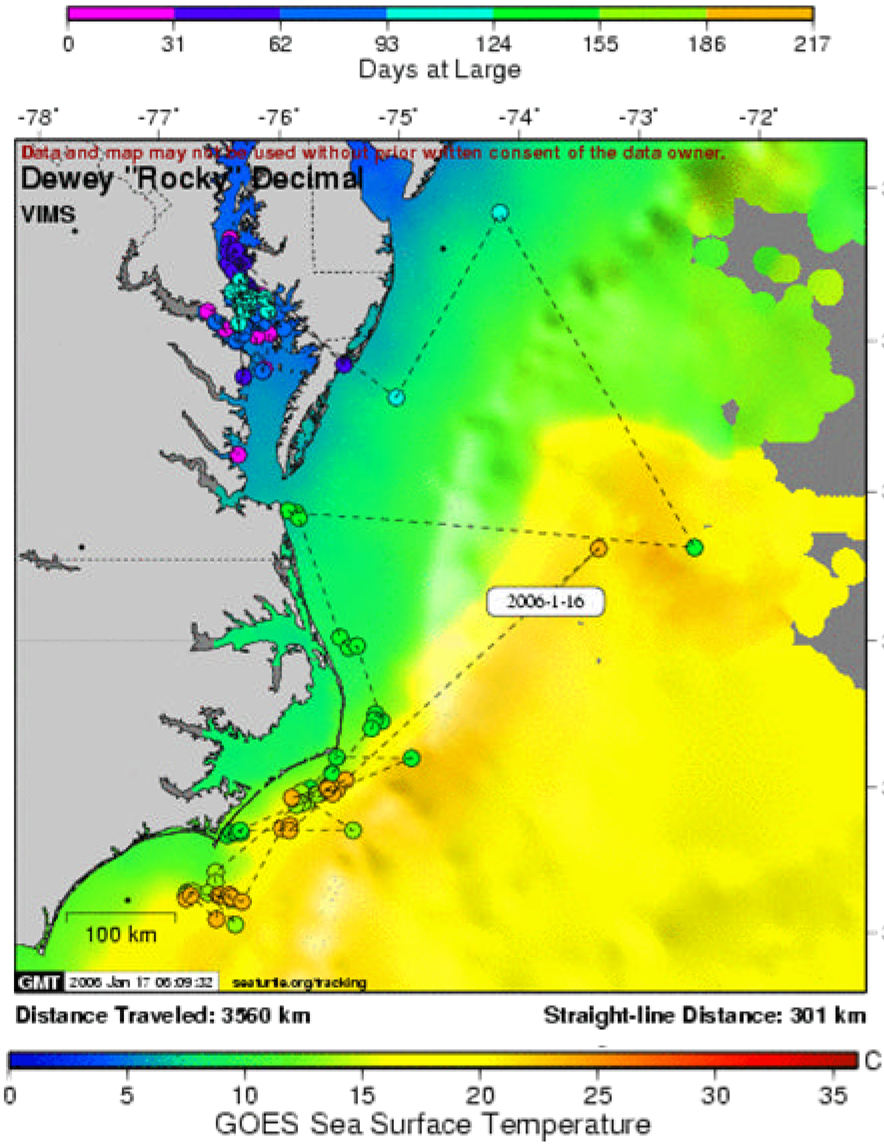


Figure 2.51 Satellite tracks of turtle #10693 from June 17, 2005 to January 16, 2006.

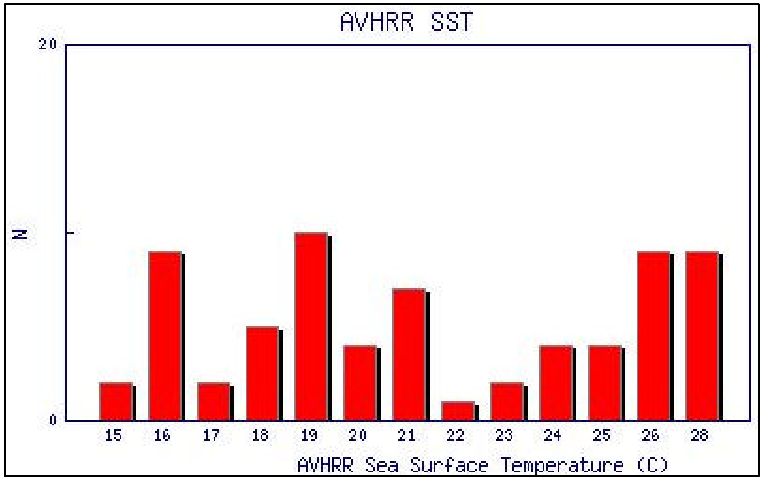


Figure 2.52 Frequency (N) of satellite telemetry locations for turtle #10693 associated with AVHRR SST. Generated in STAT (Coyne and Godley 2005).

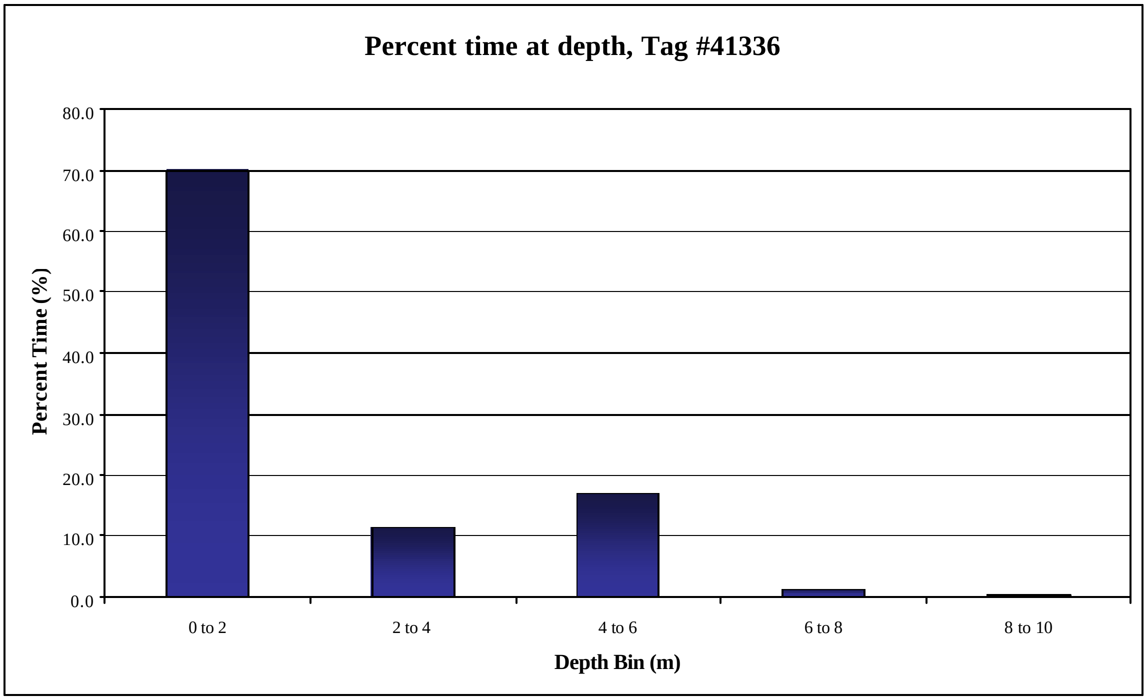


Figure 2.53 Percent time spent at surface derived from popup archival tag #41336

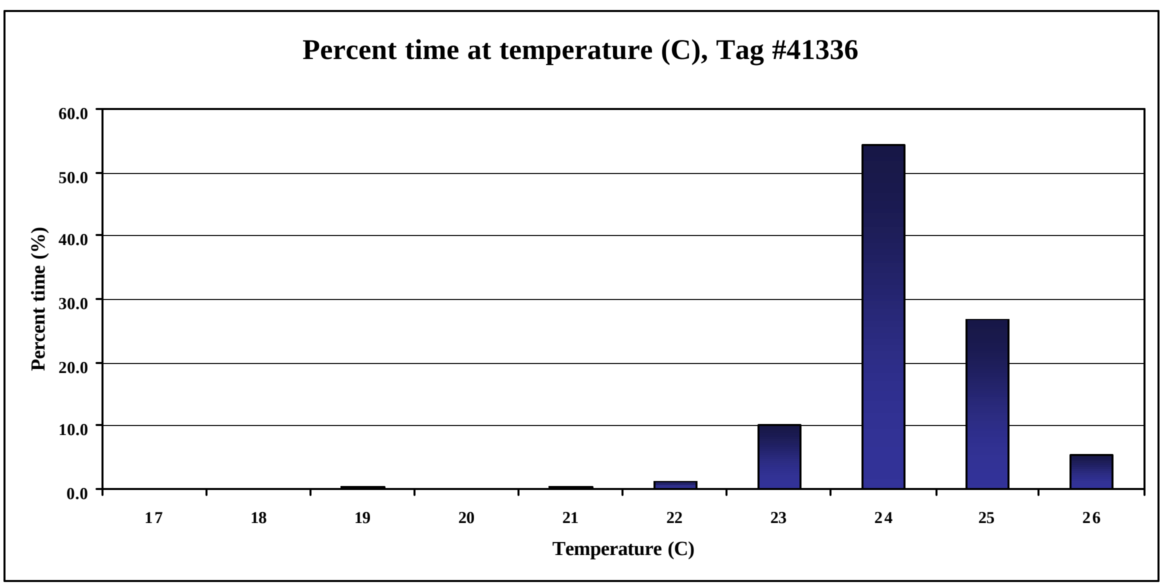


Figure 2.54 Percent time spent at temperature derived from popup archival tag #41336

2005: Satellite Tag #10401b

Loggerhead (juvenile, rehabilitated turtle)

Turtle #10401b (XXT550) originally stranded near Cape May, New Jersey in October of 2004. This turtle was found with its left front flipper entangled in a gill net. Turtle #10401b was treated by the Marine Mammal Stranding Center in Brigantine, NJ. Early in November 2004, the turtle was transported to the Virginia Aquarium and Stranding Program for rehabilitation over the winter. Turtle #10401b was released on June 17, 2005 from the mouth of the York River. After release, the turtle traveled out of the Chesapeake Bay, then north along the Eastern Shore, remaining in the Virginia portion of the Chesapeake Bay or lower Maryland Bay until mid-October when sea surface temperatures dropped below 20º to 21º C (Figure 2.55). With the drop in temperatures, the turtle moved south, establishing itself just south of Cape Hatteras, North Carolina, between the Outer Banks and the continental shelf. The turtle remained off of Cape Hatteras and the Outer Banks until transmissions ceased January 3, 2006 (Figure 2.55).

This turtle did not exhibit site fidelity to a specific region, nor did it have a statistically significant travel direction. Throughout its track, the turtle remained no farther than 99.0 km from shore, averaging 25.0 km (+/- 24.0 km SD) from the nearest shoreline. Average swim speed was 3.8 km/hr (+/-2.9 km/hr SD) and mean depth associated with the travel path was 24.5 m (+/- 13.6 m SD) (Table 2.7). Temperatures ranged between 14º C and 28º C with a mean SST of 23.0º C (+/- 3.8º C SD) (Figure 2.56; Table 2.8). Average time at surface per 24-hour period was 01:11:40 (+/- 00:47:07

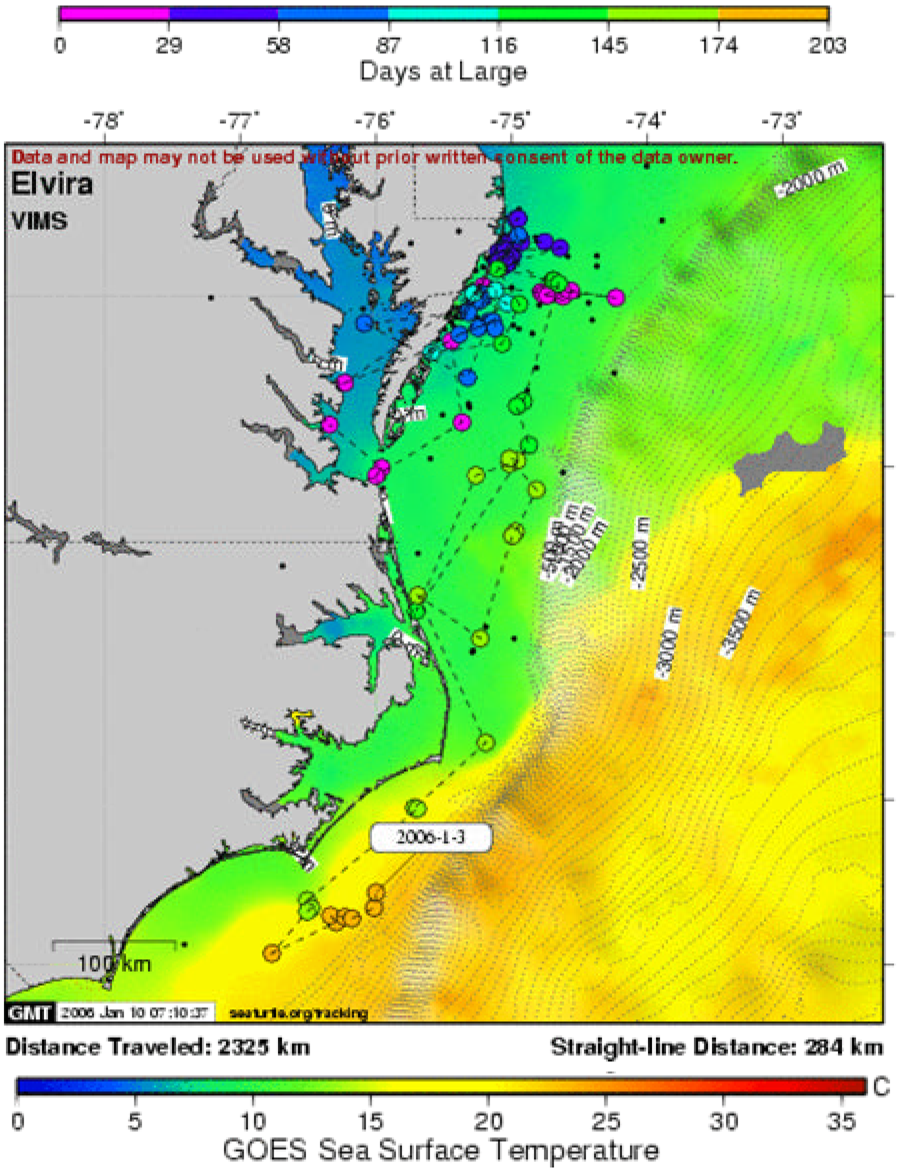


Figure 2.55 Satellite tracks of turtle #10401b from June 17, 2005 to January 3, 2006

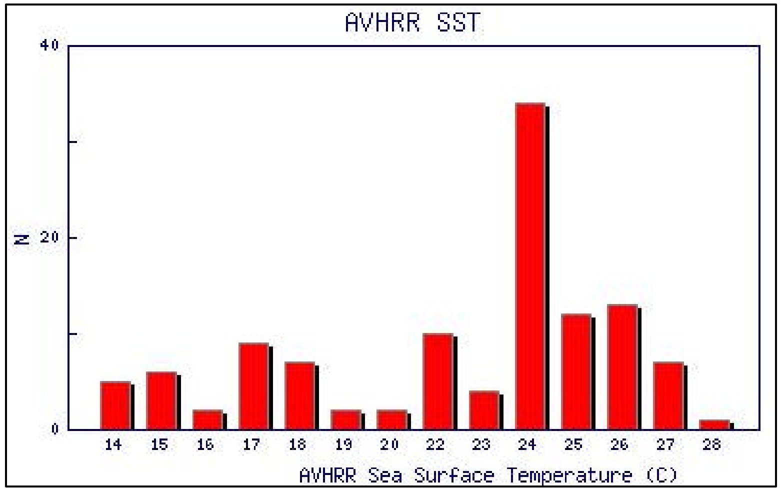


Figure 2.56 Frequency (N) of satellite telemetry locations for turtle #10401b associated with AVHRR SST. Generated in STAT (Coyne and Godley 2005).

SD). On average the turtle spent 5.0 % (+/- 3.3% SD) of its time at the surface, with a maximum surface time per 24-hour period of 45.1%.

The popup tag released from the turtle on July 2, 2005, 15 days after deployment. The tag popped off at 37.171N, -75.402W, off the ocean side of the Eastern Shore. Approximately 66% of the total data stream was successfully transmitted from the tag. Mean depth of all dives was 7.1 m (+/- 9.2 m SD) and ranged between 0 m and 41.7 m. This turtle spent 30.6% of its time within the top two meters of the water column and 51.3% of its time within the upper four meters of the water column during the four days the tag collected data (Figure 2.57). Mean temperature recorded during dives was 22.9° C (+/- 2.5° C SD), ranging between 12.1° C and 36.6° C. Turtle #10401b spent 61.2% of its time in temperatures between 22° C and 23° C (Figure 2.58).

2005: Satellite Tag #11993

Loggerhead (juvenile, rehabilitated turtle)

Turtle #11993 (XXT561) stranded mid-June 2005 on Silver Beach (near Exmore) on the Eastern Shore of Virginia. This turtle was emaciated and lethargic when first discovered and was rehabilitated for almost two months at the Virginia Aquarium Stranding Program's facilities in Virginia Beach. Turtle #11993 was released on August 30, 2005 from a beach near Lynnhaven, Virginia, to the east of the CBBT. This turtle remained between the lower Chesapeake Bay and just south of the Virginia/North Carolina border until the last week in October 2005 when sea surface temperatures dropped below 20º C (Figure 2.59). At this time, the turtle moved farther south to Cape

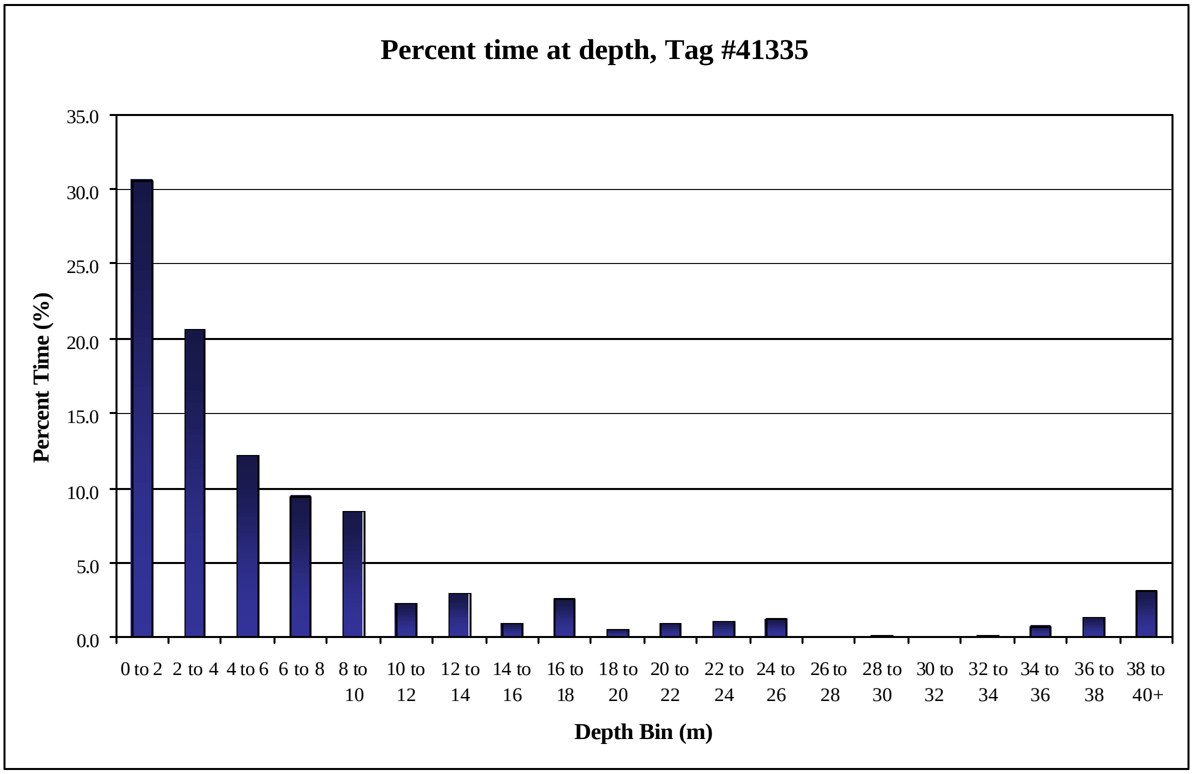


Figure 2.57 Percent time spent at surface derived from popup archival tag #41335

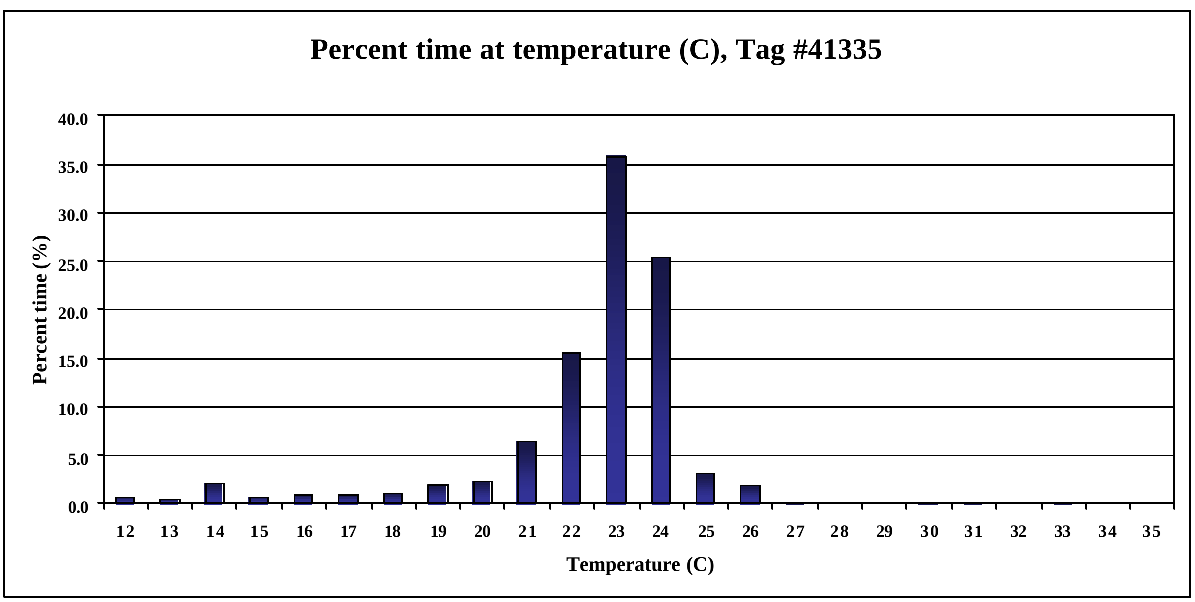


Figure 2.58 Percent time spent at temperature derived from popup archival tag #41335

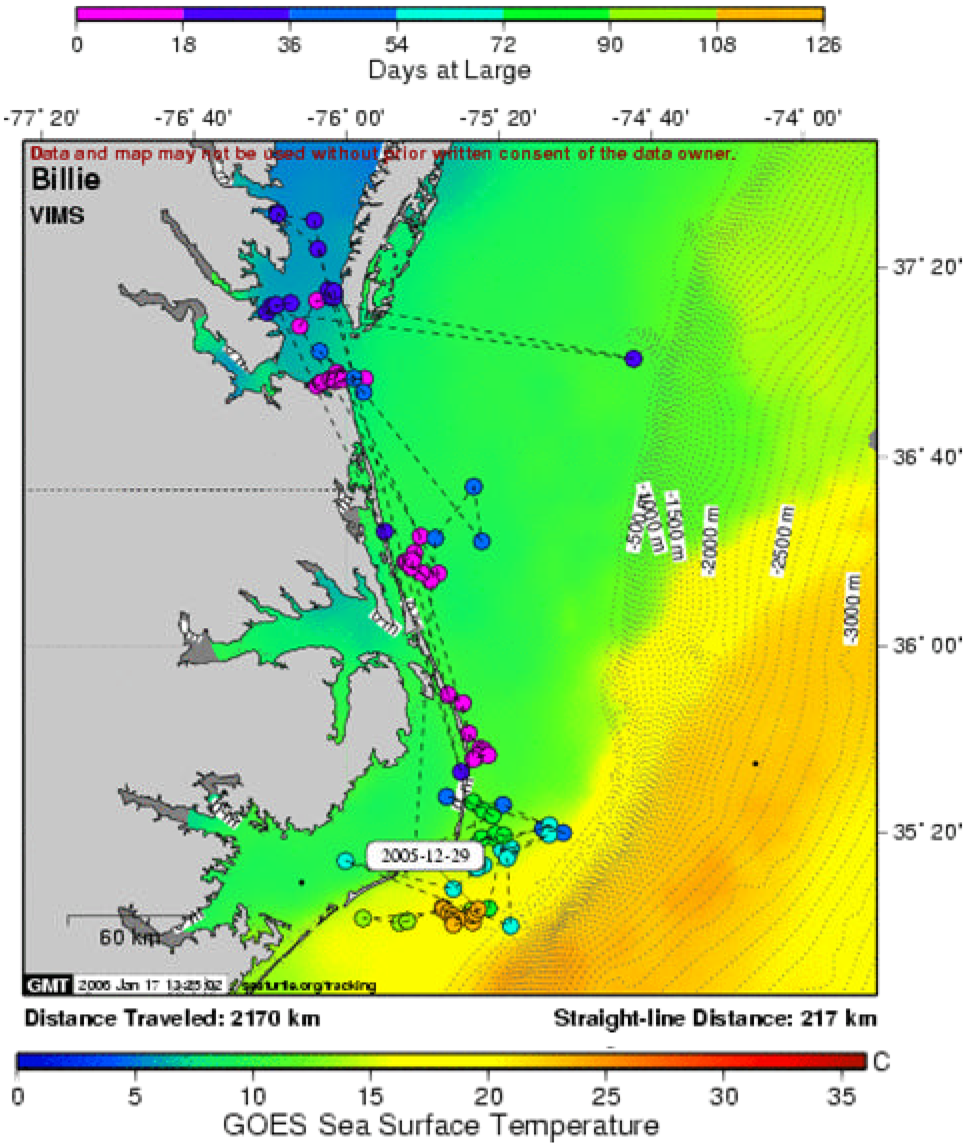


Figure 2.59 Satellite tracks of turtle #11993 August 30 to December 29, 2005.

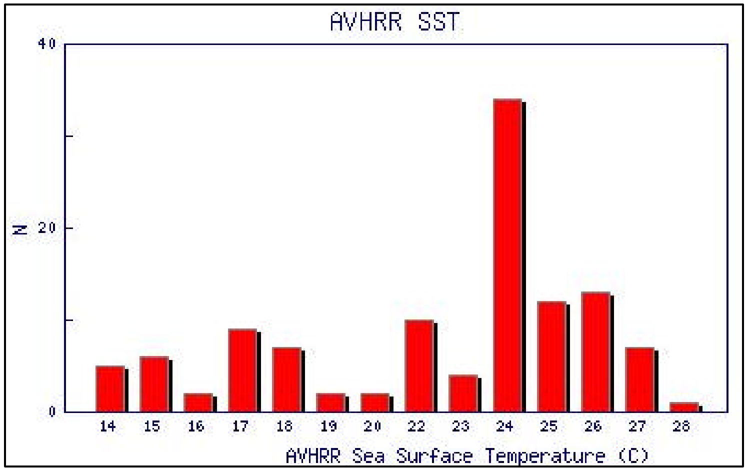


Figure 2.60 Frequency (N) of satellite telemetry locations for turtle #11993 associated with AVHRR SST. Generated in STAT (Coyne and Godley 2005).

Hatteras, North Carolina where it remained until transmissions ceased December 29, 2005.

Despite a clear trend in this turtle's movements south and east, movement analyses did not result in significant site fidelity to a specific region or a statistically significant directional bearing. This may be due to repeated north-south movements throughout the entire track resulting in equal and opposite travel vectors biasing the circular point statistics. The turtle remained an average of 13.9 km (+/- 18.5 km SD) from the nearest shoreline. Average swim speed was 3.3 km/hr (+/-3.1 km/hr SD) and mean depth associated with the travel path was 24.5 m (+/- 13.6 m SD) (Table 2.7). Temperatures ranged between 14º C and 28º C with a mean SST of 22.0º C (+/- 3.0º C SD) (Figure 2.60; Table 2.8). Average time at surface per 24-hour period was 01:58:58 (+/- 00:55:54 SD). On average the turtle spent 4.1 % (+/- 3.9% SD) of its time at the surface, with a maximum surface time per 24-hour period of 40.4%.

This turtle's popup tag released on September 3, 2005, four days after deployment. The tag popped off at 35.856N, -75.569W, off of Nags Head, North Carolina. The tag was subsequently found by vacationers from Massachusetts. They traveled home to Massachusetts with the tag before contacting VIMS in order to it. All (100%) dive data collected and archived over the course of the 4-day deployment was successfully downloaded. Mean depth of all dives was 4.8 m (+/- 5.6 m SD) and ranged between 0 m and 24.2 m. This turtle spent 50.6% of its time within the top two meters of the water column during the four days the tag collected data (Figure 2.61). Mean temperature recorded during dives was 22.1° C (+/- 3.6° C SD), ranging between 15.1° C

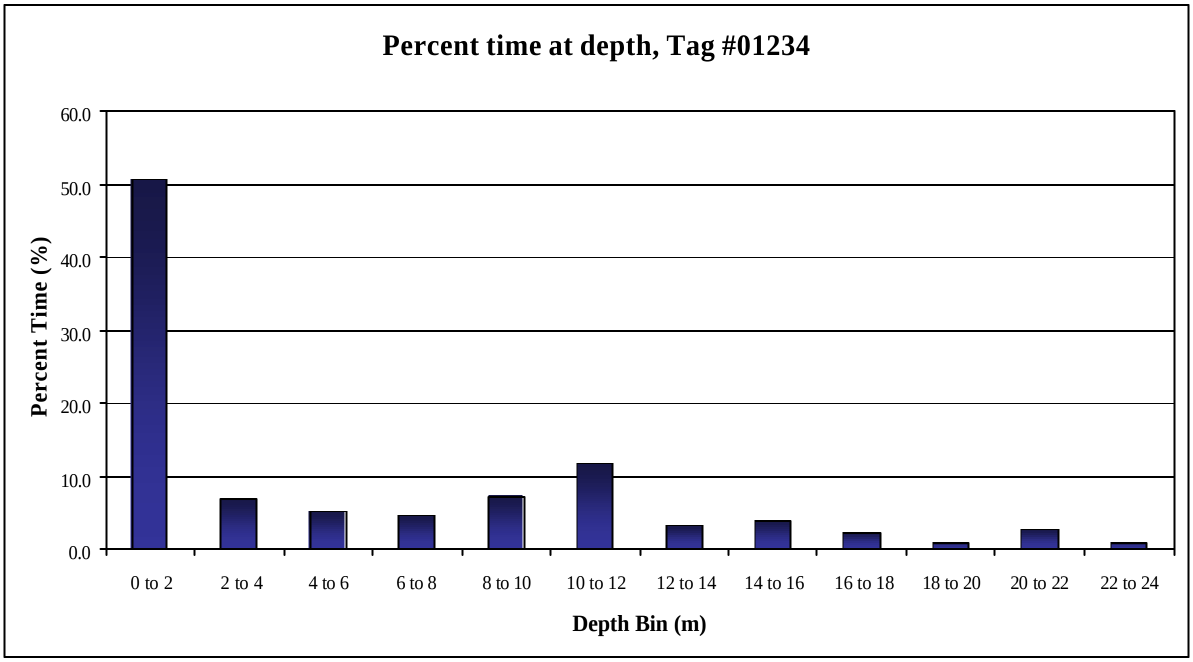


Figure 2.61 Percent time spent at surface derived from popup archival tag #01234

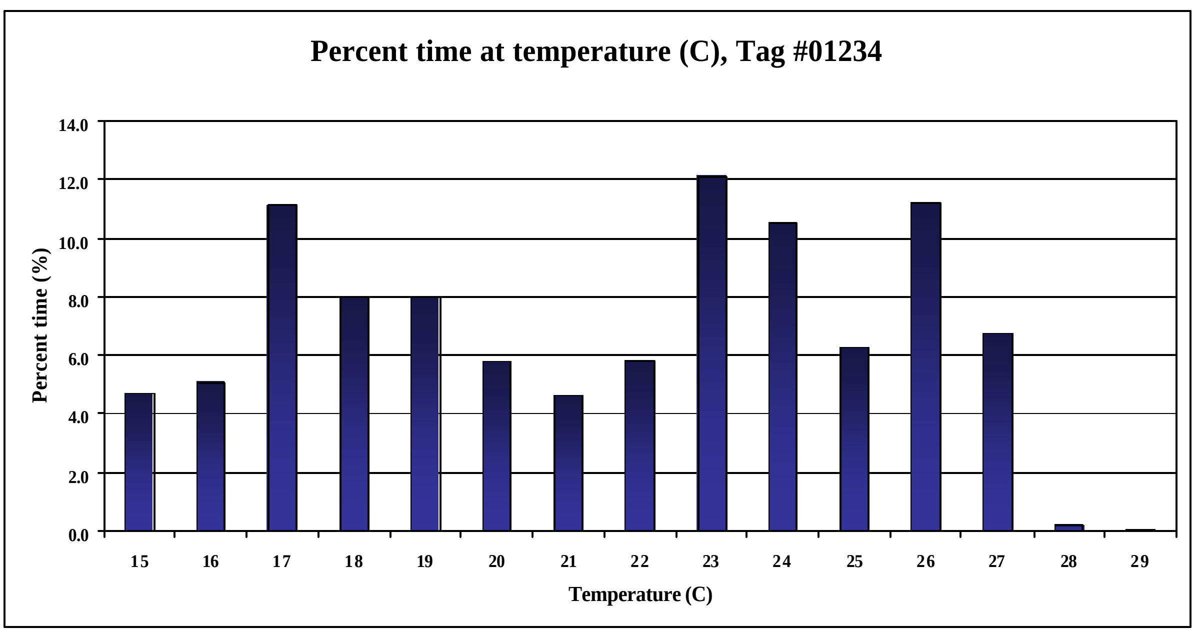


Figure 2.62 Percent time spent at temperature derived from popup archival tag #01234

and 29.3° C. This turtle spent 42.5% of its time in temperatures below 20° C (Figure 2.62).

2005: Satellite Tag #11585

Loggerhead (juvenile)

Turtle #11585 (XXT558) stranded on Cedar Island, off Virginia's Eastern Shore, late June 2005. This turtle was found with lesions on his/her and was observed to have difficulty diving. After rehabilitation Turtle #11585 was released on August 30, 2005 from a beach near Lynnhaven, Virginia, to the east of the CBBT. After release, the turtle traveled north into the Chesapeake Bay, remaining in the Virginia portion of the Chesapeake Bay or lower Maryland Bay until mid-October when sea surface temperatures dropped below 20º to 21º C (Figure 2.63). With the drop in temperatures, the turtle moved south, establishing itself just south of Cape Hatteras, North Carolina, between the Outer Banks and the continental shelf. The turtle remained off of Cape Hatteras and the Outer Banks until transmissions ceased January 3, 2006.

There was significance of travel direction (z=13.5; n=66; r=0.5) and the turtle maintained a mean bearing of 161º (+/- 3.0º SD). Throughout its track, the turtle traveled no farther than 58.0 km from shore, averaging 11.7 km (+/- 12.6 km SD) from shore. Average swim speed was 2.3 km/hr (+/-2.5 km/hr SD) and mean depth associated with the travel path was 15.7 m (+/- 11.2 m SD) (Table 2.7). Temperatures ranged between 14º C and 28º C with a mean SST of 22.7º C (+/- 2.6º C SD) (Figure 2.64; Table 2.8). Average time at surface per 24-hour period was 00:32:26 (+/- 00:17:05 SD). On average

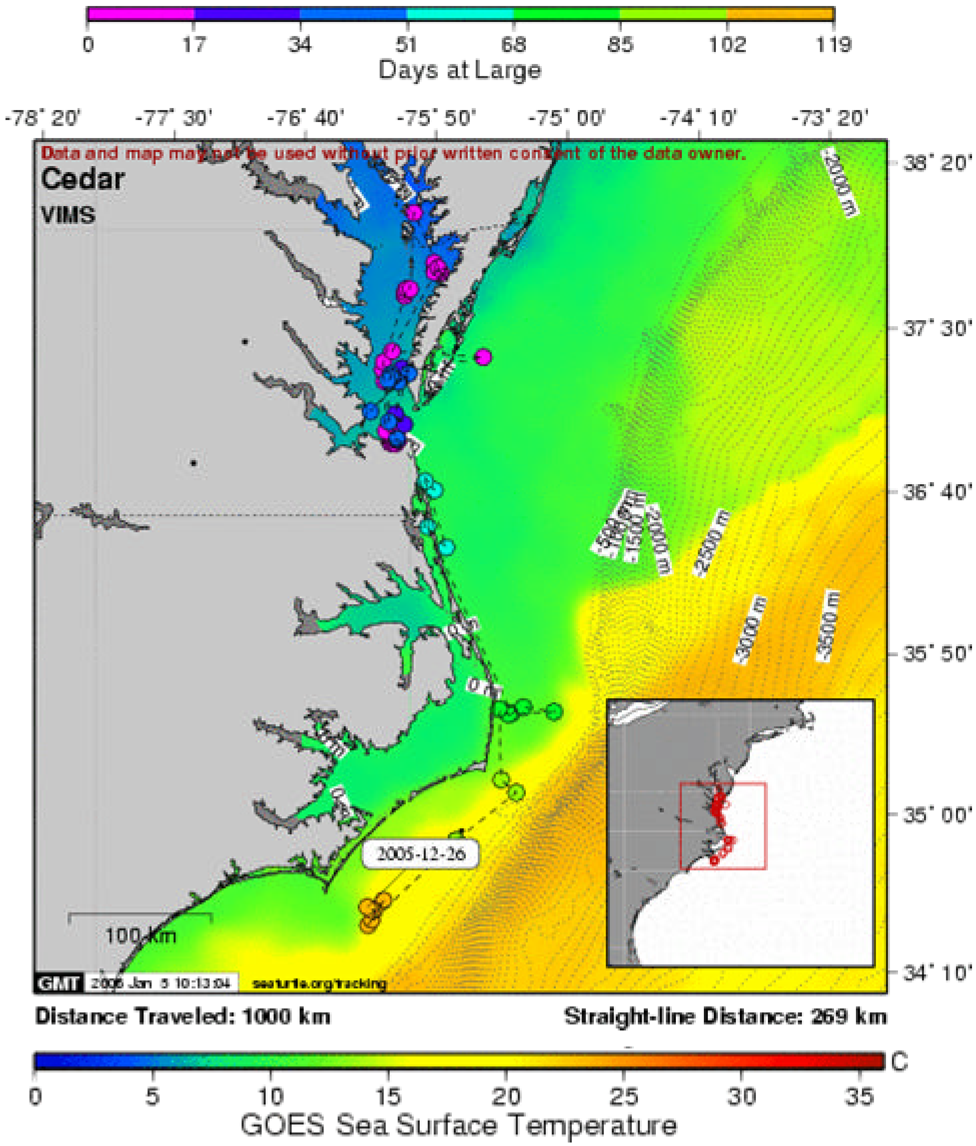


Figure 2.63 Satellite tracks of turtle #11585 August 30 to December 26, 2005.

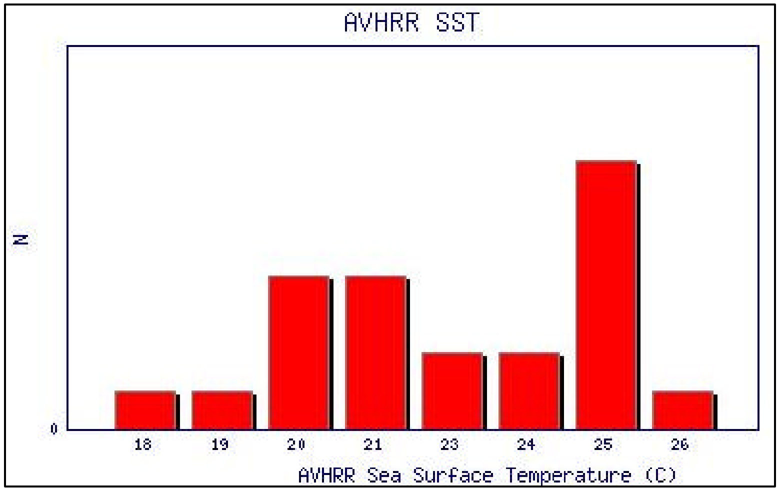


Figure 2.64 Frequency (N) of satellite telemetry locations for turtle #11585 associated with AVHRR SST. Generated in STAT (Coyne and Godley 2005).

the turtle spent 4.5% (+/- 2.5% SD) of its time at the surface, with a maximum surface time per 24-hour period of 16.5%.

2005; Satellite Tag #10378b

Loggerhead (adult male, aquarium turtle)

Turtle #10378b (XXT563) originally captured as a hatchling from a nest in North Carolina in 1992. This turtle was housed at the New Jersey State Aquarium as a display animal until 1996 when Turtle #10378b was transferred to the Virginia Aquarium. Once he reached maturity, and after exploring the possibility of transferring him to another facility, Turtle #10378b was released back to the wild. This turtle spent his entire developmental period in captivity.

This turtle was released approximately 8.5 km offshore of Virginia Beach and Sandbridge Virginia on November 1, 2005. Within 24-hours of release Turtle #10378b exhibited directed movement (z=11.3; n=59; r=0.4) south along the Atlantic coastline until approximately late December 2005 when it reached the waters off of the Georgia-South Carolina border. At this time, the turtle appeared to swim in a large circuit, probably entrained within an eddy system of the Gulf Stream (Figure 2.65). Shortly thereafter, the turtle entered the Gulf Stream and quickly moved north again until was approximately 500 km offshore of the Chesapeake Bay and Eastern Shore where it appeared to entrain within another eddy system (Figure 2.65). The turtle exhibited significantly directed travel (z=13.9; n=26; r=0.7) along the northern leg of his track. The tag was still actively transmitting as of the end of January 2006 (Figures 2.65 and 2.66). Mean SST through the end of January 2006 was 20.0° C (+/- 2.9° C SD) and SSTs

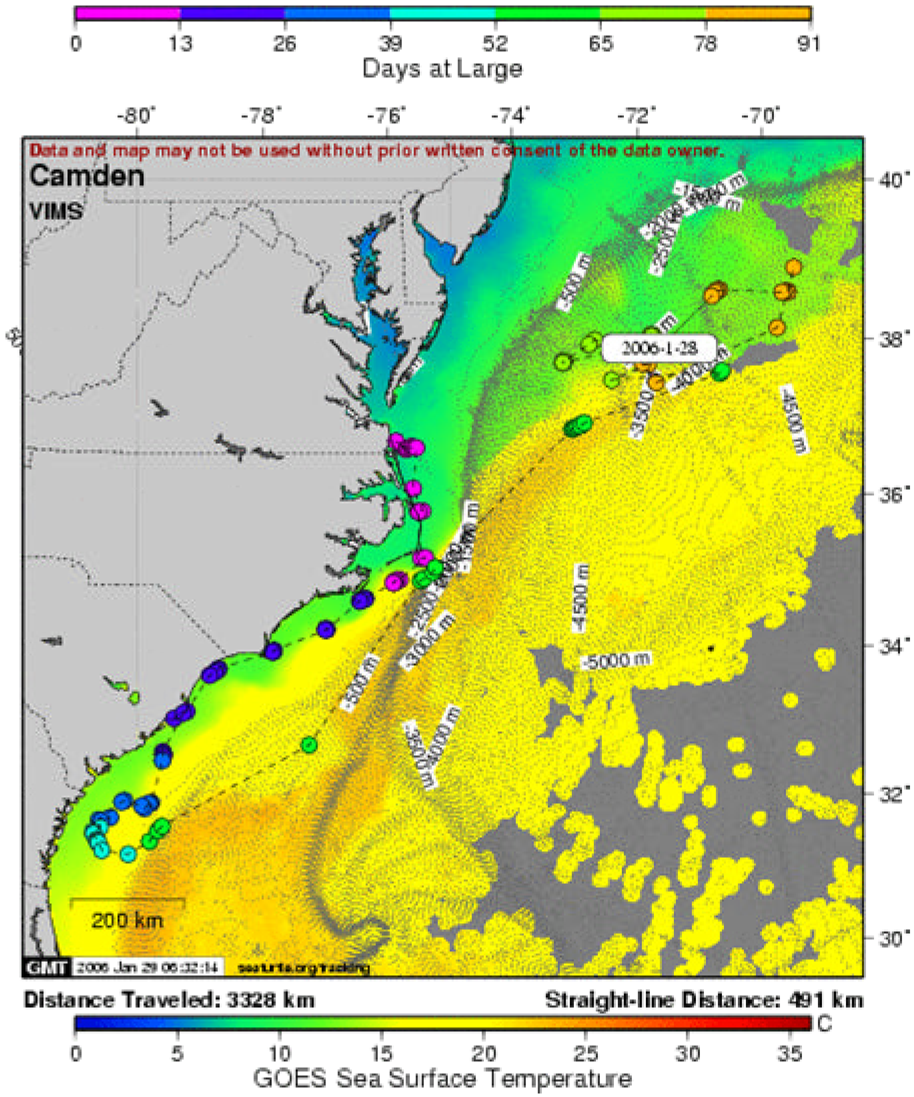


Figure 2.65 Satellite tracks of turtle #10378b November 1, 2005 through January 28, 2006.

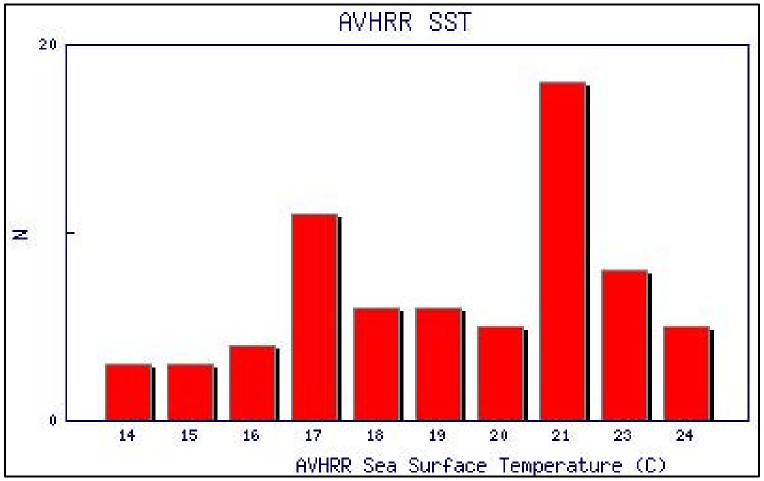


Figure 2.66 Frequency (N) of satellite telemetry locations for turtle #10378b associated with AVHRR SST. Generated in STAT (Coyne and Godley 2005).

ranged between 14° C and 24° C (Table 2.8 and Figure 2.67). Mean travel speed was 3.2 km/hr (+/- 3.2 km/hr SD) and the turtle remained an average 95.3 km (+/- 122.8 km SD) from shore during track period (Table 2.7). Average depths encountered by the turtle were 1139.0 m (+/- 1561.9 km SD), ranging up to 4869.0 m (Table 2.7). Average time at surface per 24-hour period was 02:13:52 (+/- 01:59:16 SD). On average the turtle spent 9.1% (+/- 8.5% SD) of its time at the surface, with a maximum surface time per 24-hour period of 43.3%.

The popup archival tag released from the turtle on November 10, 2005, nine days after deployment. The tag popped off at 35.223N, -75.362W, Cape Hatteras, North Carolina. Approximately 70% of the total data stream was successfully transmitted from the tag. Mean depth of all dives was 7.7 m (+/- 6.5 m SD) and ranged between 0 m and 20.2 m. This turtle spent 34.4% of its time within the top two meters of the water column during the nine days the tag collected data (Figure 2.68). Mean temperature recorded during dives was 18.8° C (+/- 1.2° C SD), ranging between 17.0 C and 23.4° C. This turtle spent 93.3% of its time in temperatures below 20° C (Figure 2.69).

DISCUSSION

Differences in daytime surface times observed between rehabilitated turtles and wild-caught turtles may be attributed to small sample sizes among species and size-classes tracked. All turtles were relocated from their original site of capture. Juvenile loggerheads may visual cues to navigate (Avens 2003). Time spent in captivity for some rehabilitated turtles may have required more time spent at the surface for some form of visual orientation in addition to orientation based on magnetic field and other cues. Turtle

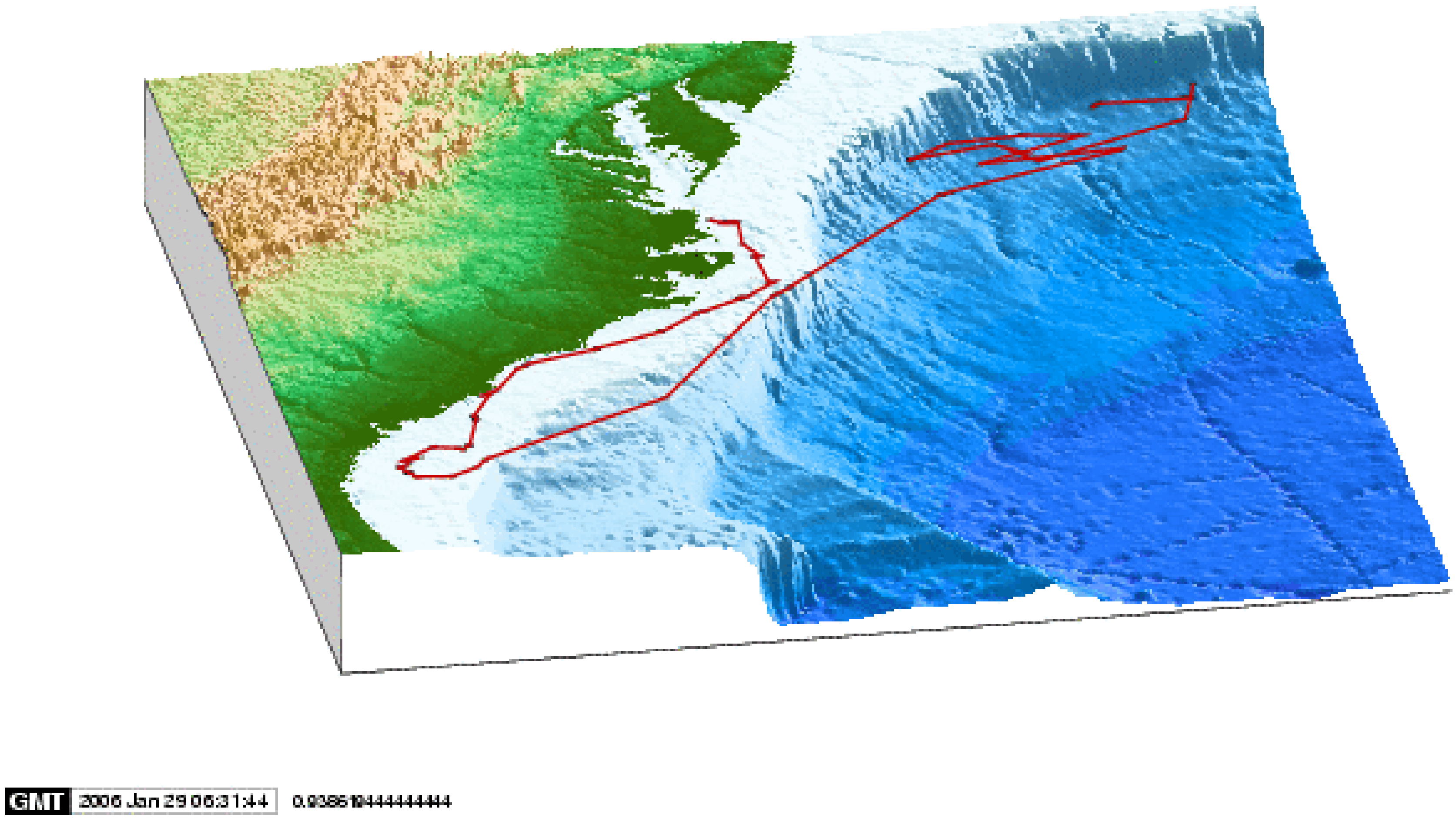


Figure 2.67 Satellite tracks of turtle #10378b plotted on a three-dimensional bathymetric contour layer generated in STAT (Coyne and Godley 2005).

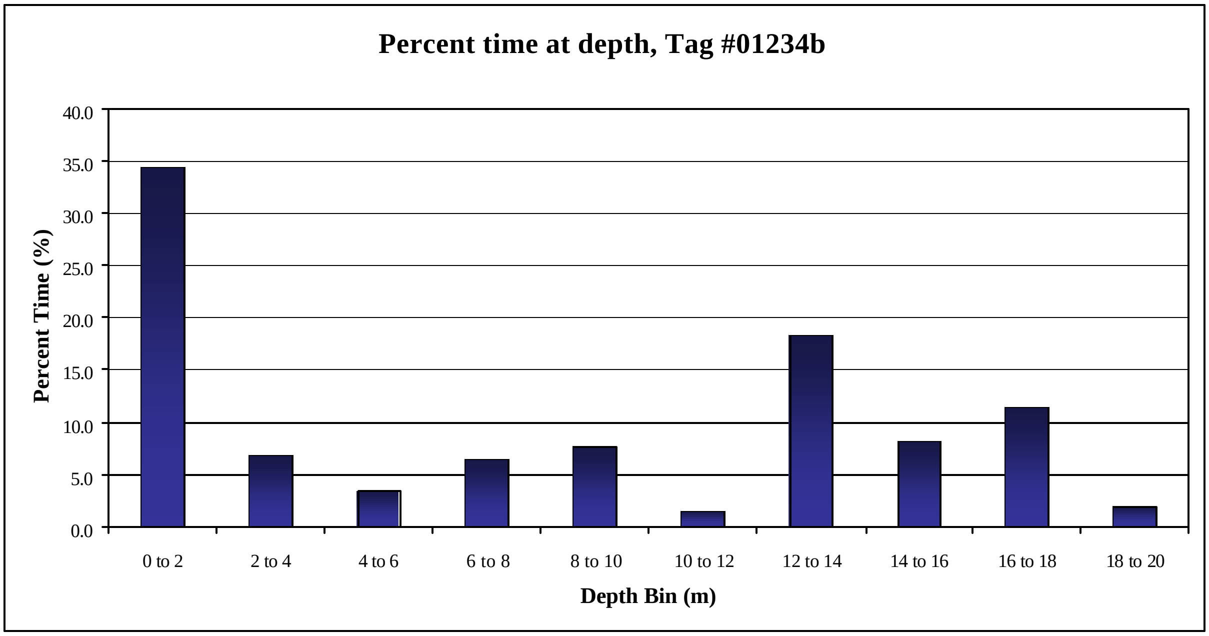


Figure 2.68 Percent time spent at surface derived from popup archival tag #01234b

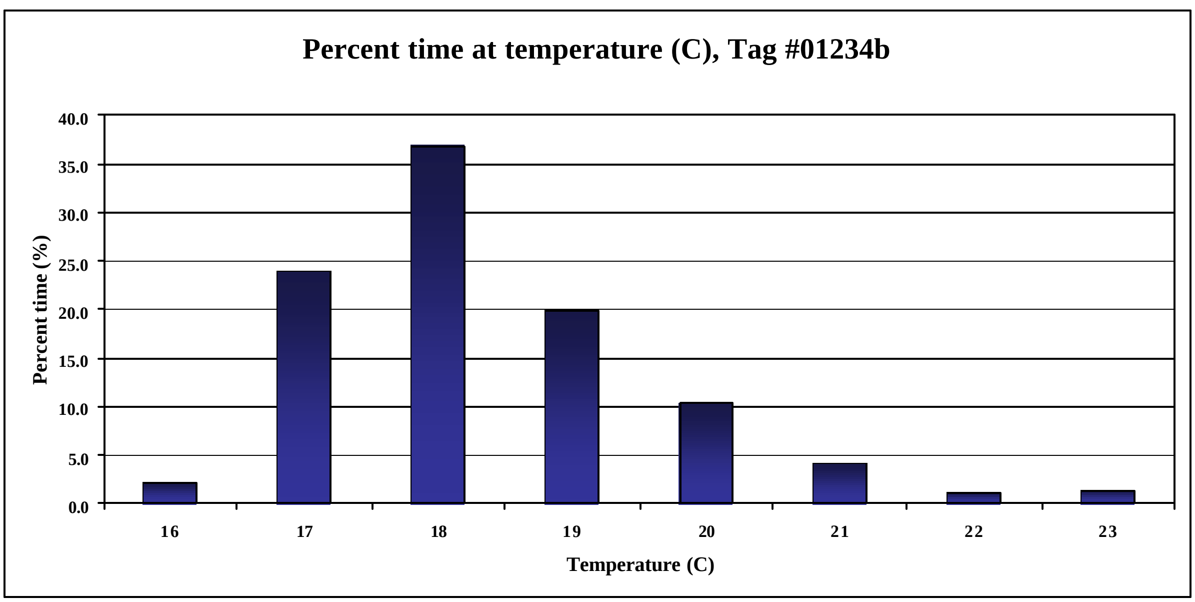


Figure 2.69 Percent time spent at temperature derived from popup archival tag #01234b

#165 increased its surfacing events during the time it passing through the CBBT (Figures 2.8). In 2002, several turtles (#199, #142, #165, #167 and #211) increased their frequency of surfacing events and/or time at surface during 'civil twilight' or approximately 15-20 minutes before sunrise or after sunset (Figures 2.8 and 2.10). Turtle #167 was also observed to increased frequency of surfacing events with the rise of the full moon. Byles (1988) presented a summary of mean surfacing times among 24 juvenile loggerheads tracked in the mid-1980's. He observed a peak in mean time spent at the surface in the 2-hour period between 0400 and 0600—a period when sunrise occurs in the summer. These observations suggest that turtles may use the sun or moon and/or the timing of their rise and set as a navigational tool. These behaviors were not as evident in 2003 and 2004. In 2003, sea temperatures were colder and turtles spent more time at the surface on average than in 2002. It is possible that increased surfacing times or frequencies may have been masked by temperature-driven surfacing behavior in 2003. Alternatively, perhaps turtles observed in 2002 required more time at the surface in the morning to compensate for extended exposure to cooler temperatures at depth during the night.

Surfacing Behavior:

Mean annual juvenile loggerhead surfacing ratios (9.9% to 25.0% or 1: 10 to 1:4) derived from radio telemetry data were higher than Byles (1988) observations (5.3% or 1:18.9) (Table 2.3), but were comparable to estimates derived by Keinath (1993) from satellite telemetry data from loggerheads migrating along the coast (10.0% to 20.0% or 1:10 to 1:5). The percent time spent at the surface among loggerheads from other studies in the southeastern United States during spring months (8.5% to 48.6%) was also comparable to the ratios observed in this study (Keinath et al. 1995; Standora et al. 1993; Nelson 1996). Byles (1988) data were derived from tracks in the middle of the Bay, mid-summer when vertical temperatures are well mixed. Turtles with highest 2002-2004 surfacing times (both species) were tracked in deeper, cooler waters of Bay mouth and/or Atlantic coastline and in one case, through a coastal upwelling event where sea temperatures vertically ranged between 9° C and 24° C. Geographic peaks or seasonal variation in density observations may be a reflection of temperature or movement driven surfacing behavior. Keinath (1993) observed that loggerheads often did not swim through well defined thermoclines.

With the exception of turtle #137 (36.5%), springtime loggerhead surfacing times are relatively close in range (7.1% to 12.7%), unlike the Kemp's ridleys tracked (13.5% to 49.2%; excluding turtles #197 and 170 who were tracked only two to four hours). Among all years, the mean percent time spent at the surface by loggerheads was 14.6% (+/- 10.0), or for every one turtle at the surface, there are 6.8 below (1:6.8). Among Kemp's ridleys, the mean percent time spent at surface among all years was 33.6% (+/- 20.2% SD; or 1:3). This is also higher than the percent time spent at the surface (3.0% to 4.3%) observed by Schmidt et al. (2002) for foraging Kemp's ridleys in Florida, however, few data are available for seasonal Kemp's ridley surfacing behaviors in the mid-Atlantic.

The adult female tracked (#211) spent far less time at the surface per respiratory event than the other turtles tracked. This is most likely due to the size and age of the turtle, resulting in greater lung capacity, lower metabolic rates and fewer respiratory events than the juvenile turtles tracked. Ideally, more adult turtles should be tracked to increase the sample size of the older age class in order to better test for differences between adults and juveniles. Differences observed among individuals may be due to species-specific differences, length of track, differences in size class and/or variations sea temperature profiles over the course of their track. The 2003 season was unique in that springtime sea temperatures were cool, delaying the annual emigration of turtles into Virginia waters. This was followed by cooler than average Bay temperatures which may have attributed to turtles spending more time within warmer surface waters. Bottom temperatures in the Bay and Bay mouth remained near 16º C to 19º C for the entire 2003 residency season. Loggerheads spent more time on average at the surface in 2003 than other years. Variations in surfacing behavior between seasons may be due to environmental factors (temperature) and/or metabolic requirements of different behaviors (foraging vs. migratory/directed movement).

Byles (1988) determined that foraging loggerheads in the summer and fall months averaged 1.4 minutes per surfacing event and 18.9 minutes per dive. The loggerhead turtles tracked during early residency season exhibited shorter mean dive durations than observed by Byles. This may be due a different in behavior among turtles tracked in the 1980's (established foragers) versus those tracked in this study (displaced swimmers) or to differences in temperature regimes between the turtles observed in the early spring and summer of 2002-2004, and the later season foragers tracked by Byles. In the spring of the year, turtles are migrating into Bay waters in order to reach their summer foraging grounds. It is possible that the turtles tracked in 2002 to 2004 were exhibiting migration behavior, or directed swimming movements from the point of release to their foraging grounds. Turtles #192 and #197 both returned to the vicinity of their original foraging and capture sites within approximately one month post-release.

Most turtles tracked early in the season from the Bay mouth exhibited directed movement—either south or north back into the Bay. Tracking work conducted in the 1980's resulted in observations of two types of foraging movements: either long term circular paths within a turtles' home range or up and down tidal channels with different tidal fluctuations (Byles, 1988). Among those turtles tracked via radio/acoustic telemetry, the degree of movements often corresponded to or may have been influenced by tidal flow. One turtle, #211, exhibited the back and forth tidal foraging movements described by Byles, 1988. Water temperatures at the time of release were well mixed, with warmer temperatures of 26.6° C versus surface temperatures of 25.4° C. This turtle was caught ten days later where she was originally captured in her known foraging grounds near the mouth of the Potomac River (Chapter 8). Turtles released earlier in the season from the mouth of the Bay may have been attempting to return to their foraging sites, exhibiting a more directed swimming or migration behavior. Waters in the Bay mouth were also typically more stratified, with temperatures below 20° C found at depth.

Most turtles radio/sonic tracked used the edges of shipping channels in the Lower Bay during portions of their track. These turtles appeared to exhibit directed movement along the edges of the channels. It is possible that in addition to Byles' observations of turtles using channels for foraging, turtles may also utilize channels during migration. Channels possibly serve as either navigational routes or simply as structures to follow regardless of direction of movement.

Due to the high cost of tracking, limited availability of test animals and variable weather and sea conditions in the Bay mouth, sample size of animals tracked is relatively small. This may contribute in part to differences in surfacing times recorded among turtles. Regardless, all turtles tracked spent more time at the surface than Byles' observations or time comparable to the higher estimates observed by Byles in the 1980's. These differences may be due in part to the length of track. However, these data also suggest that the percent time spent at the surface vary based on location, behavior and season. It should not be assumed that sea turtle surfacing behavior is constant at all times of the year or in all geographic locations.

Long-Term Movements and Behavior:

Several satellite-tracked turtles utilized the Chesapeake Bay during all or part of their observed track. These animals typically remained near shore, close to the mouths of Bay tributaries or within shipping and tidal channels. These observations were similar to radio/acoustic and satellite tracks observed by Byles (1988) and Keinath (1993). One exception was turtle #10401. This turtle remained in the upper York River between the Poropotank River and West Point at the junction of the Mattaponi and Pamunkey Rivers (Figure 2.10) for the duration of its observed track. This junction typically experiences fresh water; however this turtle was tracked during a seasonal drought that resulted in higher than normal salinities in the upper York River. Anecdotal information from local crab fishermen suggested that the blue crab distribution ranged farther up-river in 2003. Blue crabs are the primary prey for Kemp's ridley's in the Chesapeake Bay (Seney and Musick 2005).

Data from SST archives suggest that with few exceptions (turtles #168, #10693, and #10378b) most turtles began their southern migratory movements when SSTs dropped below 20º C. Most of the turtles tracked acoustically, and subsequently via satellite, through waters with bottom temperatures below 15º to 20º C and surface temperatures above 20º C, remained north of Cape Hatteras, establishing within Bay or coastal foraging grounds for the remainder of the residency season. Moon et al. (1997) report that Kemp's ridleys tested in a laboratory exhibited hyperactive behavior (defined by continuous movement of the fore flippers) and remained at the surface for extended periods of time when were temperatures dropped below 20° C. This would suggest that one possible trigger for migration, could be a drop in sea surface temperature (or maximum available temperature) below 20º C. Unfortunately, satellite transmitters failed just prior to the fall migratory window for two of the Kemp's ridleys tracked by satellite.

As turtles move from their Bay or northern coastal foraging grounds south through/past the Bay mouth, they are at greater risk of encountering coastal fisheries and hopper dredge operations. Along the east coast of the United States, Virginia is the southern-most state experiencing seasonal residency of sea turtles. A number of species will migrate into waters from Virginia to Massachusetts to forage during the late spring and summer months, all of whom must pass offshore of Virginia's coast. A number of studies have identified this region as a potentially important seasonal migratory route (Shoop and Kenney 1992; Keinath 1993; Morreale and Standora 1988). Turtles tracked from this study followed a fairly consistent route south between the coastline and outer continental shelf, corresponding to routes described in other studies (Chapter 3; Figure 2.70) (Plotkin and Spotila 2002; S. Murphy pers. comm.). Turtles utilizing Virginia's

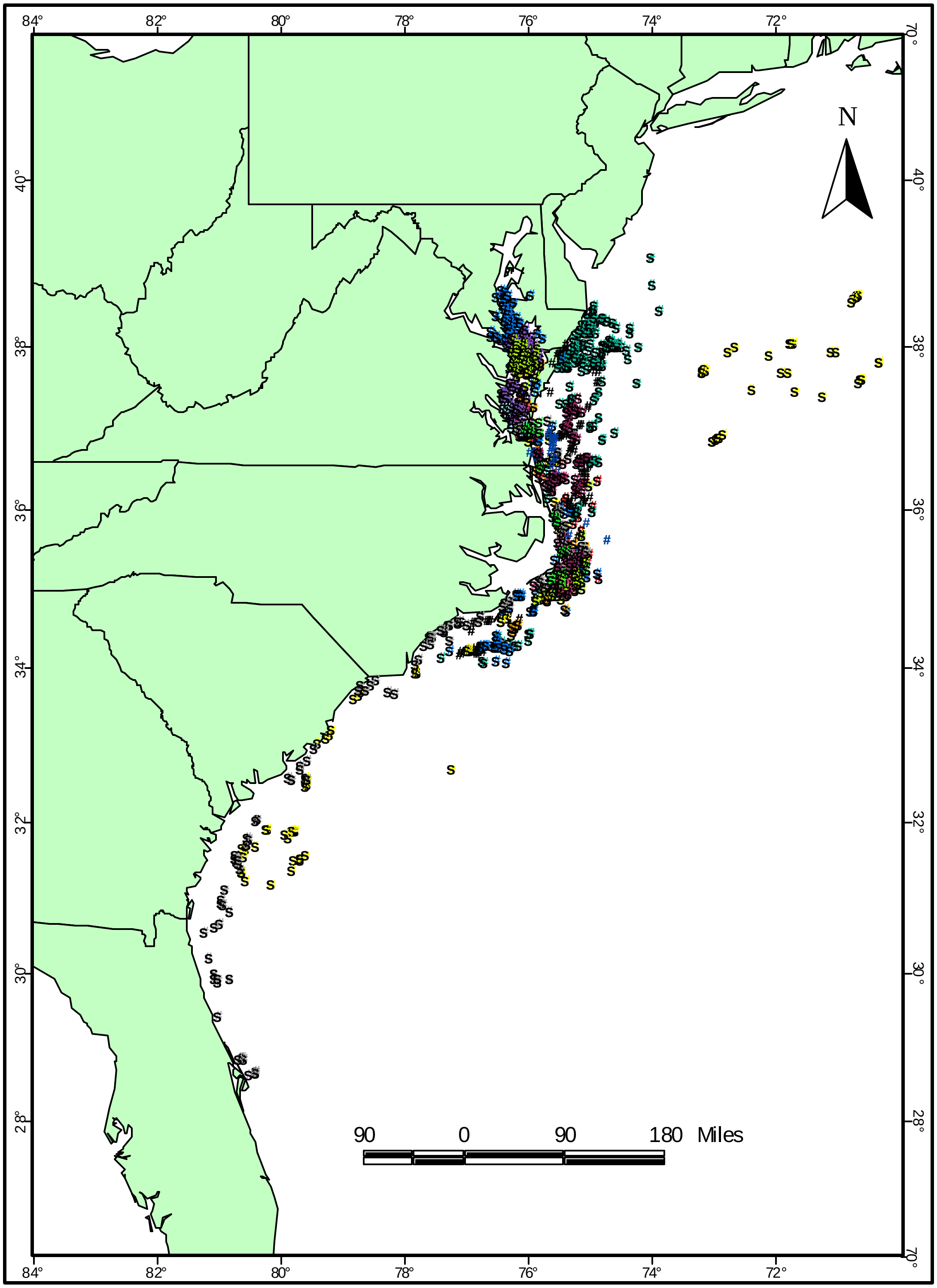


Figure 2.70 Coastal locations of all turtles tracked via satellite telemetry, 2001-2005.

waters as foraging or post-nesting habitat also utilize the region just south of Cape Hatteras as either winter habitat, or as temporary habitat between migrating south out of colder waters north of the Cape and migrating farther south later in the fall or winter (Chapter 3). It is probable that many of the turtles tracked in this study over-winter in this region despite late fall or early winter transmitter failure. This is an area where the continental shelf narrows, overlapping somewhat with the Gulf Stream (Chester et al. 1994).

It is at this juncture that two turtles (#137 and #10692) entered the Gulf Stream, and were transported north to the north Atlantic gyre and an oceanic area off the Grand Banks. Other turtles remained off of Cape Hatteras or moved farther south utilizing typical north-south migratory routes along the Atlantic coast of the United States (Figure 2.71). These tracks provide some exciting data on a behavior among subadults or large juveniles that has yet to be widely published: possible plasticity in habitat selection, or the ability of large benthic juveniles to resume a pelagic lifestyle for extended periods. A small number of head-start turtles obtained from Virginia and North Carolina nesting beaches by Keinath (1993) exhibited similar pelagic movements to the east or northeast from Virginia's waters. Several juvenile loggerheads from North Carolina's waters were also observed to follow this movement route (C. McClellan, pers. comm.). This behavior implies that there may be a degree of plasticity in habitat selection and migratory strategy among sub-adults, including an ability to readapt to a pelagic lifestyle.

It is also possible that there are behavioral differences associated with turtles originating from beaches utilized by the northern subpopulation of Atlantic loggerheads (Georgia through Virginia), versus those from nesting beaches used by southern

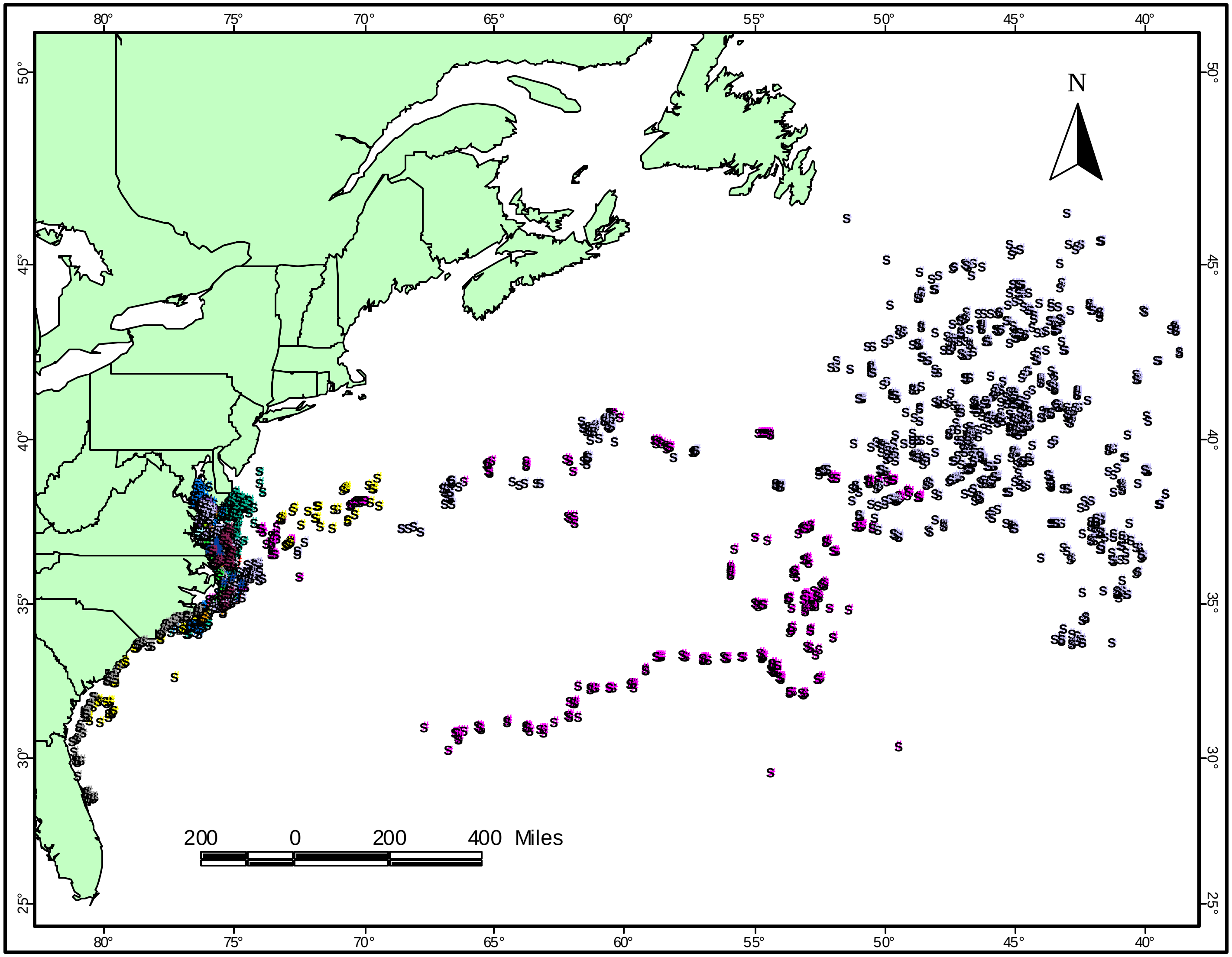


Figure 2.71 Locations of all turtles tracked via satellite telemetry, including turtles tracked into the mid-Atlantic, 2001-2005. Different colors represent different turtle tracks.

subpopulations (Florida through the northern Gulf of Mexico). Unfortunately, no genetic analyses are available for the two juvenile turtles from this study that exhibited plasticity in their habitat selection. However, the adult male loggerhead tracked in 2005-2006 (Turtle #10378b) was originally captured from a nesting beach in North Carolina as a hatchling. This turtle was kept captive as an aquarium turtle for its entire juvenile developmental period. Upon release into the wild as an adult, #10378b initially migrated south post-release, similar to the fall movements of other wild-caught juvenile and adult turtles. Almost two months post-release, this turtle's behavior altered significantly from the observed winter behavior of other turtles: he entered the Gulf Stream and migrated north again, eventually entraining within an eddy system offshore and east of the Delmarva Peninsula. Turtle #10378b is the only adult turtle to exhibit this switch to pelagic habitat in the region north of Cape Hatteras, particularly in the winter months. It is possible that years spent in captivity during this turtle's developmental period had some impact on his post-release movements as an adult. Few data are available on the long term movements and distributions of adult male loggerheads. Therefore, it is also possible that with more data, the movements of Turtle #10378b may vary significantly from other males of his species.

In 2005, the popup satellite tags on average recorded higher surface times than the Sirtrack tags deployed on the same turtle. The popup tags recorded close to real-time depths encountered by the turtles, whereas the Sirtrack tags recorded net time spent with the tag exposed above the surface of the water. Placement of the tags on the turtle may also contribute to this difference: Sirtrack tags were attached on the anterior portion of the carapace while popup tags were placed close to the postmarginal scutes, posterior of the Sirtrack tags. When the turtle comes to the surface to breath, it is likely that the popup tags would remain at least partially submerged. The popup tags have a documented potential error of +/- 1.35 m (for depth sensor) and a 0.2° C (+/- 0.1° C) temperature sensitivity that may account for some of the difference between the Sirtrack surface counts and popup depth results (P. Howie pers. comm.).

Compared to the limited duration of the radio tracks, surface counts and popup archival data indicate that time spent at or near the surface several days post-release among displaced or migrating turtles is still relatively high compared to Byles (1988) observations (5.3%). This also suggests that observed surfacing times may not have been greatly influenced by pre-release handling. The surface count and depth profile data collected in 2005 support the hypothesis that turtles may spend more time at or near the surface early in the turtle residency season or within coastal waters where vertical temperatures are more stratified than in the Bay.

Error associated with each recorded location and location class codes may bias analyses to some extent. The majority of location class codes observed was class B (Table 2.6). This maybe due to either less satellite coverage among the earlier track years and/or infrequency of surfacing events among the turtles tracked. This class has an estimated accuracy of up to or in excess of 4km (Brothers et al. 1998; Britten et al. 1999; Millspaugh and Marzluff, 2001). However, some fairly accurate class B locations have been observed from turtles trapped within fixed fishing gears with known locations as part of a mark-recapture study. Filters applied to these data in STAT help minimize erroneous locations in the reconstruction of the tracks presented in this study. The effects of location error bias are also minimized when examining large-scale migratory tracks.

For smaller scale analyses of movement within discrete near shore or estuarine habitat, results should be considered conservative. Spatial error associated with locations used to determine significance of directional movement or site fidelity would tend to give results that were either less constrained or more randomly dispersed. Therefore significant test results should result in greater significance with increased location class accuracy. Travel speed derived from these movement data also assumes a straight-line movement between recorded locations. This is not a practical assumption, particularly if turtles are exhibiting non-migratory behavior. Thus, calculated swim speeds should also be considered conservative.

Mean loggerhead swim speeds observed in this study were within the range reported by other studies (Keinath 1993; Wyneken 1997). On average, loggerhead swim speeds were greater than Kemp's ridley speeds, most likely due to the relative sizes of each species. The Kemp's ridley speeds were greater than those observed among foraging Kemp's ridleys in Florida, but were comparable or slightly higher than those observed among migrating individuals (Renaud 1995; Gitschlag 1996; Schmidt et al. 2002). Maximum speeds per individual may reflect the combined speeds of the animal, including non-sustained bursts of speed, and localized tidal or oceanographic currents. Location error bias may also contribute to the higher reported speeds. The Kemp's ridleys also were found closer to shore and in shallower waters than loggerheads. This may be due in part to different foraging strategies employed by each species. Byles (1988) observed that Kemp's ridleys were likely to be found foraging in near-shore benthic habitat and grassbeds, versus loggerheads who were more likely to be found within deeper tidal channels.

Management Implications:

It cannot be assumed that sea turtle surfacing behavior is constant at all times of the year or in all geographic locations. Turtles observed in temperate waters during the spring months or in deeper, more stratified coastal waters may exhibit different surfacing times than turtles observed during warmer months or in shallower, near shore or estuarine waters. Managers should exhibit caution when comparing aerial density estimates across seasons or geographic regions.

The mean percent surfacing times observed in this study suggest that while turtles may utilize the mouth of the Chesapeake Bay en route to their northern foraging grounds in the spring, or as a pathway to points south in the fall, it is likely that they are spending a larger proportion of their time at the surface due to the higher metabolic costs associated with migratory behavior. Despite an increase in time spent at the surface, turtles were still observed to spend time on the bottom even while exhibiting significantly directed movement. Maximum dive durations also ranged as high as 69 minutes (turtle #168). There remains the possibility for turtle-dredge interactions or interactions with various fishing gears. Limiting dredge operations or fishery effort when temperatures favor migration may help mitigate the potential for sea turtle takes, particularly in the lower Chesapeake Bay and the region between Cape Hatteras and the Bay mouth.

CHAPTER 3

INTER-NESTING AND POST-NESTING MOVEMENTS OF LOGGERHEAD TURTLES IN VIRGINIA

ABSTRACT

Virginia is the northern most nesting region regularly utilized by loggerhead sea turtles (*Caretta caretta*) along the eastern coast of the United States. Between 1992 and 2001, nine satellite transmitters were deployed on nesting loggerhead sea turtles to monitor their inter-nesting and post-nesting movements. One individual turtle, QQB-590, was observed to nest during three separate nesting seasons, once in 1993 and 1995, and twice in 1997, resulting in a two-year remigration interval with an approximate 14 day inter-nesting interval. This turtle exhibited significant fidelity (1993: $p<0.01$; $r^2= 0.06$; 1995: $p<0.001$; $r^2= 0.005$; 1997: $p<0.0009$; $r^2=0.006$) to the waters adjacent to her nesting beach or to established post-nesting habitat in the lower Delaware Bay. During the 1995 and 1997 nesting seasons, this turtle established a concentrated home range in the lower Delaware Bay ranging from 193.9 to 221.1 km^2. Three additional individuals exhibited fidelity to the waters adjacent to or just south of their nesting beach ($p<0.0009$ to 0.04; $r^2=0.02$ to 0.16) prior to a fall migration or transmitter failure. These turtles established home ranges with areas between 116.4 to 160.6 km^2. Three turtles exhibited directed movement immediately post-nesting and were tracked as far south as Georgia, Florida and the Gulf of Mexico. With the exception of QQB-590, most turtles began to move south along the coast, out of Virginia's waters much sooner than fall migrations of most juvenile turtles foraging in the Chesapeake Bay.

It is assumed that turtles nesting in Virginia are part of the northern subpopulation. The directed southern migration of the three individuals south into Florida's waters would suggest that there is some spatial overlap among subpopulations. Turtles exhibiting southern migration behavior typically remained between the outer

continental shelf and Atlantic US coastline. Fall migratory movements were observed to commence when ambient temperatures dropped below 15º to 20º C.

INTRODUCTION

In the Atlantic basin, the majority of loggerhead sea turtle nesting occurs in the western Atlantic, along the eastern coast of the United States (Dodd 1988). Nesting has been well documented on beaches ranging from Florida through North Carolina, however, few data are available on loggerhead turtles nesting further north on Virginia's beaches. Virginia is the northernmost nesting area regularly utilized by loggerhead sea turtles (*Caretta caretta*) on the east coast of the United States. Between two and ten nests are documented annually in Virginia (BBNWR 1993; Mansfield et al. 2001b). Virginia's nesting season begins in late May, continuing through mid- to late August, with nesting activity typically concentrated just north of the North Carolina/Virginia border on the beaches of Back Bay National Wildlife Refuge (BBNWR) and False Cape State Park (FCSP) (BBNWR 1993). Sporadic nesting activity is also documented along Virginia Beach and the Eastern Shore (Figure 3.1).

Four genetically distinct subpopulations have been identified among loggerheads nesting along the east coast of the United States: the northwest Florida or Panhandle, south Florida, Dry Tortugas, and northern subpopulations (Encalada et al. 1998; Turtle Expert Working Group [TEWG] 2000). The northern subpopulation encompasses turtles nesting from northeast Florida north through North Carolina (Encalada et al. 1998). Though no genetic data are available for Virginia's nesting females, it is assumed that turtles nesting in Virginia are part of the northern subpopulation. The status of the northern loggerhead subpopulation is stable at best, though possibly in decline (TEWG 2000).

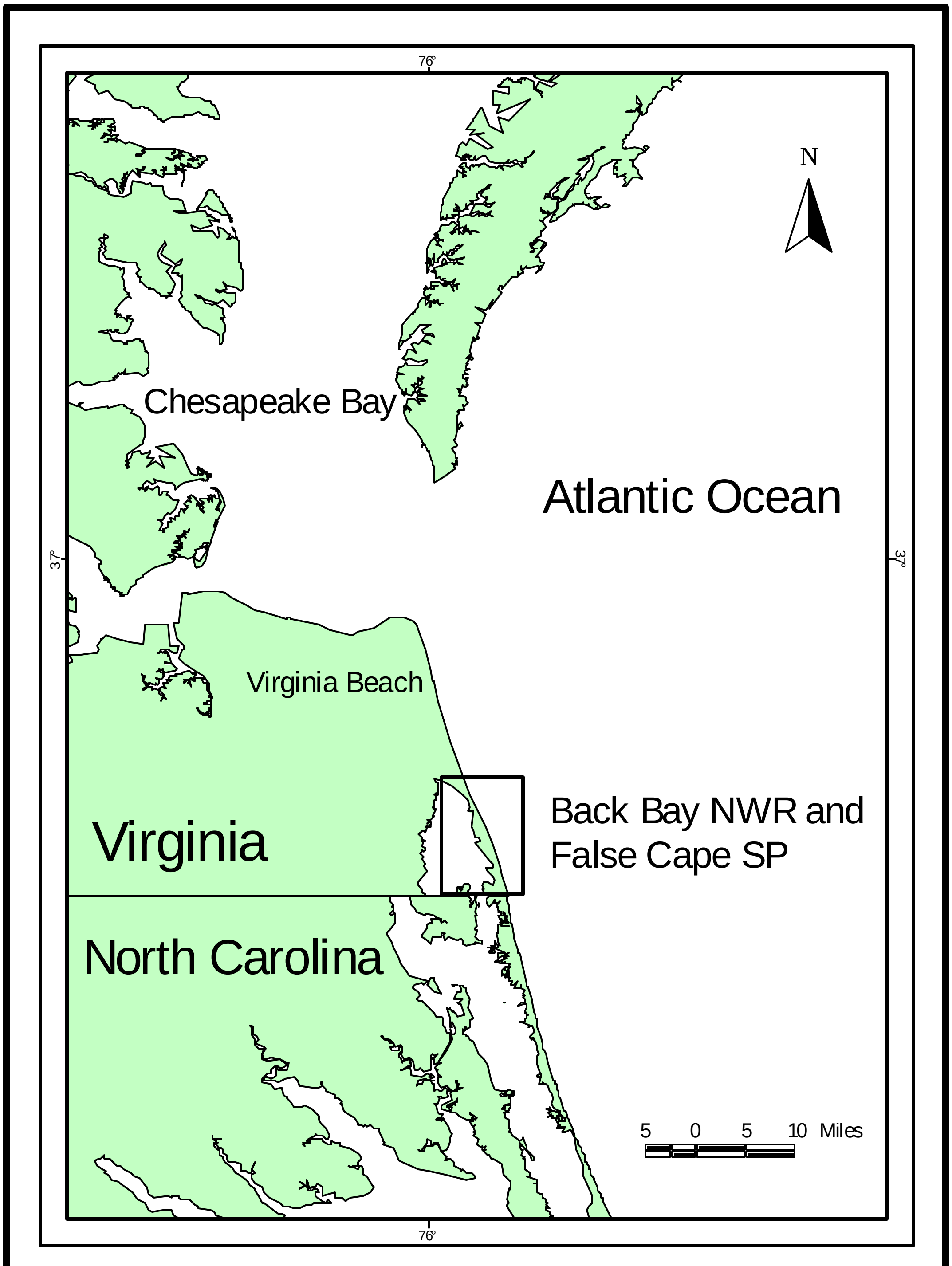


Figure 3.1 Location of study site: Back Bay National Wildlife Refuge, False Cape State Park, Virginia Beach, Virginia, USA

The Chesapeake Bay and coastal waters of Virginia support a seasonal population of juvenile foragers that are resident in state waters from May through October or early November (Lutcavage 1981; Lutcavage and Musick 1985; Musick and Limpus 1997; Coles 1999). Juveniles utilizing the Chesapeake Bay as summer foraging grounds are comprised of both the southern (46%) and northern (54%) loggerhead subpopulations, however, these analyses were conducted before genetic structure from all Atlantic nesting regions were defined and may have an associated error of 10% (Norrgard 1995; TEWG 2000). Other foraging grounds from Georgia through the Carolinas experience a similar mixing of subpopulations (Bass et al. 1998; Sears et al. 1995; Sears 1994; TEWG 2000). Adult loggerheads have been observed to utilize the Chesapeake Bay as foraging habitat; available stranding and mark-recapture data indicate that adult loggerheads compose approximately five to seven percent of the total turtle population within the Bay (Lutcavage and Musick 1995; Musick and Limpus 1997). Telemetry studies conducted on turtles nesting in Georgia, South Carolina and North Carolina indicate that a relatively high percentage of adult loggerheads migrate north into waters north of Cape Hatteras, North Carolina, including Virginia's waters, post-nesting (Bell and Richardson 1978; Plotkin and Spotila 2002; ; Griffin et al. *in review*; S. Murphy pers. comm.). It is unreported, however, whether adult females nesting on Virginia's beaches also utilize Virginia's waters as post-nesting habitat.

Displacement experiments and long term mark-recapture studies on nesting beaches indicate that individual adult sea turtles exhibit strong fidelity to specific nesting beaches (Murphy and Hopkins-Murphy 1990; Papi et al. 1995; Papi et al. 1997; Addison 1996). Nest site fidelity may occur both within a nesting season and between reproductive seasons (Bowen 1995; Addison 1996). Turtles exhibiting fidelity to a particular nesting beach or foraging site may become vulnerable to potential sources of mortality found within adjacent waters (Chapter 8). Turtles that frequent a particular habitat may increase the probability of interaction with sources of mortality sharing that same spatial region. The U.S. Army Corps of Engineers (ACOE) utilizes hopper dredges off the coast of Virginia to obtain sand for placement on oceanfront beaches along Virginia Beach as part of a multi-decadal beach renourishment program. Hopper dredging and beach nourishment are activities have the potential to adversely affect sea turtles, either directly by encounters with dredging equipment or indirectly by alteration of nesting habitat (Coston-Clements and Hoss, 1983). Up to 20 sea turtles are taken incidentally by dredging operations per year in Virginia (T. Bargo, pers. comm.). This threat may be minimized by gathering data on the inter-nesting and post-nesting movements of turtles nesting on Virginia's beaches in order to refine time constraints for near shore dredging operations.

Between 1992 and 2001, satellite data were collected on the post-nesting movements of loggerhead sea turtles found nesting within Back Bay National Wildlife Refuge as part of a long-term contract with the Army Corps of Engineers to better define the temporal distribution of nesting sea turtles within Virginia's waters. Qualitative, non-filtered track data collected from one nesting turtle in 1992 were previously reported by Keinath (1993), and all track data (1992 to 2001) were presented in contract reports to the Army Corps of engineers. However, with recent developments in spatial analyses and filtering tools, historic presentations of these data are qualitative at best; no spatial statistics were applied to these data to quantitatively define aspects of each turtles' movement. These data were also not collectively considered as a means to define adult movement patterns, or inter-nesting/post-nesting habitat in Virginia.

The primary objectives and hypotheses for this study were to:

1. Determine the post-nesting movements of adult female loggerheads found nesting in Virginia and whether these turtles utilize the Chesapeake Bay or coastal waters of Virginia as inter-nesting or post-nesting habitat;

2. Determine whether turtles found nesting in Virginia exhibit fidelity to their nesting site or to an area established during inter-nesting intervals or post-nesting;

   H_{01} Turtles nesting in Virginia exhibit random movements and distribution relative to their nesting sites.

3. Propose time windows for dredging and renourishment operations that would minimize impacts to adult nesting females utilizing Virginia's beaches and coastal waters.

METHODS

Between May and continuing through September of each year (1992-2001), personnel and volunteers from the Back Bay National Wildlife Refuge (BBNWR) conducted a combination of daytime and nighttime sea turtle nesting patrols from the northern limit of Sandbridge Beach to the southern limit of BBNWR at the North

Carolina border, a distance of approximately 10 miles. Nighttime patrols began shortly after sunset and continued until sunrise. Off-road vehicles were used to drive the beach; patrols were timed so that no part of the beach was left unobserved for more than 45 minutes. All nesting loggerheads encountered were allowed to complete their nesting sequence. After nesting, turtles were restrained until VIMS personnel could access the refuge. All turtles were flipper tagged (inconel tags), and measured.

Telonics, Inc. ST-14 and ST-6 platform terminal transmitters (PTTs) were used to track the at-sea movements of these turtles. These tags weighed less than 1% of the turtles' body weight. Tag duty cycles were set to 24-hours a day continuous operation and were attached using the methods described in Chapter 2. After tag application, each turtle was immediately released. Data from transmitters were archived and filtered using the Satellite Tracking and Analysis Tool (STAT) (Coyne and Godley 2005). Location data and Location Indicator (LI) codes (0 to -9) from tags deployed in 1992, 1993 and 1994 were converted to Location Codes (LC) based on number of transmissions received (ARGOS 1988; 1996; D. Lampe pers. comm.; Appendices A and B). Based on the level of accuracy associated with LI codes, these early data did not exceed LC 0 (Appendix A). Data were filtered based on accuracy of transmission (LC 0-3, A and B were selected), likely swim speed between locations (< 5 km hour), minimum turning angle (> 3°), likely distance between points (<50 km), locations received in time intervals greater than or equal to one hour, and topography (< 0.5 m). Tracks were reconstructed in STAT and mapped in reference to bathymetry overlays and 50 m Bathymetric contours derived from the General Bathymetric Chart of the Oceans using a one-minute spatial resolution (Coyne and Godley 2005). Location data were quantified to determine the range in depth of the water column that the turtle traveled, mean distance from shore and mean bearing of travel path. Calibrated sensor data from each PTT were converted for temperatures ranging between 5º C and 35º C via linear regression. Resulting formulae were used to convert transmitted sensor data to ambient sea temperatures.

Filtered location data were imported into ArcView 3.2 and tracks were reconstructed for spatial movement analyses (Mercator projection). Migratory routes were identified, and inter-nesting habitats were determined using tests for Monte Carlo random walk simulations, a test for site fidelity comparing observed tracks with randomly generated walks (1000 replicates) using the Spatial Analyst and Animal Movement Analyses extensions. Significance was based on $p<0.05$. Low r^2 values represent higher relative site fidelity (Hooge and Eichenlaub, 1997).

When sample size permitted, home ranges for tracks exhibiting significant fidelity to a particular area were determined using a fixed kernel density model. For comparison among turtle tracks, a fixed ad hoc smoothing parameter (H) of 5.0 was used (projection units in km) (Silverman 1986). This value provided the best spatial fit of all track data within the constraints of aquatic sea turtle distribution. Kernel output contours were set at 95% and 50% confidence levels. The 95% contour is typically used to determine the area the animal actually inhabits or uses, and the 50% contour is used to determine the "core area of activity" (Hooge and Eichenlaub 2001). Minimum sample size of location data required to estimate concentrated home ranges (50% kernel contour) was determined for each track using cumulative home range analysis. Cumulative home ranges were calculated using kernel densities estimated at daily intervals (day one, days one and two combined, days one, two and three, etc.) (McGrath 2005). These estimates were plotted over time to determine the asymptotic point at which the actual home range was achieved: a minimum two-week sample period was necessary to obtain the concentrated home range per individual.

Timing of turtle movements south of Virginia's waters, direction of travel, and significance of travel direction were determined using circular point statistics. Significance of travel direction was calculated using the Raleigh's z statistic and significant values based on $p < 0.05$ (Zar 1999).

RESULTS

A total of nine satellite transmitters were deployed on seven individual turtles between 1992 and 2001. During the summers of 1998 and 1999, several turtle crawls and nests were recorded within BBNWR. However, due to difficulties experienced by BBNWR personnel and volunteers, nighttime patrollers did not physically encounter a nesting turtle during 1998 or 1999. One individual turtle, QQB-590, was observed to nest during three separate nesting seasons, once in 1993 and 1995, and twice in 1997, resulting in a two-year remigration interval with an approximate 14 day inter-nesting interval. This turtle exhibited significant fidelity to the waters adjacent to the nesting beach or to post-nesting habitat in the lower Delaware Bay. During the 1995 and 1997 nesting seasons, this turtle established a concentrated home range in the lower Delaware Bay ranging from 193.9 to 221.1 km^2.

Three additional individuals exhibited fidelity to the waters adjacent to or just south of their nesting beach prior to a fall migration or transmitter failure. These turtles established home ranges with areas between 116.4 to 160.6 km^2. Three turtles exhibited directed movement immediately post-nesting and were tracked as far south as Georgia, Florida and the Gulf of Mexico. Mean home concentrated home range among all tracks was 159.4 km^2 (+/-43.5 km^2 SD). With the exception of QQB-590, most turtles began to move south immediately post-nesting.

Mean straight carapace lengths (SCL) for all recorded nesting events (n=9) was 90.5 cm (+/- 4.6 cm SD) (notch to notch), including three separate measurements of 95.9 cm, 96.2 cm and 96.0 cm for each of QQB-590's respective nesting seasons. SCL measurements ranged between 85.6 cm and 96.2 cm (Table 3.1).

1992: Satellite Tag #01235; Flipper tag # QQB-582

The first turtle nested on July 30, 1992. Post-release, QQB-582 traveled from Virginia Beach south of Cape Hatteras, North Carolina. Between August 5 and 10, she remained off shore of Cape Hatteras, after which she slowly moved south. By September 4, 1992 the turtle appeared to remain off the east coast of Florida until transmission failed on September 8, 1992, after 40 days. QQB-582 traveled from Virginia to the northern coast of Florida within a two-month timeframe (Figure 3.2) (Keinath, 1993).

This turtle exhibited significantly directed movement (z=14.6; n=42; r=0.59) throughout her entire track, with a mean bearing of 203º (+/- 70º SD) (rounded to the nearest degree). Due to her rapid movements south, she did not exhibit significant fidelity to any particular region. Mean travel speed was 2.1 km/hr (+/- 1.3 km/hr SD) (Keinath [1993] reported mean speed with no associated SD). She ranged up to 100.0 km from shore, averaging 39.0 km (+/- 30.9 km SD) from the nearest shoreline. Mean depth associated with her locations was 21.8 m (+/- 12.0 m SD) (Table 3.2). Temperature data

Table 3.1 Species, release size, size and location data for loggerhead turtles tracked, 1992 to 2001.

Tag Year	1992	1993*	1994	1995*	1996	1997a*	1997b	2000	2001
Release Date	7/30/1992	7/11/1993	7/8/1994	8/14/1995	8/9/1996	7/15/1997	7/20/1997	7/11/2000	7/2/2001
Primary Tag	QQB-582	QQB-590	SSB-895	QQB-590	QQB545	QQB-590	SSB-576	XXF-853	SSV650
Lengths (cm)	88.3 SCL	95.9 SCL	88.3 SCL	96.2 SCL	91.9 SCL	96.0 SCL	85.5 SCL	86.1 SCL	85.6 SCL
Track Duration (days)	40	17	98	19	197	110	60	36	41
LC**									
3	n/a	n/a	n/a	0	1	9	2	0	0
2	n/a	n/a	n/a	0	7	13	4	0	1
1	n/a	n/a	n/a	1	17	14	8	1	3
0	0	14	16	3	8	11	12	4	1
A	0	12	27	10	54	39	25	13	14
B	38	28	62	27	70	137	46	30	34
Total Locations	38	54	105	41	157	223	97	48	53

*Indicates tracks of same turtle observed nesting in 1993, 1995 and 1997

**Location Indicator codes converted to LC for years 1992, 1993 and 1994 based on number of messages received (Appendices C and D)

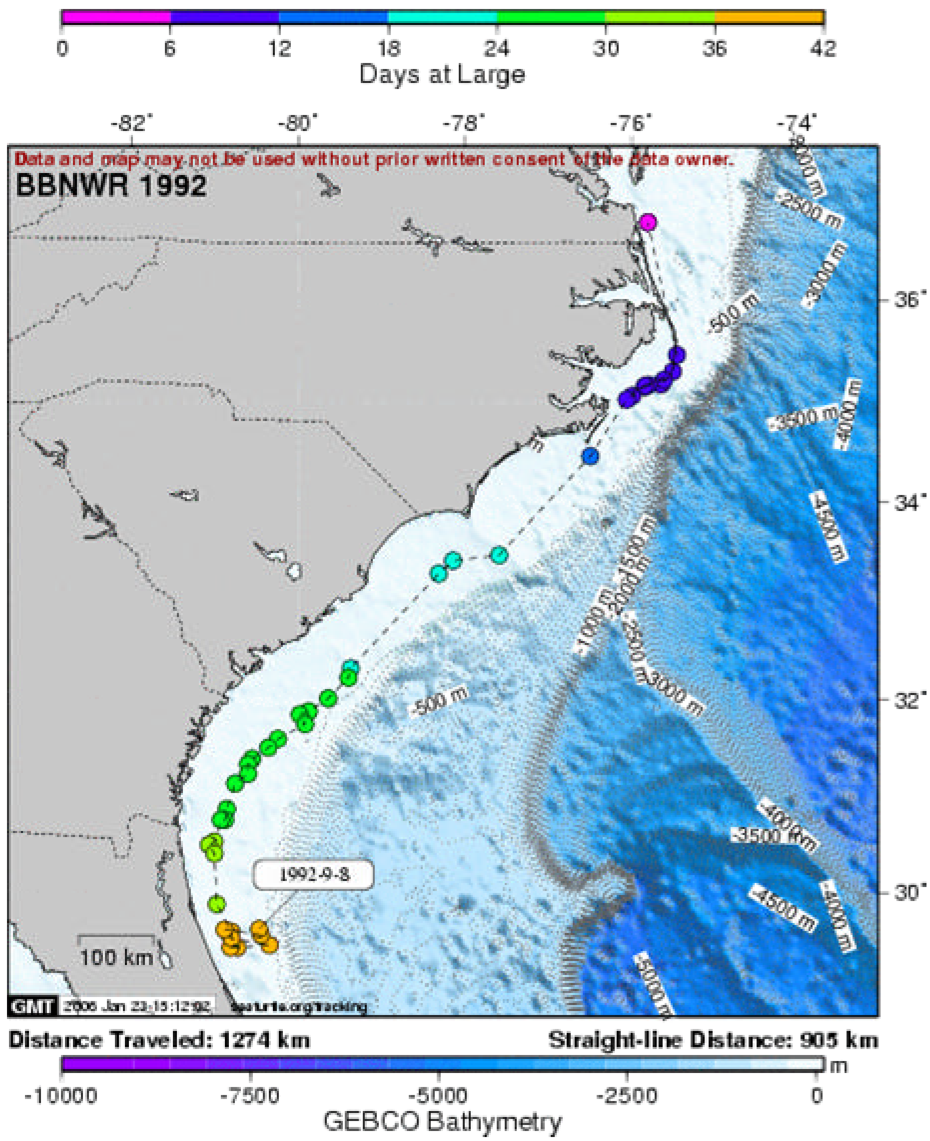


Figure 3.2 Satellite tracks of nesting loggerhead, July 30-September 8, 1992

Table 3.2 Summary statistics of turtle movement data derived in STAT, 1992 to 2001 (Coyne and Godley 2005).

Tag Year	1992	1993*	1994	1995*	1996	1997a*	1997b	2000	2001
Primary Tag	QQB-582	QQB-590	SSB-895	QQB-590	QQB545	QQB-590	SSB-576	XXF-853	SSV650
Mean Depth (m)	21.8 (+/- 12.0 SD)	8.7 (+/- 12.1 SD)	226.0 (+/- 1338.8 SD)	10.7 (+/- 13.7 SD)	13.2 (+/- 15.0 SD)	19.7 (+/- 106.0 SD)	15.1 (+/- 11.8 SD)	14.1 (+/- 12.2 SD)	17.7 (+/- 9.3 SD)
Range (m)	0 to 43.8	0 to 61.3	0 to 893.0	0 to 43.3	0 to 180.1	0 to 1355.0	0 to 53.7	0 to 64.2	0 to 34.0
Distance from shore (km)	39.0 (+/- 30.9 SD)	9.6 (+/- 19.0 SD)	79.3 (+/- 89.9 SD)	19.7 (+/- 25.1 SD)	7.8 (+/- 9.7 SD)	14.7 (+/- 14.9 SD)	9.17 (+/- 13.0 SD)	8.4 (+/- 9.8 SD)	20.8 (+/- 18.3 SD)
Range (km)	0 to 80.0	0 to 97.0	0 to 267.0	0 to 63.0	0 to 58.0	0 to130.0	0 to 66.0	0 to 40.0	0 to 64.0
Mean Speed (km/h)	2.1 (+/- 1.3 SD)	3.5 (+/- 3.4 SD)	4.0 (+/- 3.8 SD)	4.5 (+/- 3.8 SD)	1.6 (+/- 2.5 SD)	2.6 (+/- 3.4 SD)	2.2 (+/- 3.0 SD)	3.5 (+/- 3.7 SD)	2.5 (+/- 1.9 SD)
Range (km/h)	0 to 5.5	0.1 to 14.7	0.02 to 16.9	0.09 to 9.49	0 to 13.9	0 to 16.0	0 to 15.2	0 to 15.0	0.03 to 9.2
Mean Bearing (º)	203 (+/- 70 SD)	185 (+/- 103 SD)	202 (+/- 83 SD)	174 (+/- 113 SD)	196 (+/- 87 SD)	186 (+/- 99 SD)	176 (+/- 96 SD)	179 (+/- 92 SD)	203 (+/- 67 SD)

*Indicates tracks of same turtle observed nesting in 1993, 1995 and 1997 were reported by Keinath (1993), however no record of raw temperature data was found for the present analysis.

1993: Satellite Tag #01229; Flipper tag # QQB-590

In 1993, QQB-590 nested on July 12, 1993, and subsequently remained within Virginia waters just off shore of BBNWR and FCSP until July 28, 1993. Upon last transmission (17 days after tag attachment), this turtle had moved slightly north to the southern tip of the Eastern Shore (Figure 3.3). QQB-590 did not exhibit directed movement during the period her transmitter remained active ($z=0.21$; $n=43$; $r=0.07$); mean bearing of travel was 185º (+/- 103º SD). Her observed track was more constrained than random movements and she exhibited fidelity to the region directly offshore of BBNWR and FCSP ($p<0.01$; $r^2= 0.06$). Her concentrated home range (50% kernel contour) offshore of BBNWR and FCSP was 137.7 km^2. Mean travel speed was 3.5 km/hr (+/- 3.4 km/hr SD). She ranged up to 97.0 km from shore, averaging 9.6 km (+/- 19.0 km SD) from the nearest shoreline. Mean depth associated with her locations was 8.7 m (+/- 12.1 m SD) (Table 3.2). Mean ambient temperatures recorded by her tag were 23.7º C (+/- 2.8º C), ranging between 15.2º C and 26.5º C.

1995: Satellite Tag #01231; Flipper tag # QQB-590

QQB-590 was observed to nest a second year at BBNWR on August 14, 1995. Immediately after nesting, QQB-590 moved north into the lower Delaware Bay where she remained until the transmitter failed on September 7, 1995 after 19 days (Figure 3.4).

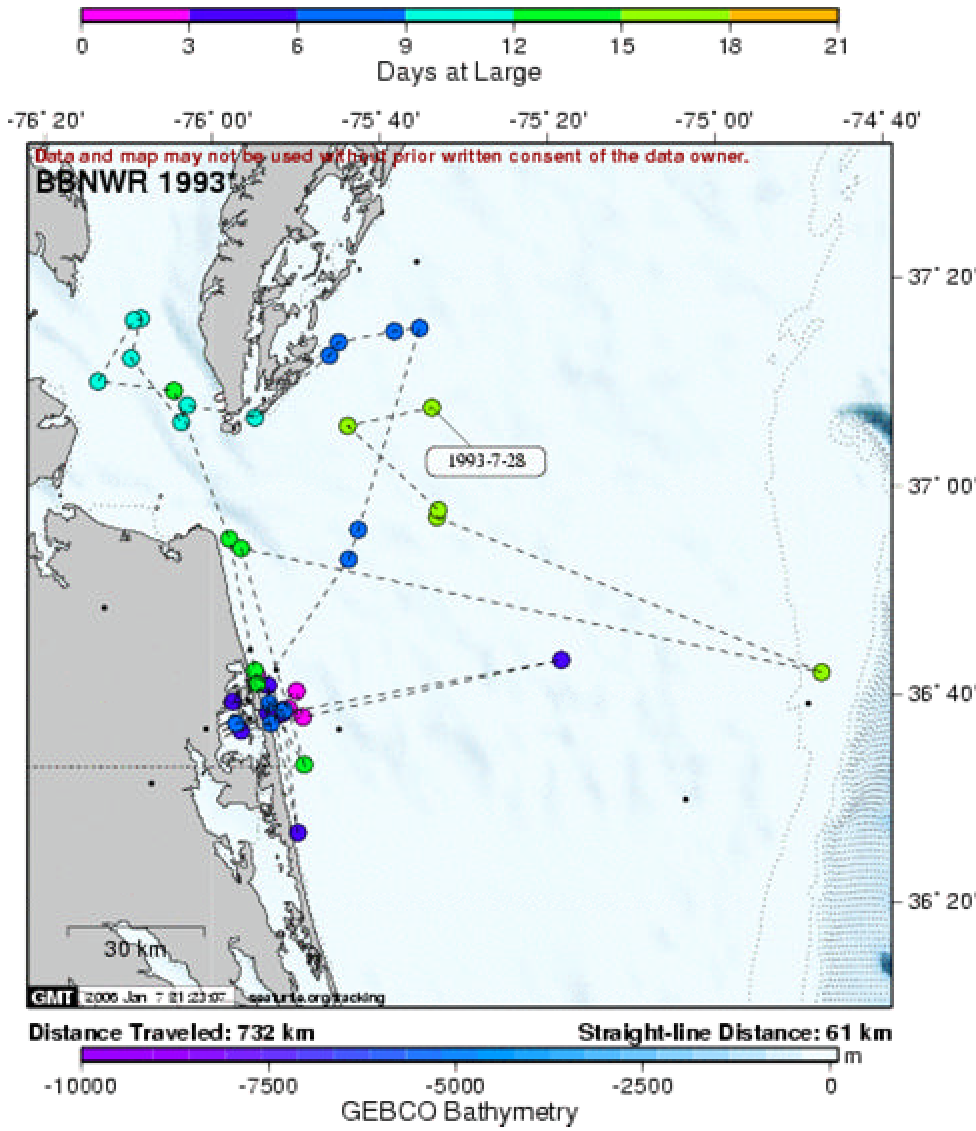


Figure 3.3 Satellite tracks of nesting loggerhead, July 12-July 28, 1993

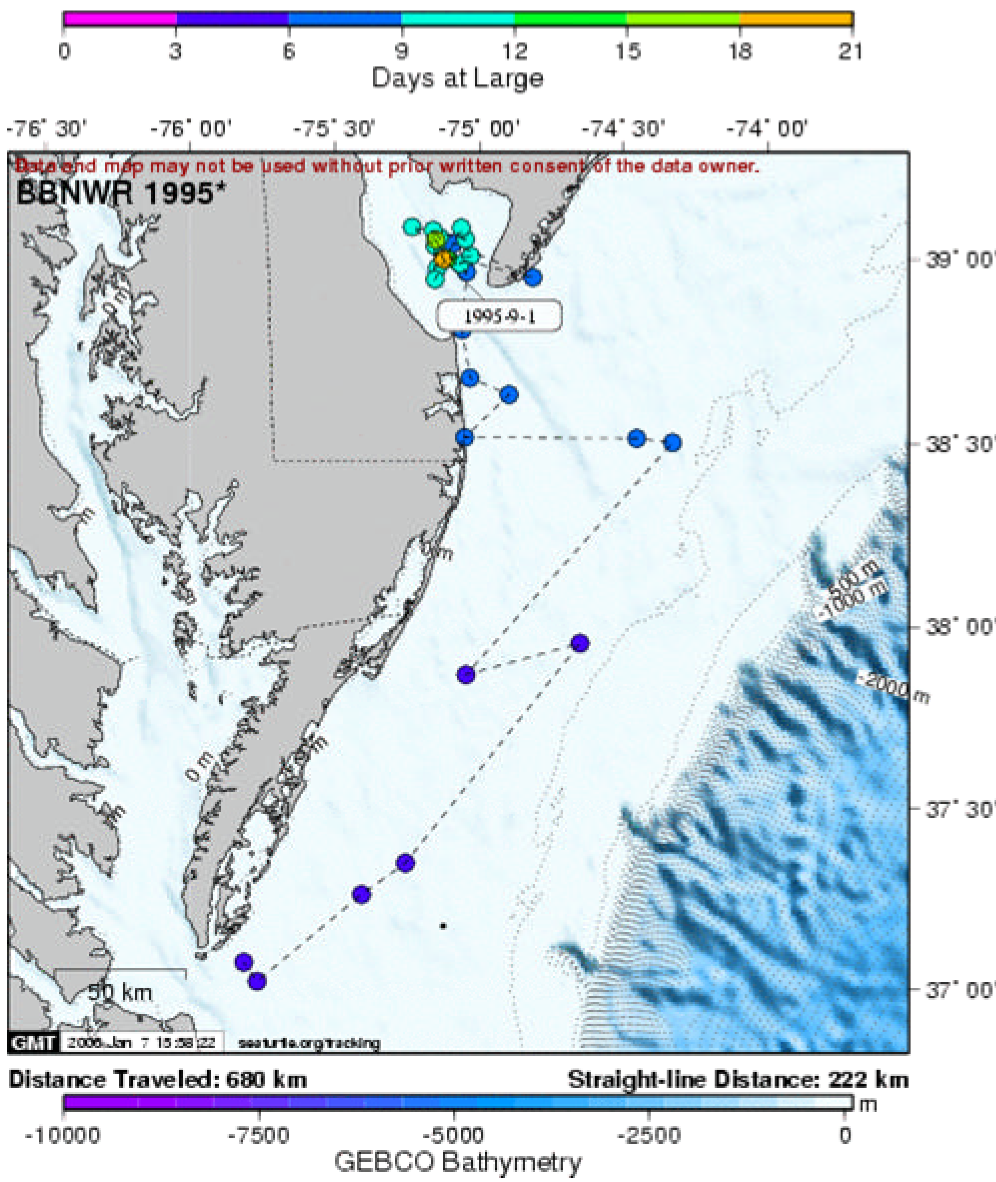


Figure 3.4 Satellite tracks of nesting loggerhead (originally tagged in 1993), August 14-September 7, 1995

Aside from her initial movements north to the Delaware Bay, QQB-590 did not exhibit directed movement during the period her transmitter remained active (z=0.66; n=29; r=15.4), maintaining a mean bearing of 174º (+/- 113º SD). Her observed track was more constrained than random movements and she exhibited a high degree of fidelity to a relatively discrete region in the lower Delaware Bay ($p<0.001$; r^2= 0.005). Her concentrated home range (50% kernel contour) within the Delaware Bay was 193.9 km^2. Mean travel speed was 4.5 km/hr (+/- 3.8 km/hr SD). She ranged up to 63.0 km from shore, averaging 9.7 km (+/- 25.1 km SD) from the nearest shoreline. Mean depth associated with her locations was 10.7 m (+/- 13.7 m SD) (Table 3.2). No temperature data were available for this track.

1997a: Satellite Tag #01236; Flipper tag # QQB-590

On July 15 1997, QQB-590 returned to nest a third time in five years on BBNWR. Shortly after her first nesting event in 1997, this turtle moved up into the Chesapeake Bay where she remained for approximately two weeks until a second nesting event on July 31, 1997 (confirmed by BBNWR personnel). This turtle appears to have a two-year remigration with a probable two-week inter-nesting interval. After her second observed nesting event in 1997, she swam up to the Delaware Bay where she remained for the rest of the summer. With the first cold snap (October 18, 1997) she began her southern winter migration. The last transmission was received off of Cape Hatteras on November 1, 1997 after 110 days (Figure 3.5).

Post-nesting, this turtle exhibited strong fidelity to the lower Delaware Bay ($p<0.0009$; r^2=0.006). The area associated with QQB-590's range (95% confidence

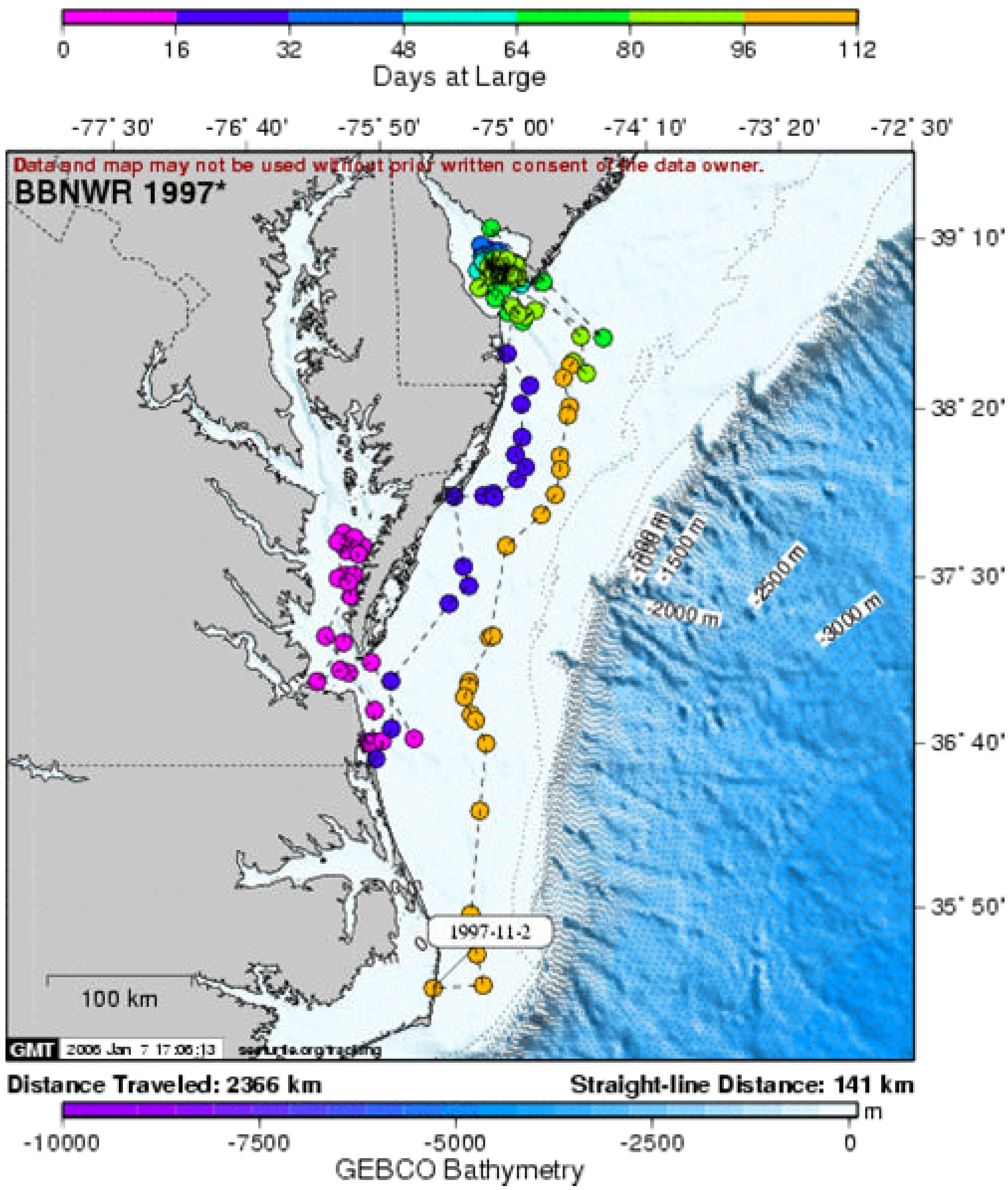


Figure 3.5 Satellite tracks of nesting loggerhead (originally tagged in 1993), July 15-November 1, 1997

contour) while in her post-nesting habitat in the lower Delaware bay was 911.4 km^2, including a 50% confidence contour of 226.4 km^2. She exhibited significantly directed movement (z=14.5; n=26; r=0.75) when temperatures dropped consistently below 20º C after mid-October (Figure 3.6). She traveled at a mean speed of 2.6 km/hr (+/- 3.4 km/hr SD) and ranged up to 130.0 km from shore, averaging 14.7 km (+/- 14.9 km SD) from the nearest shoreline. Mean depth associated with her locations was 19.7 m (+/- 106.0 m SD) (Table 3.2). Mean ambient temperatures recorded by her tag were 23.7º C (+/- 4.4º C), ranging between 31.3º C and 15.0º C.

1994: Satellite Tag #01230; Flipper tag # SSB-895

SSB-895 nested and was tagged on July 8, 1994. Post-nesting, she moved south in late July, rounding Cape Hatteras on July 12, 1994. She continued to travel south, remaining near shore, reaching Florida's waters by mid-August. Continuing south past Cape Canaveral by August 24, 1994, this turtle eventually stopped transmitting mid-October west of Key West, Florida after 98 days (Figure 3.7). SSB-895 exhibited significantly directed movement (z=8.6; n=100; r=0.29) throughout her entire track, with a mean bearing of 202º (+/- 83º SD). Due to her directed movements south, she did not exhibit significant fidelity to any particular region. Mean travel speed was 4.0 km/hr (+/- 3.8 km/hr SD). She ranged up to 267.0 km from shore, averaging 79.3 km (+/- 89.9 km SD) from the nearest shoreline. Mean depth associated with her locations was 226.0 m (+/- 1338.8 m SD) (Table 3.2). No temperature data were available for this track.

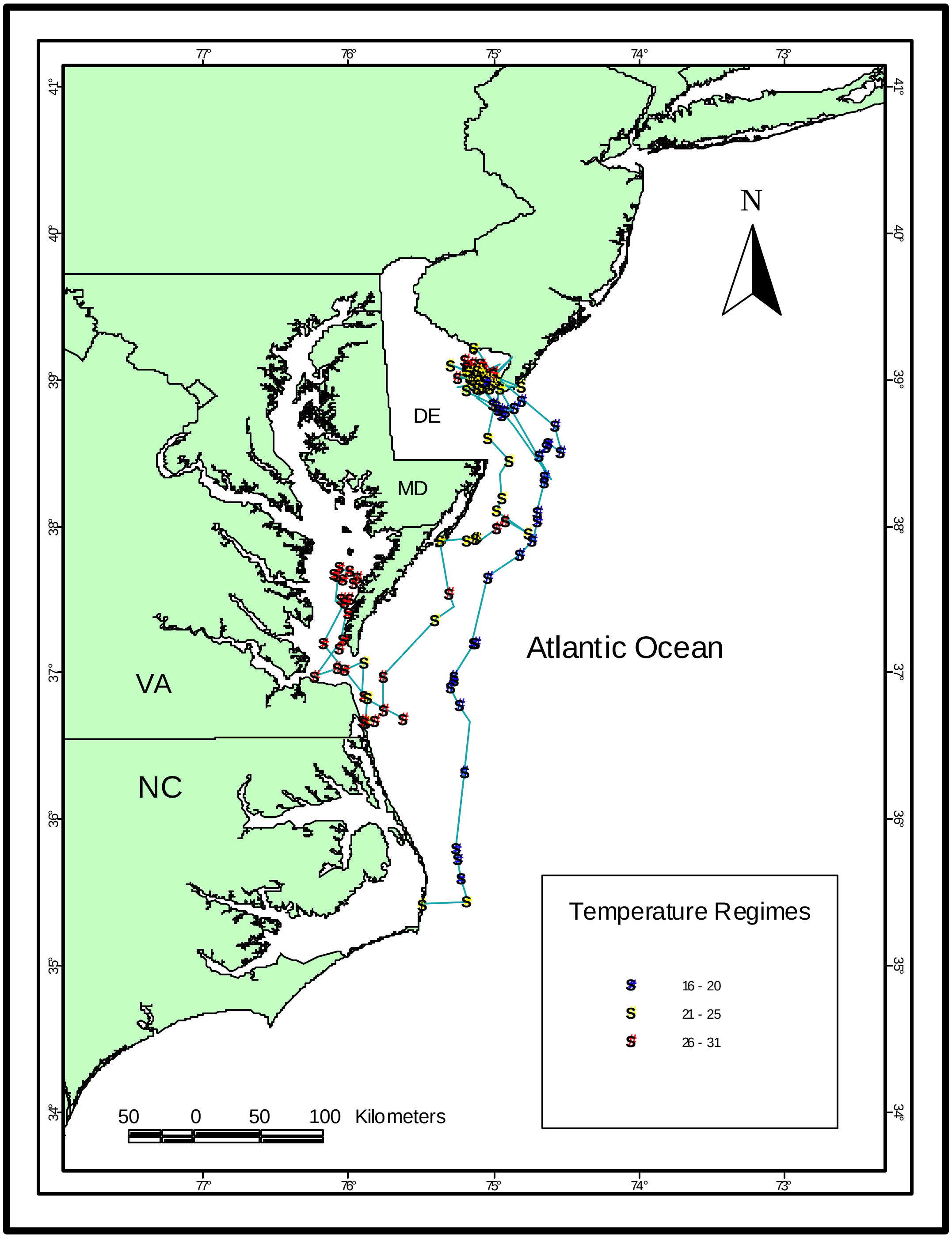


Figure 3.6 Ambient tag temperature (°C) associated with QQB-590 movements, 1997

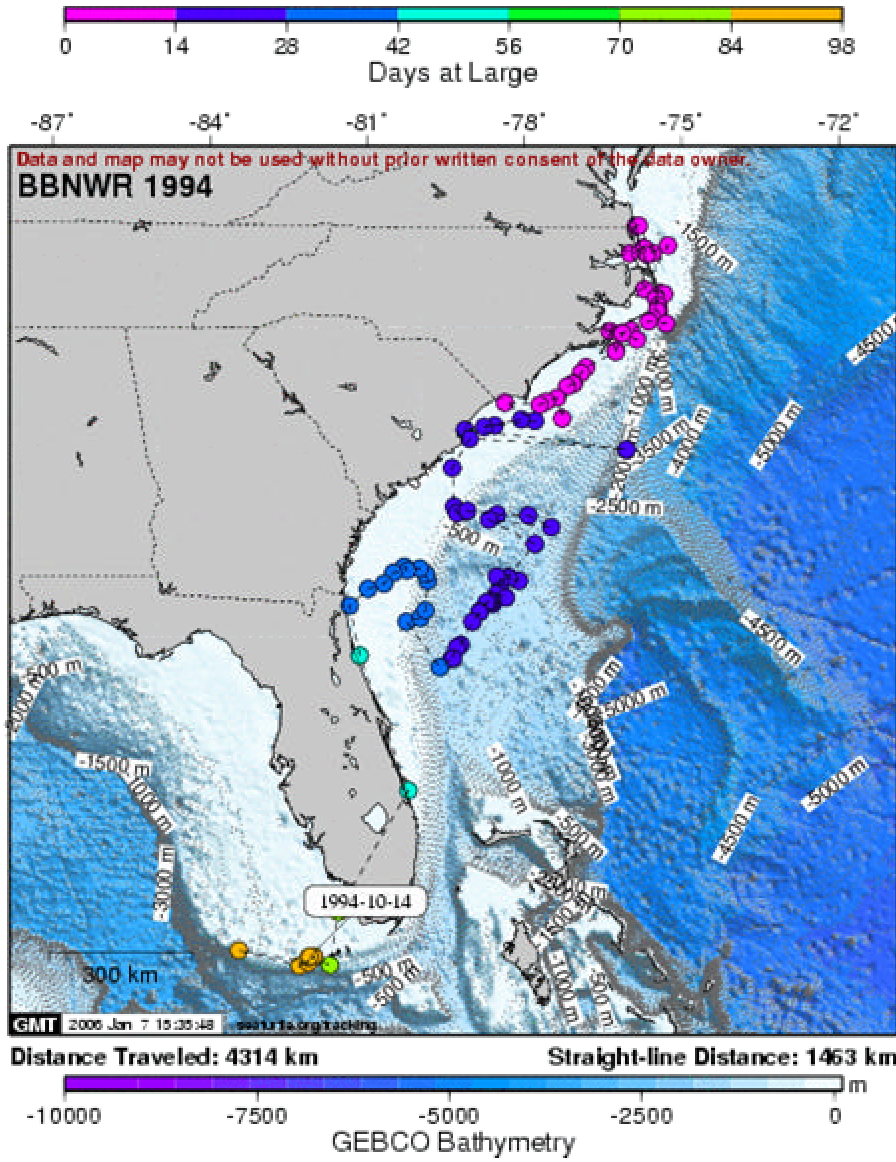


Figure 3.7 Satellite tracks of nesting loggerhead, July 8-October, 1994

1996: Satellite Tag #19962; Flipper tag # QQB-545

QQB-545 nested on August 25, 1996. She remained in the waters immediately adjacent to BBNWR, FCSP and the northern shoreline of North Carolina for two months post-nesting before migrating south on November 3, 1996. She continued to move south past Cape Hatteras on November 11, finally entering Florida waters on December 6, 1996 where she continued to travel south along the shoreline. After rounding the southern tip of Florida on February 14, 1997, final transmissions for this turtle were received on February 22, 1997 off the west coast of Florida in the Gulf of Mexico (Figure 3.8). Tag life was 197 days.

Between August 25 and November 3, 1996, QQB-545 exhibited significant fidelity ($p<0.04$; $r^2=0.02$) to water adjacent to and just south of the Virginia-North Carolina border. During this period, she did not exhibit a significant direction of travel ($z=1.4$; $n=101$; $r=0.12$). Kernel analyses indicated that her concentrated home range (50% contour) was 121.4 km^2. When ambient temperatures dropped to 16º C the first week in November, QQB-545, exhibited significantly directed movement ($z=12.6$; $n=52$; $r=0.50$) throughout the remainder of her track, with a mean bearing of 196º (+/- 87º SD) (Figure 3.9). During her southern migration, she did not exhibit significant fidelity to any particular region. Mean travel speed was 1.6 km/hr (+/- 2.5 km/hr SD). She ranged up to 58.0 km from shore, averaging 7.8 km (+/- 9.7 km SD) from the nearest shoreline. Mean depth associated with her locations was 13.2 m (+/- 15.0 m SD) (Table 3.2). Mean ambient temperatures were 19.0º C (+/- 2.8º C), and ranged between 11.4º C and 24.5º C.

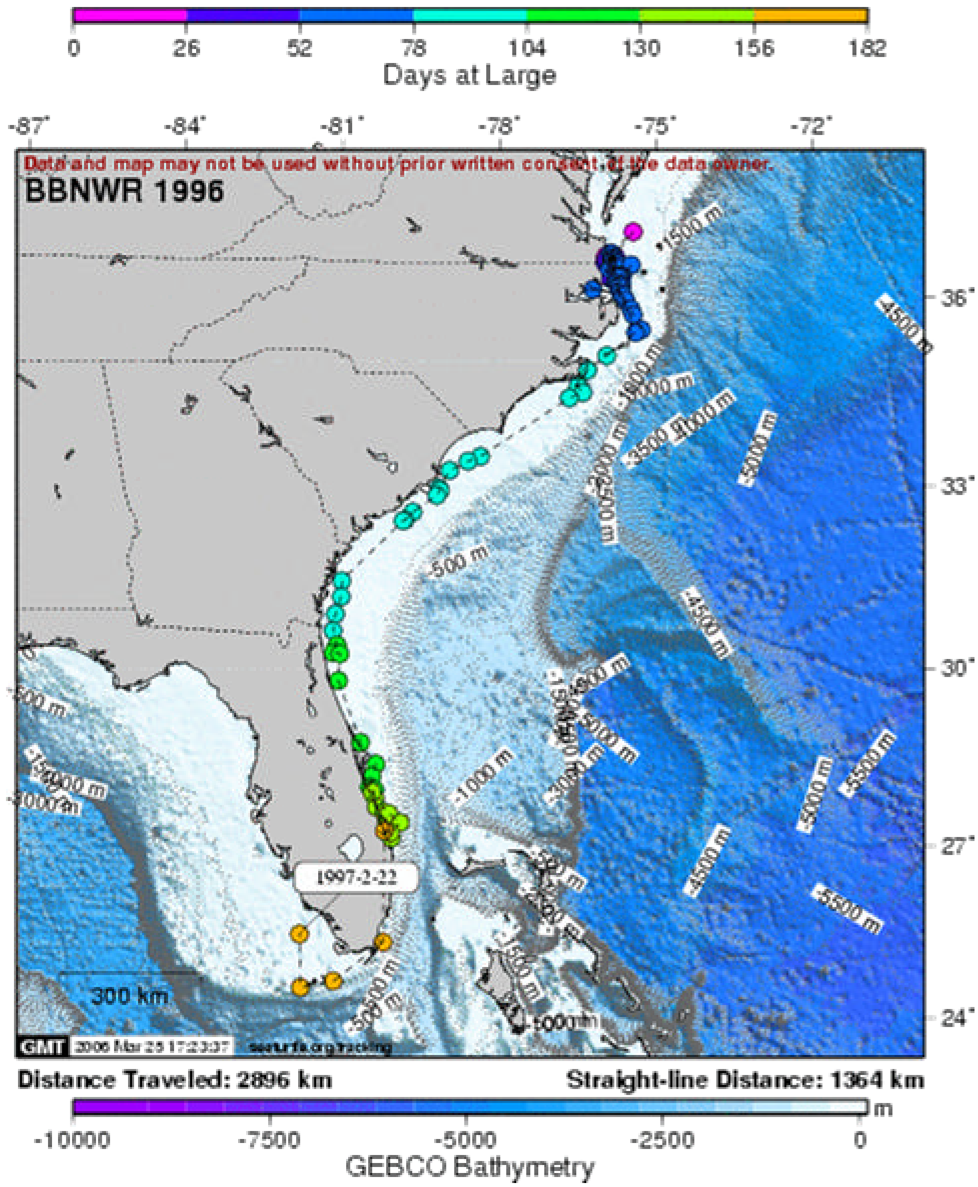


Figure 3.8 Satellite tracks of nesting loggerhead, August 25, 1996-February 22, 1997

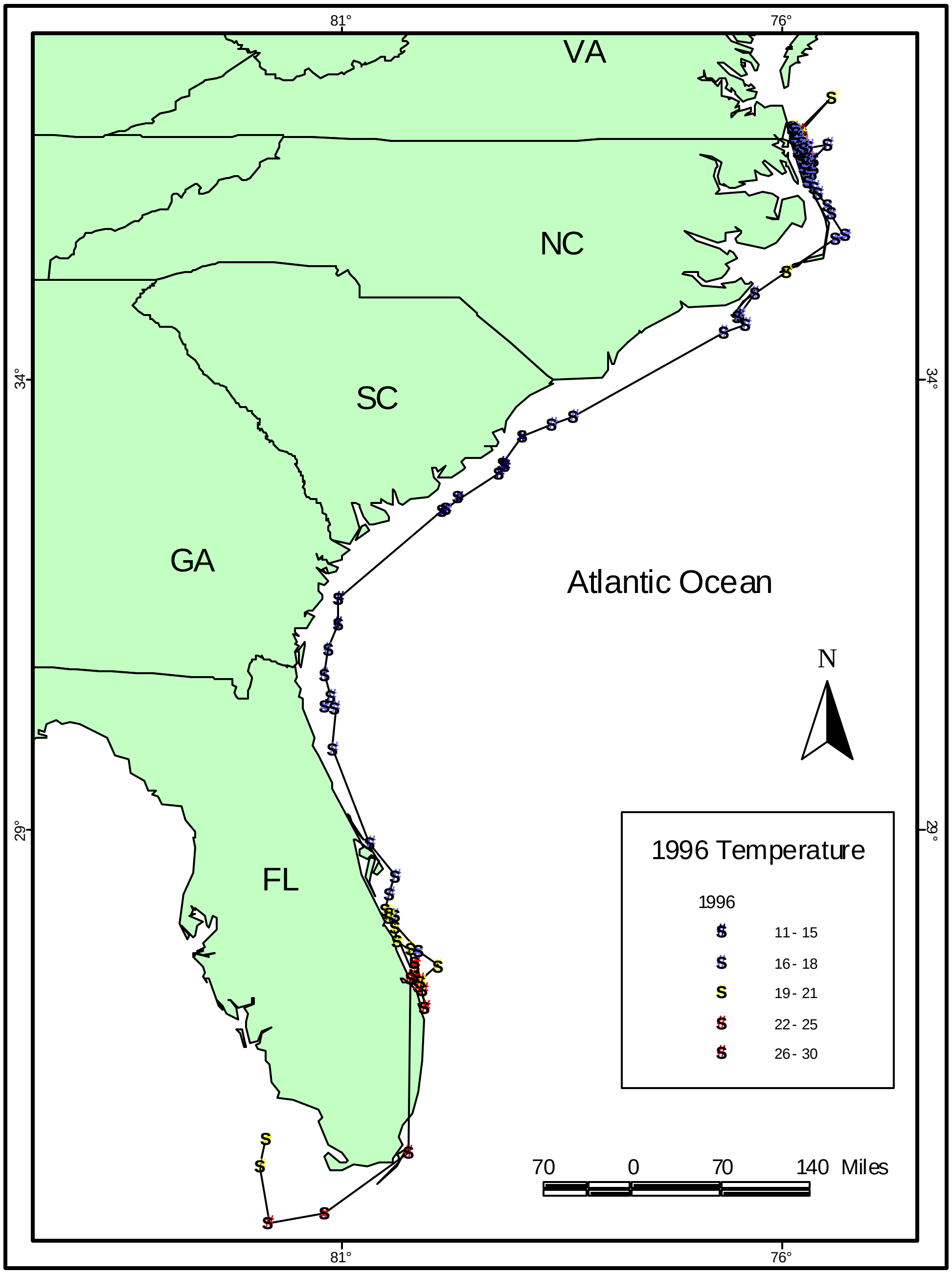


Figure 3.9 Ambient tag temperature (C) associated with QQB-545 movements, 1996

1997b: Satellite Tag #04931; Flipper tag # SSB-576

In addition to QQB-590, a second female nested at BBNWR on July 22, 1997. This turtle remained close to shore in the waters adjacent to BBNWR, FCSP and northern North Carolina until October 18, 1997 when the last transmissions were received 60 days after deployment (Figure 3.10). SSB-576 did not exhibit directed movement during the period her transmitter remained active (z=1.72; n=96; r=0.13). She maintained a mean bearing of 176º (+/- 96º SD) and exhibited fidelity to the region south of the Virginia-North Carolina ($p<0.0009$; $r^2= 0.16$) (Figure 3.10). Kernel home range analysis resulted in a concentrated home range (50%) area of 160.6 km^2. Mean travel speed was 2.2 km/hr (+/- 3.0 km/hr SD). Her tracks ranged up to 66.0 km from shore, averaging 9.2 km (+/- 13.0 km SD) from the coast. Mean depth associated with her locations was 15.1 m (+/- 11.8 m SD) (Table 3.2). Mean ambient temperatures were 23.6º C (+/- 2.4º C), ranging between 19.0º C and 31.8º C.

2000: Satellite Tag #19961; Flipper tag # XXF-853

XXF-853 nested on July 12, 2000. This turtle immediately moved south, remaining very close to the shoreline of the Outer Banks, North Carolina. On August 4, 2000, she entered into Pamlico Sound through Oregon Inlet, moving between the Sound and Inlet several times from August 4 to 16. Temperature data from the satellite transmitter coupled with NOAA Buoy and sea surface satellite data confirmed her presence in the warmer waters of the Sound. Transmission ceased on August 16, 2000, 36 days after tag application (Figure 3.11). SSB-576 did not exhibit directed movement during the period her transmitter remained active (z=1.3; n=54; r=0.16), maintaining a

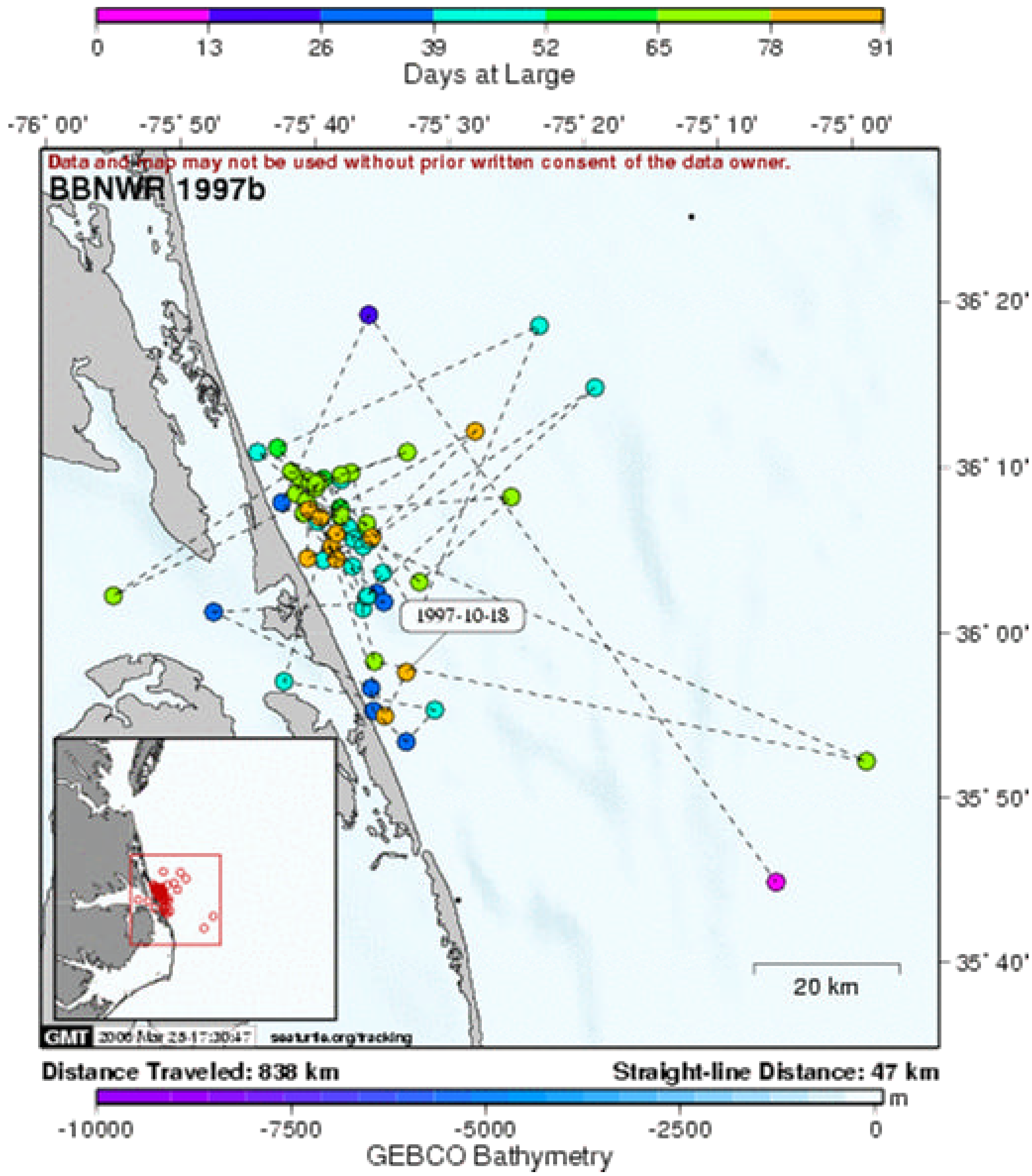


Figure 3.10 Satellite tracks of nesting loggerhead, July 22-October 18, 1997

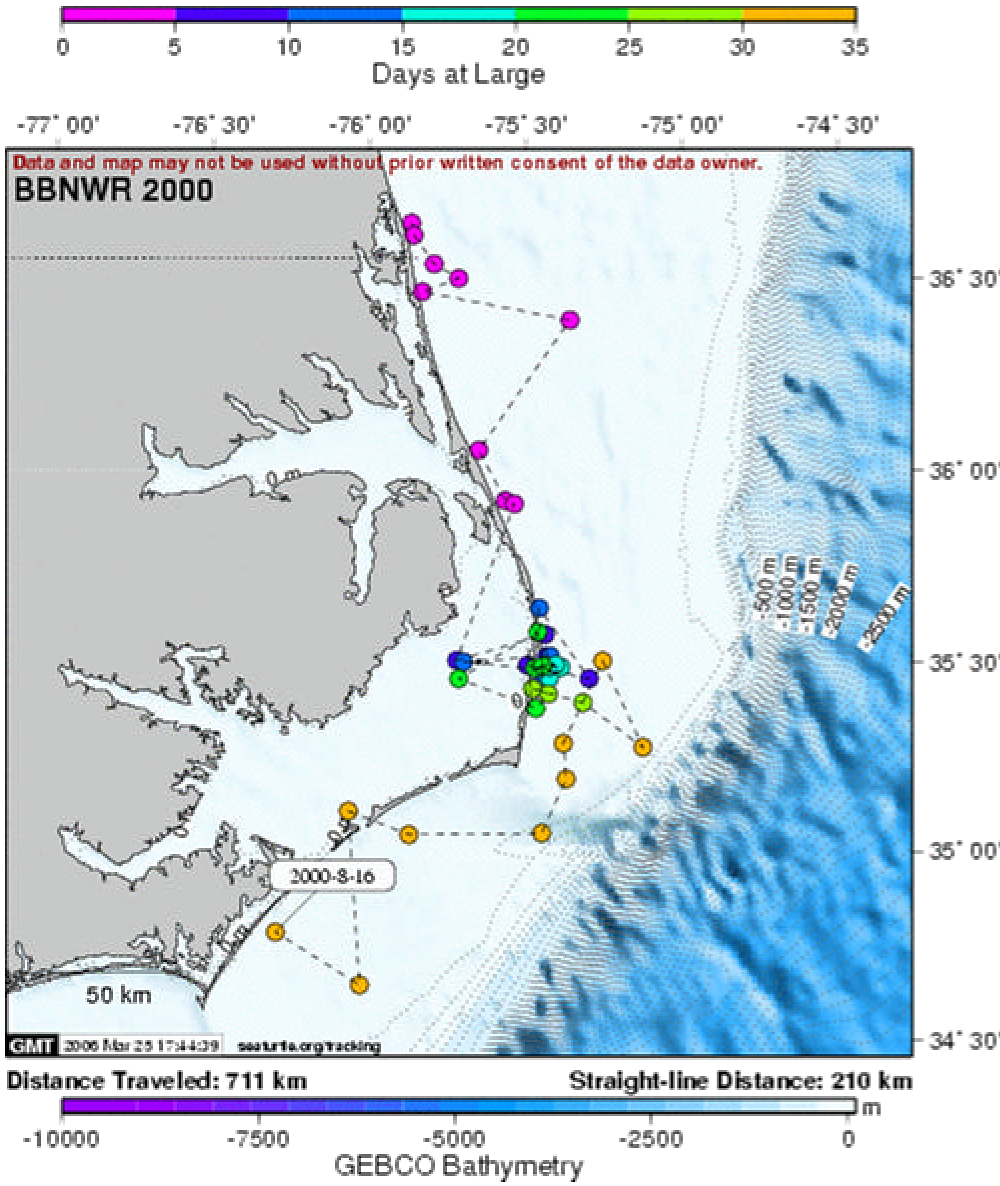


Figure 3.11 Satellite tracks of nesting loggerhead, July 12-August 16, 2000

mean bearing of 179º (+/- 92º SD). She exhibited fidelity to the region just north of Cape Hatteras ($p<0.04$; $r^2= 0.14$) (Figure 3.11) and her concentrated (50%) kernel home range spanned an area of 116.4 km^2. Mean travel speed was 3.5 km/hr (+/- 3.7 km/hr SD) and tracks ranged up to 40.0 km from shore, averaging 8.4 km (+/- 9.8 km SD) from the nearest shoreline. Mean depth associated with her locations was 14.1 m (+/- 12.2 m SD) (Table 3.2). Mean ambient temperature was 28.5º C (+/- 3.3º C), and ranged between 20.8º C and 32.3º C.

2001: Satellite Tag #19961; Flipper tag # SSV-650

SSV-650 nested and was tagged on July 2, 2001. After nesting, this turtle moved immediately south remaining very close to the shoreline of the Outer Banks, North Carolina, as she moved south to the Georgia coastline where she remained until transmissions ceased on August 13, 2001 after 41 days (Figure 3.12). SSV-650 exhibited directed movement ($z=16.1$; $n=60$; $r=0.5$) throughout her entire track, with a mean bearing of 203º (+/- 67º SD). During her southern migration, she did not exhibit significant fidelity to any particular region. Mean travel speed was 2.5 km/hr (+/- 1.9 km/hr SD). She ranged up to 64.0 km from shore, averaging 20.8 km (+/- 18.3 km SD) from the nearest shoreline. Mean depth associated with her locations was 17.7 m (+/- 9.3 m SD) (Table 3.2). Tag temperature data indicated that this turtle encountered increasingly warmer waters as she traveled south. Unfortunately, calibration data received from Telonics were inadequate to determine exact sea surface temperatures for this tag's transmissions.

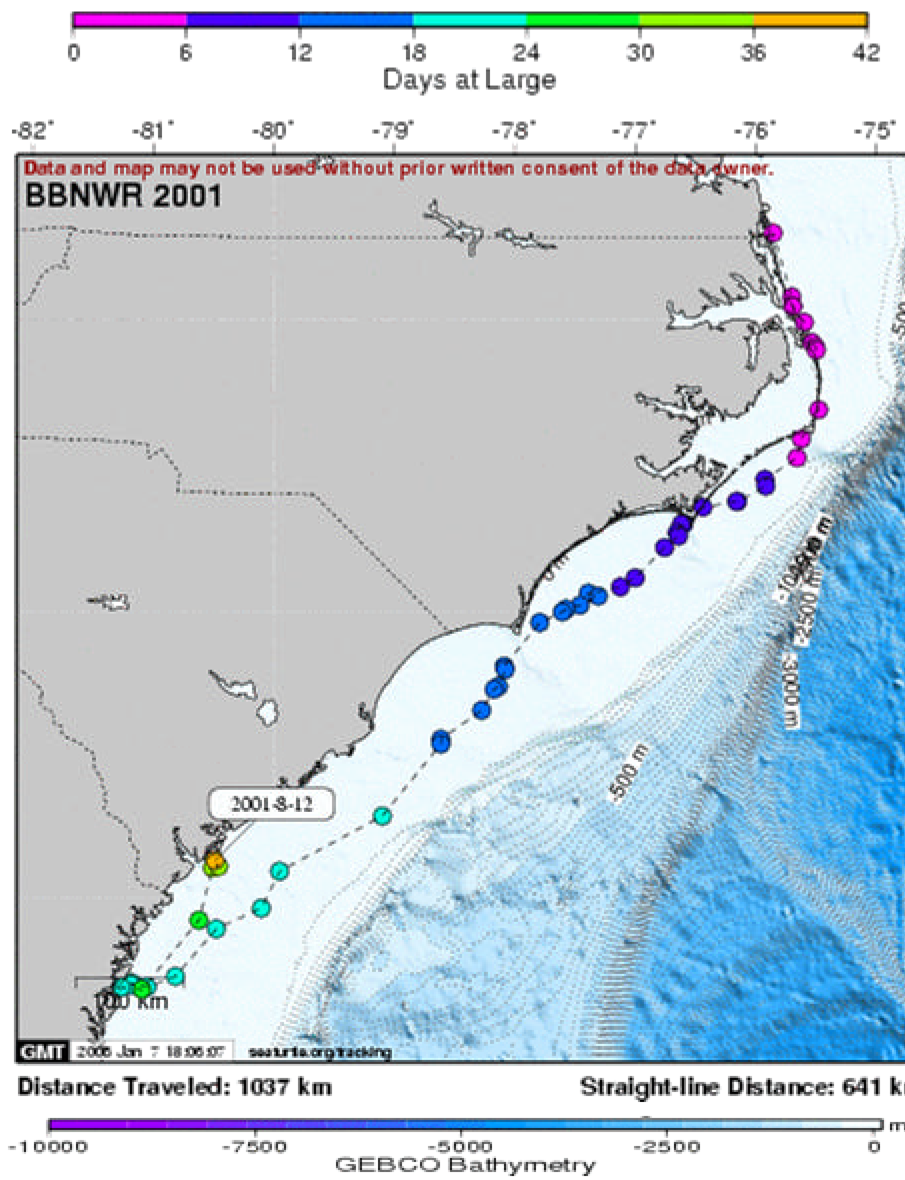


Figure 3.12 Satellite tracks of nesting loggerhead, July 2-August 13, 2001

DISCUSSION

The mean size (89.8 cm SCL) of adult females found nesting in Virginia is smaller than the estimated 92.0 cm SCL size of maturity for loggerheads throughout their US and Caribbean range (TEWG 2000). Carapace lengths of QQB-590 were the only lengths to exceed 92.0 SCL (Table 3.1). Mean carapace length for the remaining six turtles was 87.7 cm +/- 2.4 cm SD. The low mean SCL may be an artifact of a small sample size, however, these turtles most likely represent the majority of individuals nesting in Virginia over a ten-year period. It is possible that there is a correlation between relative size and migratory distance between nesting sites and inter-reproductive foraging areas (Godley et al. 2003). Unfortunately, most tags ceased to transmit prior to when the turtles established their over-wintering habitat.

The sample size of tagged turtles was small, in part due to the high cost of satellite telemetry, few numbers of nests occurring in Virginia in any given year, and the potential to miss the one or two turtles nesting on the study beaches during the survey period. Despite these factors, the tracks associated with QQB-590 during her 1993, 1995 and 1997 nesting seasons indicate that there is a good probability that of the few turtles utilizing Virginia's beaches to nest, some will exhibit some degree of philopatry to Virginia beaches and adjacent beaches in North Carolina during subsequent nesting events. QQB-590 exhibited fidelity between different reproductive seasons to the same post-nesting habitat: the lower Delaware Bay. She also exhibited fidelity to a relatively discrete area in the lower Chesapeake Bay during her documented inter-nesting interval in 1997. Based on her early nesting event in 1993 and subsequent fidelity to the waters adjacent to her nesting beach, it is likely that she nested a second time on refuge beaches prior to the end of her 1993 reproductive season. It is also probable that she nested unobserved in 1995 prior to being tagged. Her post-nesting movements in 1995 indicated that she was tagged during her last nesting event that season, as she traveled north to the Delaware Bay, similar to her 1997 post-nesting movements. These data provide rare insight to the movements of one nesting female over the course of several reproductive seasons, illustrating that some loggerhead sea turtles consistently use Virginia's beaches as a suitable nesting site and utilize the Chesapeake and/or Delaware Bays as inter-nesting and post-nesting habitat.

Loggerhead turtles are known to nest on average three to four times within a season (reviewed by Miller 1997). It is likely that the turtles tracked in this study nested unobserved either prior to or after tag application. In addition to QQB-590, three of the individuals tracked exhibited fidelity to the waters adjacent to their nesting beaches, or slightly south. It is possible that these turtles nested additional times unobserved on neighboring beaches. Nesting occurs along North Carolina's entire shoreline; however in the northern half of the state (from Ocracoke Inlet to the Virginia border) slightly more than 80 nests are recorded on average compared to 530 in the southern half of the state (W. Cluse pers. comm.).

Turtles utilizing Virginia's foraging and nesting habitat were also observed to utilize the region just south of Cape Hatteras for a period of time. Considering juvenile movements described in Chapter 2 and the movements of an adult forager described in Chapter 8, it is probable that some turtles may over-winter in this region. This is an area where the Gulf Stream often overlaps a narrow region of the continental shelf, resulting in an area where warmer waters are trapped or advected between the outer shelf and coastline (Chester et al. 1994). This region appears to be an area of importance to a number of highly migratory species, including various species of teleosts and sharks (Conrath 2005). Unfortunately, several tags failed prior to winter and no data were available to determine whether some individuals over-winter in this region.

Observed home ranges were smaller than those observed for adult and juvenile foragers in the Chesapeake Bay (Chapters 2 and 5). This may be due in part to location sample size. To date, few published studies utilize kernel analyses to describe sea turtle movements. Among recent papers, smoothing parameter values (H) are rarely reported, limiting comparisons among studies (Seminoff et al. 2002; Schmidt et al. 2003; Shaver et al. 2005; Griffin et al. *in review*). Small smoothing parameter values result in smaller kernel areas with finer resolution (Hooge and Eichenlaub 1997). Without understanding the underlying model parameters, comparisons between studies using kernel density estimates is very limited.

Migration strategies were variable among all individuals tracked. With the exception of QQB-590, all adults moved south post-nesting, either meandering south and exhibiting site fidelity to the northern North Carolina coastline, or exhibiting directed movement south of North Carolina's waters (Figure 3.13). Three turtles began their southern movements in late July. The remaining three turtles traveled south to Florida, two of which began their southern migration within a week of nesting in Virginia. These adults began their migration sooner than juveniles tracked by VIMS in the early 1990's (Keinath et al. 1992; Keinath, 1993). It is possible that some adults only may use Virginia's waters and beaches as nesting habitat, moving south after the last nesting event, or to nest again on southern beaches. Having completed their nesting cycle, these

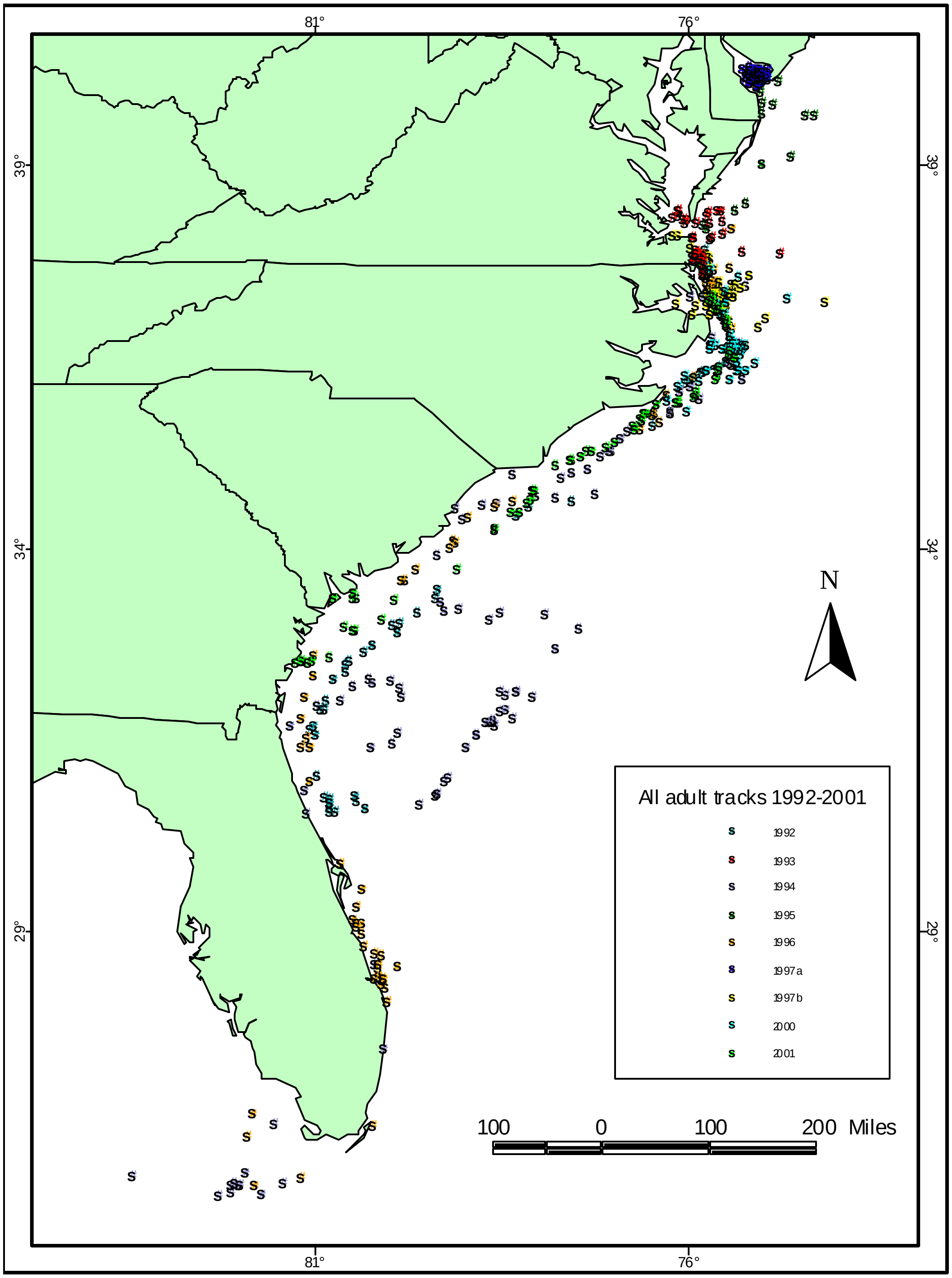


Figure 3.13 Locations from all adult turtles tracked 1992 to 2001

turtles may also have migrated south towards their inter-reproductive foraging grounds and into warmer waters that allow year-round residency. The exception to this was QQB-590 who utilized the Chesapeake Bay and Delaware Bay as internesting and probable foraging habitat until her fall migration in 1995 and 1997.

Along the east coast of the United States, Virginia is the southern-most state experiencing seasonal residency of sea turtles. Temperatures in late fall through early spring are too cold to support a year-round population of turtles in Virginia. A number of species will migrate into waters from Virginia to Massachusetts to forage during the late spring and summer months, all of whom must pass offshore of Virginia's coast. A number of studies have identified this region as a potentially important seasonal migratory route (Shoop and Kenney 1992; Keinath 1993). Turtles tracked from this study followed a fairly consistent route south between the coastline and outer continental shelf, corresponding to routes described in Chapter 2 and other studies (Figure 3.13) (Morreale and Standora 1988; Shoop and Kenney 1992; Keinath 1993; Plotkin and Spotila 2002; S. Murphy pers. comm.).

No data have been collected to determine the genetic stock of the adult nesters in Virginia. Juveniles utilizing the Chesapeake Bay as summer foraging grounds are comprised of both the southern and northern loggerhead subpopulations (Norrgard 1995). Virginia hosts the northern-most nesting beaches along the east coast of the United States. This would suggest that Virginia nesters should belong to the northern population. Observed migration patterns indicate that some Virginia nesters integrate with southern subpopulations in addition to the northern subpopulation. The two turtles tracked into the Gulf of Mexico migrated well into the range of the southern and northwestern Florida subpopulations. As far west as Texas, it is estimated that 10% of sea turtle strandings along the Texas coast are from the northern subpopulation (TEWG 2000).

Plotkin and Spotila (2002) suggested that while there are overlaps among post-nesting migratory routes utilized by nesters from both the southern and northern subpopulations, these subpopulations may be behaviorally distinct. Plotkin and Spotila cite data from studies tracking turtles from southern subpopulation nesting beaches that were observed to migrate south to the Gulf of Mexico or Caribbean Sea post-nesting versus turtles nesting on beaches from Georgia through North Carolina that migrated north to waters from Virginia to New Jersey (Bell and Richardson 1978; Meylan et al. 1983; Plotkin and Spotila 2002). Six of the seven turtles tracked from Virginia moved south relatively quickly after their last observed nesting event. These included three turtles that migrated into Florida's waters by fall and one into Georgia's waters as early as mid-August. However, three turtles remained north of or in the vicinity of Cape Hatteras, North Carolina. This would suggest that, at least among turtles found nesting along the northern limits of the loggerhead nesting range, there is some behavioral overlap between northern and southern subpopulations. It would also suggest that Virginia's waters and waters to the north and south of Cape Hatteras provide important post-nesting and/or inter-nesting habitat to adult females nesting throughout the mid-Atlantic region. This is supported by Griffin et al. (*in review*) who reviewed published tracking data (n=19 turtles) and unpublished data (n=68 turtles) from loggerheads nesting between Georgia and Virginia, and concluded that 59% to 66% of these turtles migrated north of Cape Hatteras post-nesting. This would imply that Virginia's waters not only provide important developmental habitat for foraging juvenile sea turtles, but also important post-nesting habitat for northern subpopulation adults.

A number of the tags deployed ceased transmissions after only a few weeks. This may be due to a number of factors, including antenna failure, bio-fouling or corrosion of saltwater switches, method of attachment, and/or turtle behavior influencing any of these variables. The method of tag attachment used has been successful: on two occasions, one adult turtle was recaptured a year after receiving a tag. In each case, tags were still firmly attached to her carapace (Chapter 8). One juvenile loggerhead that had been radio-tracked was found a year later as a dead stranding off the Virginia coast. This turtle was moderately decomposed, yet the tag was still epoxied to the turtle's carapace. In each case, some damage was recorded to the tags' antennae and/or body. Duty cycles were also set to a continuous 24-hour a day transmission, which would drain battery supplies relatively quickly.

Error associated with each recorded location and LC may bias analyses to some extent. The majority of location codes observed was class B (Table 3.1). This maybe due to either less satellite coverage among the earlier track years and/or infrequency of surfacing events among the turtles tracked. This class has an estimated accuracy of up to or in excess of 4km (Brothers et al. 1998; Britten et al. 1999; Millspaugh and Marzluff, 2001). However, some fairly accurate class B locations have been observed from turtles trapped within fixed fishing gears with known locations as part of a mark-recapture study (Chapter 8). Filters (topography, turning angle, swim speed) applied to these data in STAT help minimize erroneous locations in the reconstruction of the tracks presented in this study. The effects of location error bias are also minimized when examining large-scale migratory tracks. For smaller scale analyses of movement within discrete near shore or estuarine habitat, results should be considered conservative. Spatial error associated with locations used to determine significance of directional movement or site fidelity would tend to give results that were either less constrained or more randomly dispersed. Therefore test results should result in greater significance with increased location class accuracy. Travel speeds derived from these movement data also assume a straight-line movement between recorded locations. This is not a practical assumption, particularly if turtles are exhibiting non-migratory behavior. Thus, calculated swim speeds should also be considered conservative.

Turtle behaviors such as fidelity to a particular nesting or foraging area may contribute to incidental takes by hopper dredges operating in the lower Chesapeake Bay, Bay Mouth, or offshore of the Virginia Beach oceanfront. Among the turtles tracked over the ten-year period of this study, four of the seven nesters exhibited fidelity to waters between the Chesapeake Bay mouth and Cape Hatteras. Turtles were resident in this area from the beginning of the nesting period through the fall, until temperatures dropped to at least 15º to 20º C. To minimize or eliminate potential interaction with adult nesters in Virginia, dredging and renouirishment operations along the southern coast of Virginia should occur only from late fall to early spring.

CHAPTER 4

SEA TURTLE SURFACING BEHAVIOR AND SIGHTABILITY

ABSTRACT

The primary objectives of this study were to determine how seasonal differences in sea turtle respiratory behavior, or sightability, are reflected in observed aerial densities by comparing observed respiratory behavior (Chapter 2) to predicted behavior; and to assess biases of census models by determining whether standardized aerial survey methods overestimate sea turtle populations in the spring. Aerial population surveys were conducted in Bay waters from 2001-2004 (Chapter 5). Predicted surfacing rates were calculated using simultaneous linear equations assuming constant abundance, solving for sightability, or surfacing time. Predicted sightability by survey and year modeled the observed early season (spring) peaks in densities followed by sharp declines late June or early July. Peak predicted values for sightability ranged from 0.25 (or 25%) in 2001, to 0.28 (28%) in 2002, 0.21 (21%) in 2003 and 0.27 (27%) in 2004, and corresponded to recorded sea surface temperatures of 21° to 25° C. Predicted sightability estimates for the summer/fall months closely modeled Byles' observed surfacing time of 5.3%, indicating a behavioral change in surfacing behavior between the spring and summer/fall months: a decrease in sightability due in part to an increase in benthic feeding behavior.

Using the historic respiratory correction factor (5.3%; Byles 1988) and strip transect analyses, mean springtime population estimates ranged between 1,800 and 4,060 turtles. Adjusting for increased sea turtle sightability (25.0% based on maximum predicted values), these estimates are dramatically reduced to between 360 and 810 turtles, indicating that historic juvenile sea turtle densities in Virginia have been overestimated for springtime observations. Managers should not assume that sea turtle sightability or surfacing behavior is constant at all times of the year or in all geographic

locations when analyzing aerial data. Turtles observed in temperate waters during the spring months or in deeper, more stratified coastal waters may exhibit different surfacing times than turtles observed during warmer months or in shallower, near shore or estuarine waters. Managers should exhibit caution when comparing density estimates across seasons or geographic regions. Large differences (1:18 vs. 1:10, 1:4, or 1:3) in seasonal sea turtle sightability bias historic abundance estimates of sea turtles in Virginia.

INTRODUCTION

Significant data gaps exist for the juvenile life stage in Atlantic loggerhead population models (TEWG 2000; Heppell et al. 2005). Virginia's Chesapeake Bay provides important seasonal foraging habitat for juvenile loggerhead sea turtles. Juveniles found in Virginia's waters are benthic foragers, feeding primarily on blue crabs (*Calinectes sapidus*), horseshoe crabs (*Limulus polyphemus*), channel and knobbed whelk (*Busycon canaliculatum*; *Busycon caricas*) while resident in Virginia (Seney 2002; Seney and Musick in press).

Aerial surveys were conducted from 1982-1985 and 1991-1992 to determine minimum densities of Chesapeake Bay juveniles using strip transect analyses. These estimates were adjusted to reflect the turtles' respiratory behavior since sea turtles are only visible to aerial observers within the top one to two meters of water column in the Chesapeake Bay. Turtles counted at the surface represent only a fraction of the overall population. A correction was used for turtles that cannot be seen below the observable surface. This correction was determined based on the percentage of time turtles spend at the surface versus time they spend below the surface, resulting in a ratio that estimates for every one turtle observed at the surface, there are 'x' number of turtles swimming below the surface. Using radio and acoustic telemetry, Byles (1988) determined that loggerhead sea turtles spend approximately 5.3% of their time at the surface while foraging in the Bay during summer months—or for every one turtle observed at the surface, there are approximately 18.9 turtles below the surface.

Aerial surveys conducted in the 1980's and early 1990's indicate that maximum population estimates adjusted for surfacing behavior or sea turtle sightability, range between 6,500-9,700 turtles for Virginia waters within any given season (Byles 1988; Musick et al. 1985; Keinath et al. 1987). These estimates were based on the number of aerially observed sea turtles extrapolated to account for the entire Chesapeake Bay and adjusted to reflect surfacing times and diving behavior (Byles 1988; Keinath 1993). Importantly, the highest turtle densities were observed during the spring of the year (May-June), implying that the greatest numbers of sea turtles visit Virginia waters during springtime (Byles 1988).

Byles (1988) density estimates were based on three main assumptions: 1) surfacing and dive behavior among turtles in independent; 2) turtles are only counted once per survey; and 3) turtles observed aerially were exhibiting behavior similar to that observed by Byles (1988) using radio telemetry. The correction factor used to account for turtles below the observable surface was based on summer and fall foraging behavior. Byles assumed that all turtles in the Chesapeake Bay were exhibiting the same foraging behavior as those turtles he observed in the Western Bay. No data were collected for respiratory behavior during the spring when turtles are first migrating into the bay and aerially observed sea turtle densities are highest.

Recent estimates of sea turtle surfacing behavior indicate that sea turtles may spend as high as 10% to 50% of their time at the surface in the spring months (Chapter 2). Based on these data, it is likely that surfacing behavior significantly affects turtle sightability in the spring; however, sample sizes in this study were relatively small. It is also possible that turtles migrating north in the spring, stop briefly in the lower Chesapeake Bay on their way to their northern seasonal foraging grounds.

If sea turtles spend more time at the surface in the spring versus the summer, then these turtles are more likely to be observed and counted during aerial surveys, and historic aerial population estimates have overestimated juvenile sea turtle abundances in the Chesapeake Bay. On a management level, it is imperative that the best possible data be used to determine relative sea turtle abundances in Virginia waters. These data in turn are used to help determine appropriate take limits for local fisheries and permitted federal activities, such as hopper dredging, which are known to take turtles as by-catch. Limits for incidental takes allowed per fishery have yet to be established for Virginia's fisheries. It is important that take limits reflect the number of turtles that may be safely removed from a population without contributing to that population's decline.

The primary objectives and hypotheses for this study were to:

1. Determine how seasonal differences in sea turtle respiratory behavior, or sightability are reflected in observed aerial densities by comparing observed respiratory behavior to predicted behavior;

   H_{02} There is no difference between observed respiratory behavior, or sightability (Chapter 2; Byles 1988), and predicted sightability;

2. Assess biases of census methods: determine whether historic aerial survey methods overestimate sea turtle populations in the spring.

METHODS

Predicted Sightability:

Simultaneous linear equations for each year of aerial surveys (2001-2004; Mansfield et al. 2002a; 2002b) were solved for predicted sightability by survey date, assuming constant abundance and using mean observed annual Bay abundances. Predicted sightability estimates were plotted by survey month against sea surface temperatures collected per survey day from the VIMS Ferry Pier data logger in the York River, Virginia.

Respiration Analyses, or Observed 'Sightability':

Juvenile loggerheads (n=8) and Kemp's ridleys (n=5) were tracked during the spring through summer of 2002-2004 for up to 24 hours in the lower Chesapeake Bay and Bay mouth using the methods described in Chapter 2. Daytime surface ratios were calculated (total surfacing time/total track time) and analyses of variance (ANOVA) were conducted for differences between individuals (individual turtle tracks were treated as independent samples); significance based on $p<0.05$ (Chapter 2).

Aerial Monitoring:

Aerial surveys were conducted based on the protocol established by Byles (1988), Keinath et al. (1987), and Keinath (1993) (Chapter 5) in the 1980's. Surveys were flown in an over-wing aircraft (Cessna XP II) at an altitude of 152 m, and at a speed of 130 km/hr. Approximately 60 transect lines were established over the Chesapeake Bay based on the locations of transect lines used in the 1980's (Figure 4.1; Appendix C) (Keinath et

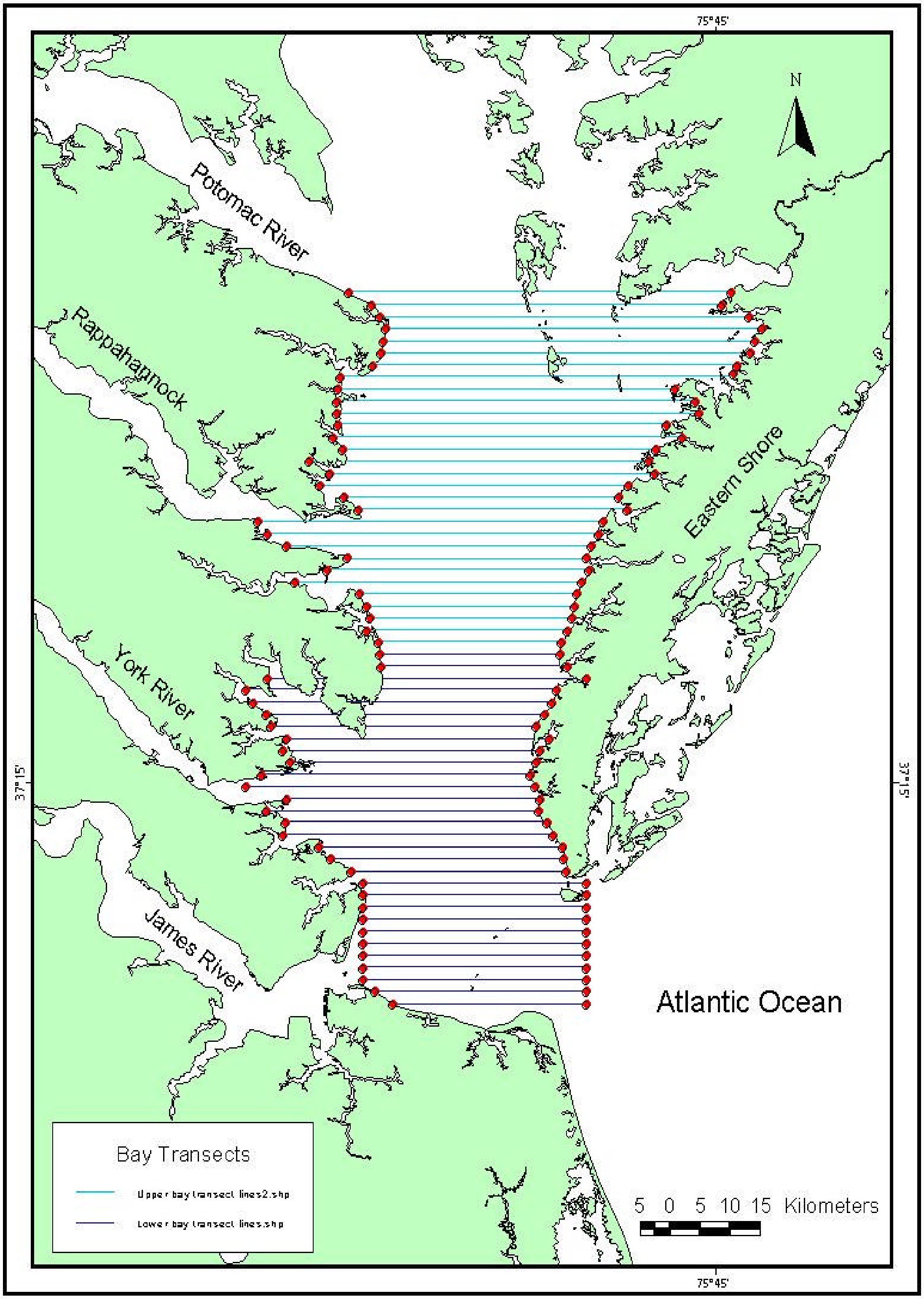


Figure 4.1 Aerial transect locations in the Chesapeake Bay

al. 1987). These lines fall within identified loggerhead sea turtle habitat: no more than five miles up a tributary and in waters deeper than three meters (Byles 1988). Two study regions, the Upper Bay and Lower Bay, were established based on the area surveyed in the 1980's. A total of sixty east-west transects were determined with thirty transects falling within the Lower Bay region (36° 56.5N to 37° 25.5N) and thirty within the Upper Bay region (37° 25.5N to 37°.55.5N) (Figure 4.1; Appendix C).

Eight lines were randomly chosen for each survey, four within the Upper Bay region and four within the Lower Bay region. These transect lines were flown with the aid of a GPS unit. Surveys were flown once a week between May and the end of September or October in any given year (2001-2004), weather and sea state permitting. Two trained observers, one on each side of the plane, scanned the sea surface for turtles. The time was recorded at the start and end of each transect line. Each transect took between 12 and 20 minutes to complete. Transect lines flown were spaced far enough apart that the likelihood of a turtle swimming at higher known velocities (3.5 km/hr) counted subsequently within two adjacent transect lines was negligible (Byles 1988). When a turtle was sighted, the following were recorded:

- Sighting angle from the transect line;
- Time and date of observation;
- Species (and number);
- Weather, sea state; solar glare.

The perpendicular distance of each turtle from the transect line was recorded as an angle of degree using Suunto inclinometers. GPS units were not used to record the location of objects sighted since the airplane's electronics, located above the observer seats, often disrupted satellite signals and reliable location data were not consistently available.

Byles (1988) and Keinath (1993) estimated population densities using strip transect methodology. For the purpose of this Chapter, strip transect methods were used to illustrate how differences in sea turtle sightability may influence historic and current density estimates if the assumptions of this method and historic survey design are accepted. Strip transect analyses assume that all turtles are counted within a given distance (effective strip width) from each transect line. Any turtles that fell outside of the census strip were not analysed. Both Byles (1988) and Keinath (1993) determined that the effective visual swath within which the peak sighting efficiency occurs is between 50 meters (18º) and 300 meters (63º) from the transect line (Musick et al. 1985). Due to the underside of the airplane preventing observations directly on the transect line, sighting angles were used to determine whether turtle observations fell within the effective visual swath adjacent to the transect line, abeam of the airplane. Similar angles of observation were recorded from the Cessna XP II aircrafts flown during 2001-2004. Thus, the visual swath surveyed included 250 meters on either side of the plane. Over 90% of all sea turtle sightings occurred within this range (Musick et al. 1985). Minimum surface density estimates were calculated using the effective strip width combined with transect length (Byles 1988; Musick et al. 1985). Minimum sea turtle densities were determined using the following equations (Keinath 1993):

$$\mathbf{D = N / A} \qquad \text{Eq. 4.1}$$

where: D = density of sea turtles observed

N = Total number of turtles observed

A = Area surveyed (km^2)

and:

$$\mathbf{A = (O \times W) \times L} \qquad \text{Eq. 4.2}$$

where: O = Number of observers in the plane

W = Width of survey area (km) per observer

L = Length of survey transect (km)

or:

$$\mathbf{D = N / (0.5\ km \times L)} \qquad \text{Eq. 4.3}$$

Using radio and acoustic telemetry data, Byles (1988) determined that loggerhead sea turtles spent approximately 5.3% of their time below the sea surface while resident in the Bay during the summer and fall months. Aerial survey observations only record those animals at the surface or within about one meter of the surface. The minimum density estimates must be multiplied by a correction factor in order to account for turtles below the observed sea surface. The correction factor is determined based on the ratio of time spent below the surface to time at the surface. The ratio used by VIMS for summer and fall estimates is 18.9:1 (turtles below surface to turtles at surface) (Musick et al., 1985; Byles, 1988). Thus, in order estimate the total number of turtles within the flight path, the following equation was applied:

$$\mathbf{Dcorr = S \times D} \qquad \text{Eq. 4}$$

where: Dcorr = Turtle density corrected for dive behavior

S = Surfacing ratio (or 'sightability'), or 18.9

Densities were then determined for the Lower Bay and Upper Bay regions by extrapolating the corrected densities to the entire study region:

$$\mathbf{P = D_{corr} \times A_{tot}} \qquad \text{Eq. 5}$$

where: P = Estimated turtle population

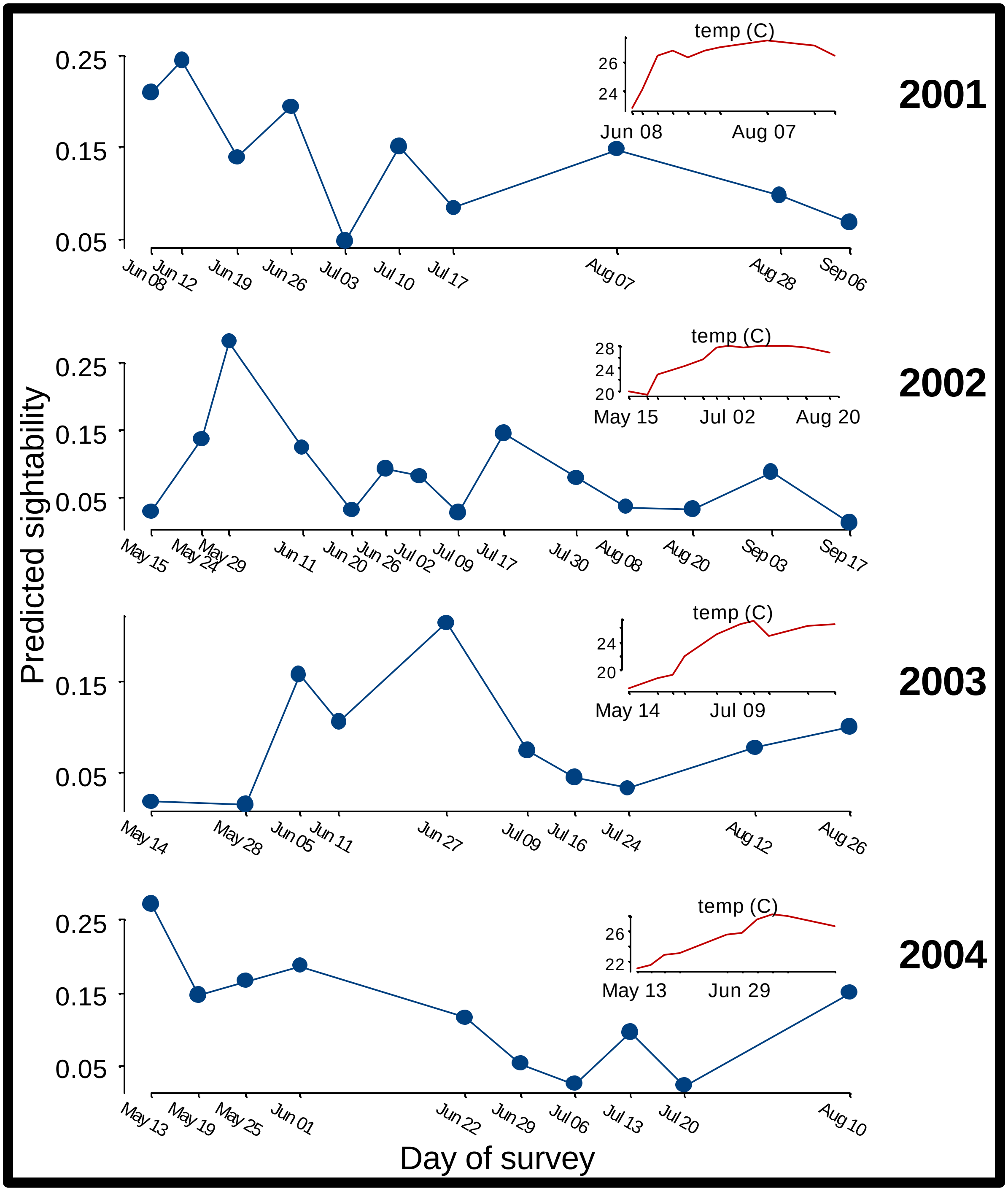
A_{tot} = Total study area (km^2)

Estimates of total area for the entire lower and upper Bay regions were determined in ArcView 3.2 to be 1,529.36 km 1,879.41 km^2 respectively (Mercator projection). Sightability corrections of 5%, 10%, 25% and 50% were applied to mean springtime (May-June) density estimates observed from 2001 to 2004 in the Lower Chesapeake Bay. Lower Bay survey area was calculated from distances and area recorded in ArcView 3.2 (UTM-1983).

RESULTS

Predicted Sightability:

Predicted sightability by survey in any given year modeled the observed early season (spring) peaks in densities, followed by sharp declines late June or early July (Figures 4.2-4.5). Peak predicted values for sightability occurred in May or June, and



Figures 4.2-4.5 **2001 to 2004 predicted sightability estimates by aerial survey flown**

ranged from 0.245 (or 24.5%) in 2001, to 0.282 in 2002, 0.215 in 2003 and 0.271 in 2004. These peaks corresponded to recorded sea surface temperatures of 21° to 25° C (Figure 4.6). Mean annual springtime sightability ranged between 10.6% and 16.0%. Low values of predicted sightability early spring in 2002-2004 may be due to the timing of surveys prior to the peak turtle migration into the Bay and may account for the relatively low r^2 value in Figure 4.6. The lowest predicted sightability values of turtles while resident in the Bay occurred from mid-to late June through late August or early September when sea temperatures were above 25° C (Figures 4.2-4.6). Predicted sightability values for July through August or September ranged between 4.7% and 15.1% in 2001, 1.3% to 8.8% in 2002, 3.3% to 10.0% in 2003 and 2.4% to 15.0% in 2004 (Figures 4.2-4.5). Mean predicted sightability for summer and fall ranged between 6.3% and 10.0%.

Observed Sightability:

Observed springtime and early summer mean daytime surfacing times ranged between 9.9% and 25.0% for loggerheads and between 30.0% and 32.9% for Kemp's ridleys (Chapter 2). There were significant differences among all individuals tracked. The highest overall mean surfacing among all individuals were observed among the Kemp's ridleys (30.0% to 59.8%). Table 4.1 summarizes the spring and early summer results from 2002-2004 radio tracking data. The observed mean surfacing times in 2002-2004 were higher than the 5.3% surfacing time observed by Byles (1988) in the summer and fall (Chapter 2). Compared to the predicted sightability estimates, Byles estimate of sightability (5.3%) appear to fall within the range of predicted estimates later in the

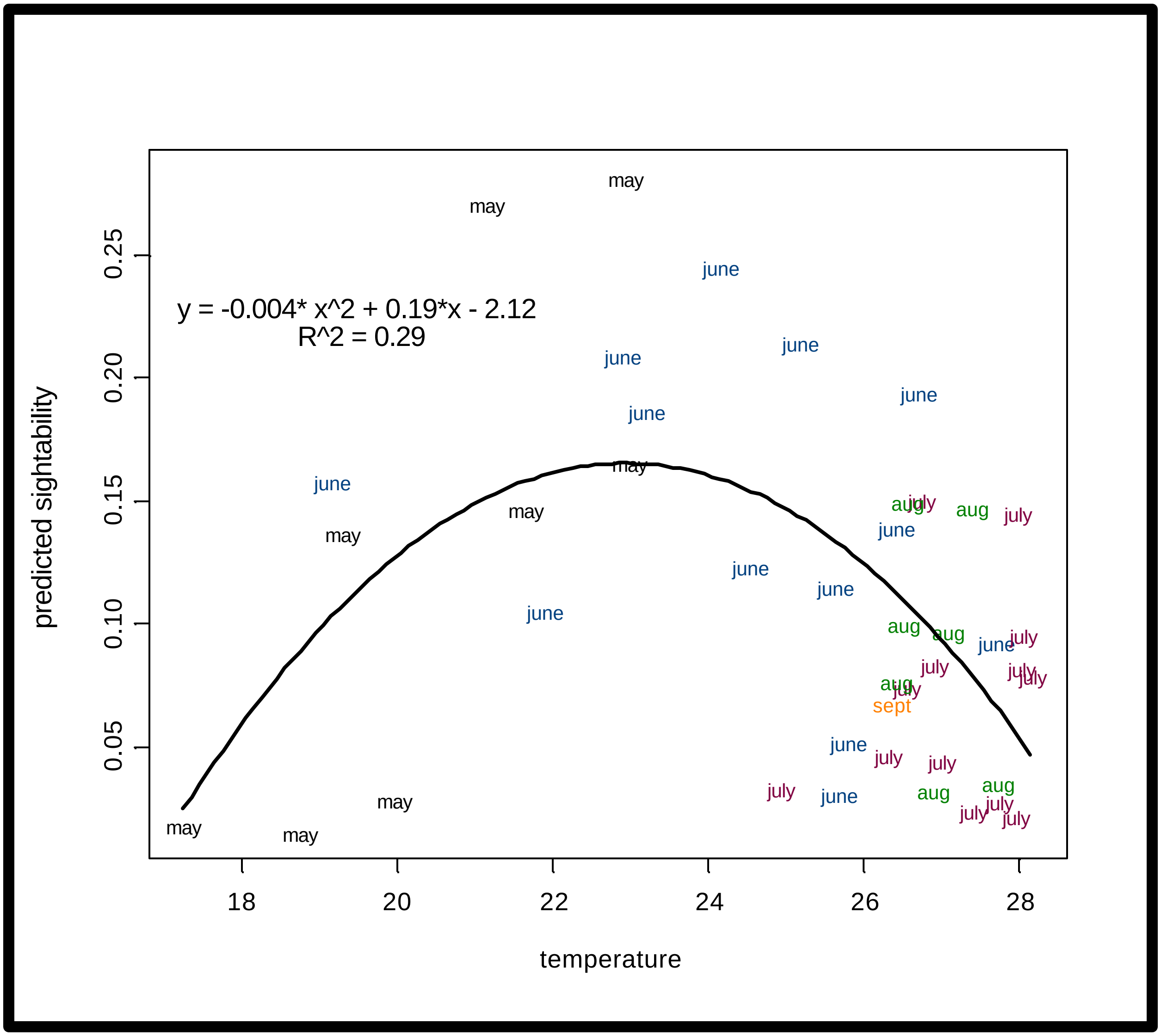


Figure 4.6. 2001-2004 predicted 'sightability' estimates vs. sea surface temperature by month with fitted parabolic curve.

Table 4.1 Summary of observed springtime for Lower Chesapeake Bay sea turtle respiratory behavior in Virginia, 2002-2004 (Mansfield and Musick 2003; 2004).

Year	Survey Dates	N*	Surface T (°C) Range	Bottom T (°C) Range	Mean Surface Time	Ratio	Range
2002	5/23 to 7/17	4 loggerheads	22 to 25	18 to 24	9.9% (+/-2.9% SD)	~1:10	7.1% to 12.7%
		1 Kemp's ridley			45.7%	~1:2	n/a
2003	**6/18 to 8/14	2 loggerheads	18 to 26	9 to 19	25.0% (+/-16.3% SD)	~1:4	13.5% to 36.5%
		2 Kemp's ridleys			32.9% (+/- 23.1% SD)	~1:3	16.5% to 49.2%
2004	6/3 to 7/21	1 loggerhead	19 to 26	12 to 23	12.29%	~1:8	n/a
		3 Kemp's ridleys			30.0% (+/-25.8% SD)	~1:3	13.7% to 59.8%

* Excludes tracks less than 2 hours in length
**2003 experienced a late spring and later residency season

season (Figure 4.7). Similarly, the observed surfacing times in 2002-2004 reflect the higher estimated sightability early in the season (May-June) (Figure 4.7).

Aerial Density Estimates:

A complete analysis of aerial density data is found in Chapter 5. Peak densities were observed in May and/or June of each year, similar to historic observations. Using the historic respiratory correction factor (5.3%; Byles 1988), maximum annual springtime (May-June) population estimates ranged between 2,700-5,000 turtles in the Lower Bay. Mean springtime estimates, using the historic correction factor, ranged between 1,600 and 5,800 turtles. However, when corrections are applied adjusting for increased sea turtle sightability in the spring, these estimates are dramatically reduced (Table 4.2). These results indicate that historic sub-adult abundances may overestimate springtime observations in Virginia by as much as 50% to 80%.

DISCUSSION

Predicted Sightability:

Assuming that abundances remain relatively constant throughout the sea turtle residency season in Virginia (May-October), predicted sightability may reflect a shift in turtle behavior: a decrease in sightability due to an increase in benthic feeding behavior. Virginia is located along a seasonal migratory corridor for sea turtles traveling north to summer foraging grounds. Within the northeastern United States, Virginia is the southern most state that does not have year-round residency of sea turtles. It is possible that some turtles stop briefly in Virginia's waters before continuing the migration north, therefore

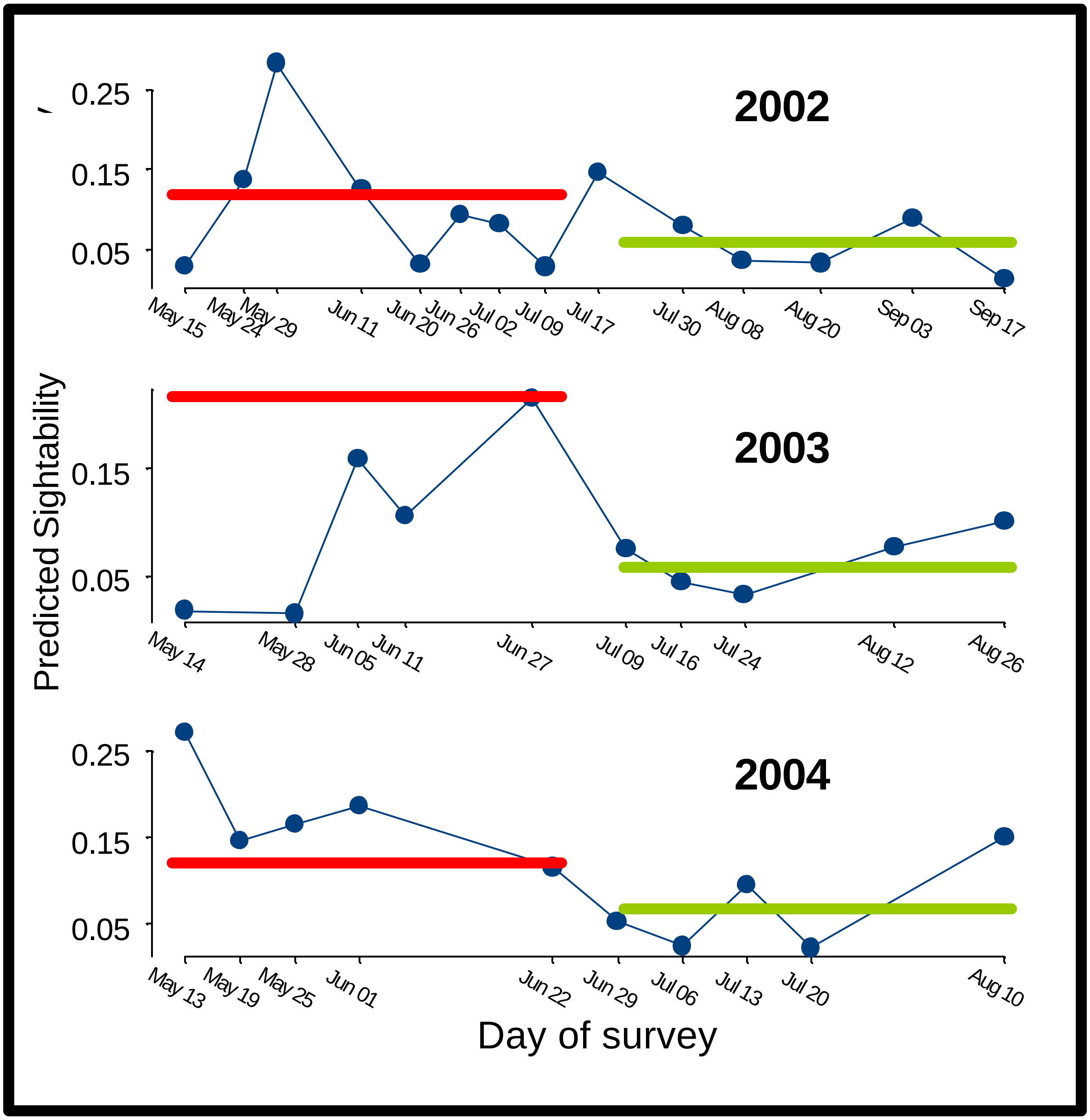


Figure 4.7 2002-2004 predicted 'sightability' estimates vs. sea surface temperature by month. Red line indicates observed springtime surfacing times; green line indicates Byles (1988) summer/fall surfacing observations

Table 4.2 2001-2004 May-June observed densities (turtles/km^2) in the Lower Chesapeake Bay corrected for different surfacing behavior, or sightability (uncorrected values extrapolated to area of Lower Bay)

Year	Uncorrected	5% Sightability	10% Sightability	25% Sightability	50% Sightability
2001	203.17	**4063.4**	2031.7	**812.7**	406.3
2002	92.27	**1845.4**	922.7	**369.1**	184.5
2003	163.93	**3278.6**	1639.3	**655.7**	327.9
2004	90.12	**1802.4**	901.2	**360.5**	180.2

negating the assumption that abundance remain constant. While emigration may be a factor in the spring, observed surfacing behaviors indicate that there must also be a drop in sightability due to a behavioral change, not simply changes in standing stocks. Virginia also experiences a springtime stranding event each May/June where 50%-60% of the annual state strandings occur (Mansfield et al. 2002a; 2002b). A net mortality loss of 150-250 turtles does not completely account for the drop in observed densities (Table 4.2).

Laboratory experiments conducted by Moon et al. (1997) suggest feeding behavior may be correlated to ambient water temperatures. This study found that there was a decrease in feeding activity among immature green (*Chelonia mydas*) and Kemp's ridley sea turtles when temperatures dropped below 15° C and 20° C respectively. Among the Kemp's ridleys, feeding activity ceased below 12° C, and increased considerably when temperatures were raised between 15° to 20° C and 20° to 25° C. It is possible that the behavior, aerial observations and movement patterns of turtles in the Chesapeake Bay are linked to thermally driven feeding behavior. Turtles first entering the Bay in the spring of the year experience colder, stratified waters and may be more likely to exhibit directed migratory movement. The increased metabolic costs of this behavior may result in a greater time spent at the surface, as suggested by the surfacing behavior presented in this study. As temperatures warm and mix, turtles may spend more time feeding on the bottom. Foraging strategies utilizing tidal flow would conserve energy, reducing a turtle's oxygen requirements, resulting in less time spent at the surface.

Observed Respiratory Behavior:

Mean loggerhead surfacing behaviors in spring (9.9% to 25.0%) were higher than Byles (1988) observations (5.3% to 7.3%). Compared to the predicted sightability estimates, Byles data appear to closely correspond to the predicted estimates later in the season (Figure 4.7) and the observed surfacing times reflect the higher estimated sightability early in the season (May-June) supporting the hypothesis that a behavioral shift occurs between spring and summer. High spring densities observed by offshore/lower Bay aerial surveys in Virginia may also be due in part to warmer surface temperatures over steep thermoclines influencing sea turtle sightability. Byles (1988) data were from tracks in the middle of the Bay, mid-summer when vertical temperatures are well mixed (Chapter 2). Turtles with highest 2002-2004 surfacing times (both species) were tracked in deeper, cooler waters of Bay mouth and/or Atlantic coastline and in one case, through a coastal upwelling event where sea temperatures vertically ranged between 9° C and 24° C. 2002 springtime loggerhead ranges are relatively close (7.1% to 12.7%), unlike the Kemp's ridleys tracked in 2003 (13.5% to 49.2%). There was a very late, cold spring in 2003, followed by cooler than average Bay temperatures which may have attributed to turtles spending more time within warmer surface waters. Variations in surfacing behavior between seasons may be due to environmental factors (temperature) and/or metabolic requirements of different behaviors (shifting from migratory behavior to foraging behavior).

Differences between observed and predicted sightability (Figure 4.7) may also be due to the small sample size of radio-tracked sea turtles and the individual track paths observed. The timing of the radio tracking events did not correspond exactly to the days that aerial surveys were conducted (the data from which were used to generate the predicted sightability estimates), possibly accounting for some variability between the predicted and observed values. More tracking data are needed to refine surfacing times in order to develop a predictive model to adjust observed aerial densities based on turtle behavior (or the probability of detecting turtles), species, size class, spatial distribution and environmental influences. However, existing aerial density estimates should be corrected for seasonal differences in surfacing behavior or sightability. A minimum correction factor of 9.9% (~1:10; Chapter 2) should be used to adjust loggerhead densities in the spring. With more data, an upper level correction of 25.0% (1:4; Chapter 2) may be appropriate for years experiencing colder spring temperatures or regions experiencing pronounced coastal upwelling. Mean Kemp's ridley estimates were relatively consistent among years, however there was geographic variation among surfacing times, particularly within the 2003 upwelling event along the Virginia Beach oceanfront. A minimum correction factor of approximately 30.0% (1:3; Chapter 2) should be considered for estimating Kemp's ridley densities in the spring months, or within coastal waters assuming that aerial observers consistently and accurately identify turtles by species. Without adjusting for seasonal shifts in surfacing behavior, it is likely that historic population estimates of juvenile sea turtles in Virginia have been overestimated, particularly in the spring when turtles are first migrating into the Bay.

Aerial Density Estimates:

Large differences (1:18 vs. 1:10, 1:4 or 1:3) in seasonal sea turtle sightability significantly bias historic abundance estimates. Higher spring densities observed by offshore/lower Bay aerial surveys in Virginia, may be due to warmer surface temperatures over steep thermoclines influencing sea turtle sightability. Geographic peaks or seasonal variation in density observations may be a reflection of temperature or movement driven surfacing behavior.

In the process of establishing reasonable take limits per fishery in Virginia, it is imperative that existing sea turtle stocks be fully understood. Aerial strip transect methods risk a negative bias in density calculations: this method assumes that all animals are seen and recorded within the survey strip. These analyses do not correct for perception bias, or for turtles that are at the surface but not seen by observers (Marsh and Sinclair 1989; Guenzel 1997). Thus, strip transect methods only provide minimum density and population estimates. On a management level, underestimating an endangered/threatened turtle sub-population is less detrimental than overestimating the population. Abundances generated by aerial population surveys are also prone to several sources of error including observer error, the effects of sea state and glare. Using such large correction factors (5%, 10% or 25%) to account for turtles not observed below the sea's surface can at best provide a relative index of abundance.

Management Implications:

It should not be assumed that sea turtle sightability, or surfacing behavior, is constant at all times of the year or in all geographic locations when analyzing aerial data. Aerial data present a 2-dimensional snapshot of turtle distributions. Changes in surfacing behavior affect aerial density estimates in the same way as changes in standing stocks: an increase in either result in an increase in observed density. However, changes in standing stock reflect changes in actual turtle numbers, while changes in surfacing behavior simply reflect how many of the actual number present you are likely to see. Turtles observed in temperate waters during the spring months or in deeper, more stratified coastal waters may exhibit different surfacing times than turtles observed during warmer months or in shallower, near shore or estuarine waters. Managers should exhibit caution when comparing density estimates across seasons or geographic regions.

CHAPTER 5

SEA TURTLE POPULATION ESTIMATES IN VIRGINIA

ABSTRACT

The primary objectives of this study were to adjust historic and recent density estimates to reflect seasonal differences in sightability; to present current population estimates of sea turtles in the Chesapeake Bay; and to determine whether an increase in sea turtle mortality in Virginia is a reflection of an increase in turtle abundance.

Aerial population surveys were conducted in Bay waters from 2001-2004. To compare with historic data, strip transect analyses were used to estimate sea turtle abundances. Densities were spatially extrapolated to the Lower or Upper Bay survey areas and corrected for surfacing behavior. Estimates include Byles (1988) assumption of constant sightability (5%), 10% spring (May-June) sightability, and 25% sightability. In the Lower Bay, mean annual estimates ranged between 1,326 and 2,597 turtles assuming constant sightability (5%), 1,033 and 2,088 turtles assuming a springtime correction of 10% sightability, and 799 to 1,600 turtles assuming 25% sightability. Mean annual Upper Bay estimates ranged between 1,480 to 2,805 turtles assuming constant sightability, 1,072 to 1,619 assuming 10% sightability, and 737 to 1,198 turtles assuming 25% sightability. Assuming constant sightability, total mean abundances for the entire Bay were between 2,850 and 5,479 turtles. Density estimates derived from strip transect analyses must be considered as minimum estimates due to negative biases associated with this method and seasonal sea turtle sightability.

Fewer turtles were observed during the 2001-2004 surveys than in the 1980's or 1994. There were significant differences in densities between the 2001-2004 surveys and surveys in the 1980's ($p<0.05$). Surveys in the 1980's often resulted in large spikes in turtle observations during one or two early season surveys. These spikes were absent in

survey observations from 2001-2004. A comparison of median densities and abundances between observations from the 1980's and 2001-2004 resulted in a three-fold reduction of turtles since the 1980's. Comparisons of uncorrected density medians from the 1980's vs. 2000's resulted in a 67.1% decline in turtle densities. High spring spikes in observed densities are likely a result of differences in surfacing behaviors in the spring months vs. warmer summer months and/or some turtles entering into the Bay as a stop-over place to feed along their migration route to northern summer foraging habitats.

Peak density observations in the 1980's were back-calculated to solve for surfacing behavior. Assuming constant abundance, turtles would have spent 37.4% to 49.3% of their time on the surface to account for the high springtime densities observed in the 1980's. Mean predicted surfacing behavior (or sightability) for all 1980's surveys was 45.0%. These predicted surfacing rates were significantly higher than predicted estimates from the 2001-2004 surveys ($p<0.05$; Chapter 4). To account for the decline in predicted surfacing behavior between the 1980's and present, Bay temperatures in the 1980's must have been significantly cooler than in 2001-2004. However, there were no significant differences in surface temperatures associated with surveys days in the 1980's vs. 2000's. Thus, it is likely that some percentage of turtles briefly enter the Lower Bay in the spring before migrating farther north. It is also likely that the number of these transient animals have declined significantly since the 1980's.

Significantly fewer turtles ($p<0.05$) were observed in both the spring (May-June) and the summer (July-August) of 2001-2004 compared to surveys in the 1980's. A comparison of median densities in the spring result in a 63.2% reduction in densities from the 1980's to the 2000's. A 74.9% reduction in densities occurred during the summer residency period from the 1980’s to present. Changes in sightability due to variations in annual temperatures and an early spring influx of transient turtles may mask actual population trends. Summer density estimates may provide a better understanding of changes in population over time since the effects of migratory behavior and of colder temperatures on turtle sightability are minimized. It is likely that Virginia has experienced up to a 75% decline in resident foragers since the 1980’s.

The decline in sea turtle densities over the past two decades is significant and should be monitored through continued aerial survey work in both the Upper and Lower Bay regions. It is possible that the Chesapeake Bay has reached its carrying capacity for sea turtles; significant declines in blue crabs (*Callinectes sapidus*) over the past two decades may deter transient springtime turtles and/or reduce the number of summer foragers in the Bay. Future research should include conducting offshore and coastal surveys for comparisons with historic estimates to determine whether this decline is reflected in the coastal population. Fishery-based management strategies should prioritize the Lower Bay fisheries and coastal waters north of Cape Hatteras, North Carolina to Maryland in the early spring. The waters north of Cape Hatteras, including all of Virginia’s state waters should be considered as either essential habitat or as an area of special concern for sea turtle conservation.

INTRODUCTION

One goal set forth by NMFS and the Turtle Expert Working Group (TEWG) in the recovery plan for Atlantic sea turtles includes identifying the maximum number of individual turtles (per species) that may be taken incidentally per fishery while still allowing for the recovery of the species (TEWG, 2000). To accomplish this goal, it is necessary that the status and condition of existing sea turtle stocks be understood (TEWG, 2000). Every year, sea turtles seasonally utilize the Chesapeake Bay and coastal waters of Virginia as foraging grounds and developmental habitat (Lutcavage, 1981; Lutcavage and Musick, 1985; Musick and Limpus 1997). Since 1979, the Virginia Institute of Marine Science (VIMS) has recorded high sea turtle mortalities in the spring of the year when sea turtles first migrate into Virginia's waters (Lutcavage, 1981; Lutcavage and Musick, 1985; Keinath et al., 1987; Coles 1999; Mansfield et al., 2002a; 2002b). The vast majority of these strandings are juvenile loggerhead (*Caretta caretta*) and Kemp's ridley (*Lepidochelys kempii*) sea turtles. State stranding counts have risen 200% to 300% over the last ten years (Mansfield et al., 2002a; 2002b; Musick and Mansfield 2004). This increase may in part be due to an increase in actual mortality, an increase in stranding effort, or an increase in Virginia's sea turtle population over time.

During the early 1980's, mark-recapture population modeling indicated that approximately 3,000 sea turtles inhabited the Bay each year (Lutcavage, 1981; Lutcavage and Musick, 1985). Due to sampling size and the possibility that some assumptions associated with the population model may not have been met, this number was deemed a minimum estimate. Aerial surveys were used to determine the relative abundance and seasonal distribution of sea turtles found in the Chesapeake Bay and coastal waters

(Byles, 1988; Keinath et al., 1987). Aerial censuses conducted from 1982-1987 and in 1994 suggested that 6,500 to 9,700 and 3,000 turtles respectively are found in Virginia's lower Bay waters (Byles, 1988; Musick et al., 1984; Keinath, 1993). These estimates were based on the number of aerially observed sea turtles extrapolated to account for the Lower Chesapeake Bay, an area of approximately 1300 km^2. These studies assumed that sea turtle behavior remained constant throughout the residency season. Observed density estimates were adjusted to reflect surfacing times and diving behavior using the 5.3% (18.9:1) surfacing times observed by Byles (1988) for summer/fall foragers (Chapters 2 and 4). Historically, the largest number of sea turtles was typically observed during the spring of the year in the lower Chesapeake Bay, implying that the greatest sea turtle abundances occurred during the spring. However, recent data suggest that there are seasonal differences in surfacing behavior, or sightability, that negatively bias these historic springtime estimates (Chapters 2 and 4).

Sea turtle population estimates for the Chesapeake Bay were not quantified in over 10 years due to lack of available funding. Aerial surveys were reestablished in 2001-2004. Density estimates from these surveys were compared to historic estimates made in the 1980's to determine whether Virginia's sea turtle stocks are increasing or declining.

The primary objectives and hypotheses for this study were to:

1. Determine whether an increase in sea turtle mortality in Virginia is a reflection of an increase in turtle abundance:

H_{01} There is no difference among sea turtle density estimates observed from 1982 to 1987 compared to densities observed from 2001 to 2004;

2. Adjust historic and recent abundance estimates to reflect seasonal differences in sightability;

3. Update current density estimates of sea turtles in the Chesapeake Bay using more robust line transect analyses.

METHODS

Aerial Monitoring:

Aerial surveys were conducted based on the protocol established by VIMS (Byles, 1988; Keinath et al., 1987; Keinath, 1993) in the 1980's. Surveys were flown in an over-wing aircraft (Cessna XP II) at an altitude of 152 m, and at a speed of 130 km/hr. Approximately 60 transect lines were established over the Chesapeake Bay similar to the transect lines used in the 1980's (Keinath et al., 1987). Two study regions, the Upper Bay and Lower Bay, were established based on the area surveyed in the 1980's. A total of sixty east-west transects were determined with thirty transects falling within the Lower Bay region (36° 56.5N to 37° 25.5N) and thirty within the Upper Bay region (37° 25.5N to 37°.55.5N) (Chapter 4, Figure 4.1; Appendix C).

Eight lines were randomly chosen for each survey, four within the Upper Bay region and four within the Lower Bay region. Surveys were flown once a week during the peak of the stranding season, and bi-weekly during the non-peak period, weather and sea state permitting. Two observers, one on each side of the plane, scanned the sea surface for turtles and fishing activity. Time at the start and end of each transect line was recorded. Each transect took between 12 and 20 minutes to complete. Flight lines were spaced far enough apart (> 2km) that the likelihood of a turtle swimming at higher known velocities (3.5 km/hr) counted subsequently within two adjacent transect lines was negligible (Byles, 1988). When an animal or fishing activity was sighted, the following were recorded:

- Sighting angle from the transect line;
- Time and date of observation;
- Species (and number);
- Weather, sea state; solar glare.

The perpendicular distance of each turtle from the transect line was recorded as an angle of degree using Suunto inclinometers. Estimates of total area for the entire lower and upper Bay regions were determined in ArcView 3.2 to be 1,529.36 km^2 and 1,879.41 km^2 respectively (Mercator projection).

Density estimates among years:

Byles (1988) estimated population densities using two methods: line and strip transect analyses. Strip transect methods and formulae are presented in Chapter 4. This method assumes that all turtles are counted within a given distance from the transect line and that any turtles falling outside of the census area are not recorded. These assumptions risk a negative bias in density calculations and do not correct for perception bias (Marsh and Sinclair 1989). Byles (1988) did not find significant differences in abundance estimates generated using strip and line transect analyses. Both Byles (1988) and Keinath (1993) opted to use the simpler strip transect method to calculate sea turtle abundance estimates for Virginia waters.

Strip transect analyses were used in this study to compare density estimates (uncorrected for surfacing behavior) from the 1980's and early 1990's to uncorrected density observations in 2001-2004. A combination of raw data and data obtained from dissertations and contract reports were used to reconstruct the aerial dataset from the 1980's. Due to some loss of historic archives, including perpendicular sighting angles associated with turtle observations, comparisons could only be made on the scale of mean density estimates per survey day, not per transect flown. All comparisons were restricted to the Lower Chesapeake Bay region due to infrequent historic Upper Bay surveys or insufficient historic Upper Bay data. In the 1980's and early 1990's, this region corresponded approximately to transect lines 1-24 (Figure 5.1). Some historic analyses did not include transect lines or surveys where no turtles were observed. Unless zero-density surveys were observed prior to or after the turtle residency season, these data were included for this study.

Density data from the 1980's and 2001-2004 were tested for normality using the Kolmogorov-Smirnov test. Log transformed data were pooled and tested for differences between the 1980's and 2001-2004 using paired t-test analyses. Significance was based on $p<0.05$. The distributional characteristics of raw density datasets from the 80's and

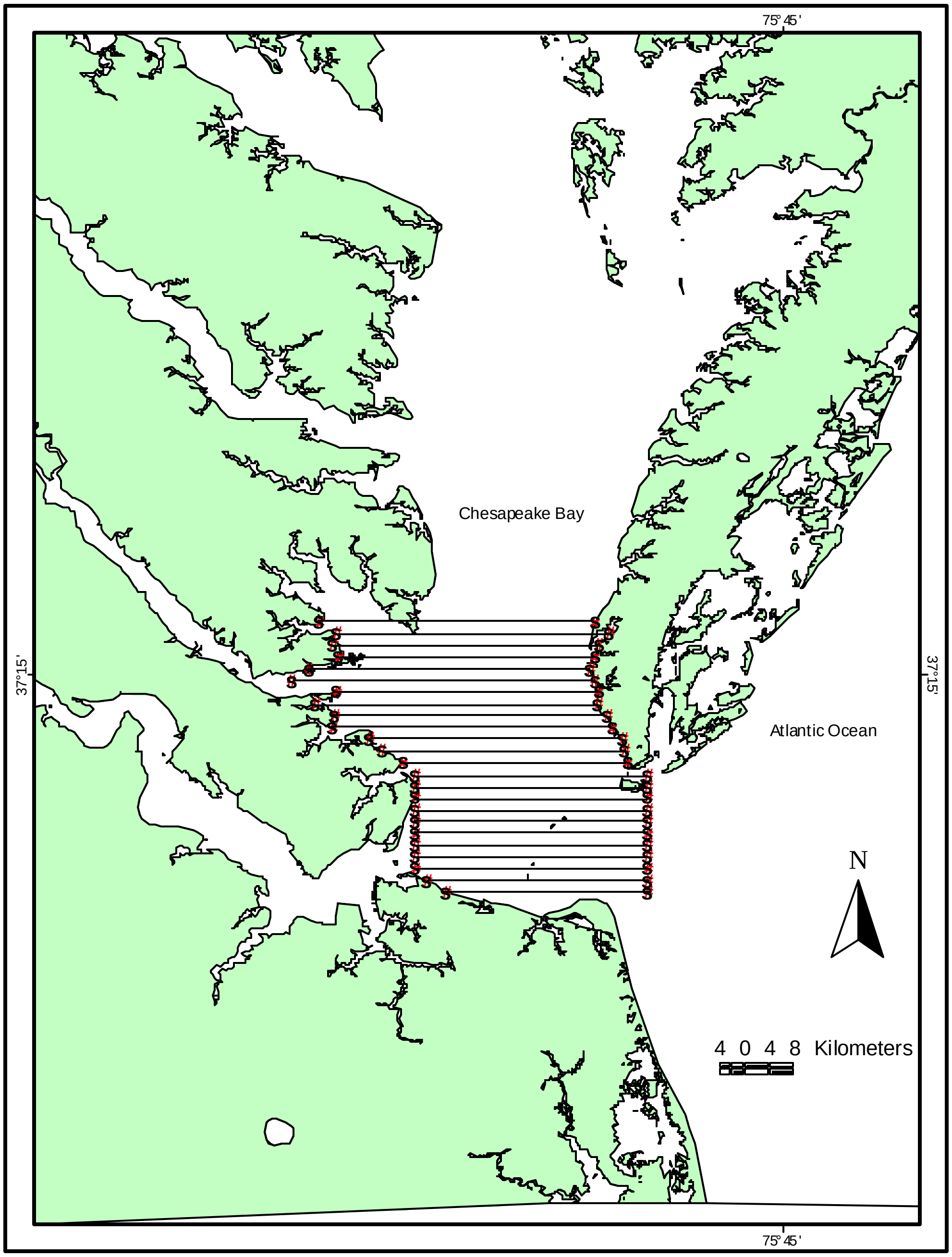


Figure 5.1 Lower Bay transect lines (1024) flown during aerial surveys in the 1980's and 1990's.

2000-2004 were plotted over time using boxplots. A comparison of medians yielded the percent change in densities over time and by season.

For comparison, strip transect methods were also used to present the effects of seasonal differences in sightability on annual abundance estimates. Mean densities per survey were treated with 5%, 10% and 25% corrections for sightability. Annual abundances were calculated for the Lower Bay in the 1980's and 1994, and for both the Lower and Upper Bay for 2001-2004. Abundance estimates were calculated assuming both 10% and 25% sightability corrections during May and June surveys, and Byles (1988) 5% correction for July through August.

Peak springtime density observations in the 1980's (1982, 1983, 1985-1987) were back-calculated to solve for surfacing behavior, assuming constant abundance. Peak predicted surfacing rates were compared to predicted spring values from 2001-2004 (Chapter 4) using a paired t-test (significance based on a $p<0.05$).

2001-2004 density and abundance estimates:

Perpendicular distances from turtle sighting in the 1980's could not be completely reconstructed from available archives, therefore line transect analyses could only be performed on data from 2001-2004. Line transect estimates assume that there is a drop in detectability of turtles with distance away from the transect line. Abundances are estimated based on a function of detection, or $g(x)$ (Byles 1988; Buckland et al. 1993), where:

g(x) = the probability of detecting an object at x distance from the transect line.

It is assumed that the probability of detecting an object at the transect line is 100%, or g(0)=1 (Buckland et al. 1993; Guenzel 1997; Garrison et al. 2003). This assumption is violated in aerial surveys since the region directly under the airplane along the transect line is obscured from view (Blaylock 1992). To compensate for this unobserved area, 50 m was subtracted from each perpendicular sighting distance, left truncating the observed distances to the point where observations were possible (Byles 1988; Blaylock 1992; Keinath 1993). Adjusted distances were used to calculate the probability of observing an animal at any given distance from the transect line. This method assumes that all objects are observed adjacent to the transect line (or adjusted line) out to some distance (w) away from the line. This distance, or effective strip width (w), is scaled to the outermost observations reflected in the observed perpendicular sighting distances (Buckland et al. 1993; Blaylock 1992). Using Program Distance (version 5.0 beta), the frequency of turtle sightings was plotted against distance. The resulting histogram was scaled so the area under the histogram is equal to 1. A probability density function, f(x), was fitted to the frequency of sightings using a half-normal model with cosine adjustments. This model was chosen using Akaike's Information Criterion (AIC), based on the smallest AIC value among fitted models tested in Distance (Buckland 1993).

Density estimates from line transect analyses were generated in Program Distance for pooled data from 2001-2004, Upper and Lower Bay to minimize effects of small observational sample sizes.

RESULTS

2001-2004 aerial monitoring:

Eleven surveys were flown between June 8 and October 16, 2001. Seventeen surveys were flown between May 7 and October 28, 2002. The first two of these surveys occurred prior to the turtle residency period and were eliminated from the analyses. Ten surveys were flown between May 14 and August 26, 2003 and twelve were flown between May 13 and October 13, 2004 (Tables 5.1-5.5). Surveys were flown weekly, weather permitting, until the end of July. From August through October, surveys were flown bi-weekly. In 2001, only one flight was flown in September due to the Federal Aviation Administration ban on all small aircraft in the lower Chesapeake Bay. This ban was in effect between September 11 and October 1, 2001. In 2003, a combination of severe weather and Hurricane Isabel shortened the survey season, resulting in no fall surveys.

In the Lower Bay, 200 transect lines totaling 3,195.61 km^2 in observed area were flown during 2001-2004. A total of 149 Upper Bay transects were flown, covering an observed area of 2,283.88 km^2. Fewer Upper Bay lines were flown due to deteriorated weather and sea conditions. Most turtles observed were found between 100 and 300 meters from the transect line (Figure 5.2). Turtles falling outside this range were eliminated from strip transect analyses. With the exception of 2003 surveys, turtle

Table 5.1 Summary of 2001 aerial density estimates by survey day (strip transect analyses)

Date	Portion of Bay	No. of Transects	Area Observed (km^2)	No. of Turtles Observed	Mean Turtle Density (turtles/ km^2)	SD of Mean Density
6/8/2001	Lower	4	64.80	8	0.125	0.074
6/8/2001	Upper	1	18.97	1	0.056	--
6/12/2001	Lower	4	66.34	10	0.155	0.083
6/12/2001	Upper	4	84.73	9	0.128	0.117
6/19/2001	Lower	4	59.68	8	0.134	0.124
6/19/2001	Upper	4	77.78	2	0.021	0.025
6/26/2001	Lower	4	64.96	8	0.121	0.040
6/26/2001	Upper	4	75.61	5	0.071	0.083
7/3/2001	Lower	4	56.92	2	0.033	0.038
7/3/2001	Upper	2	25.79	0	0.000	--
7/10/2001	Lower	4	63.23	9	0.140	0.066
7/10/2001	Upper	4	79.00	2	0.025	0.029
7/17/2001	Lower	4	72.62	3	0.049	0.062
7/17/2001	Upper	4	90.87	4	0.044	0.087
8/7/2001	Lower	4	65.05	4	0.064	0.096
8/7/2001	Upper	4	79.93	9	0.109	0.075
8/28/2001	Lower	4	62.30	6	0.099	0.081
8/28/2001	Upper	4	77.50	1	0.012	0.024
9/6/2001	Lower	4	61.88	4	0.067	0.095
9/6/2001	Upper	4	81.61	1	0.011	0.023
10/2/2001	Lower	4	63.42	1	0.017	0.034
10/2/2001	Upper	4	76.01	0	0.000	--
All	Lower	44	701.20	63	0.091	0.047
All	Upper	39	767.62	34	0.043	0.044

Table 5.2 Summary of 2002 aerial density estimates by survey day (strip transect analyses).

Date	Portion of Bay	No. of Transects	Area Observed (km^2)	No. of Turtles Observed	Mean Turtle Density (turtles/ km^2)	SD of Mean Density
5/7/02	Lower	4	57.87	0	0.000	0.000
5/7/02	Upper	0	--	--	--	--
5/15/02	Lower	4	65.37	0	0.000	0.000
5/15/02	Upper	0	--	--	--	--
5/24/02	Lower	4	65.14	2	0.032	0.037
5/24/02	Upper	4	67.46	8	0.116	0.099
5/29/02	Lower	4	75.66	5	0.081	0.162
5/29/02	Upper	4	81.65	16	0.198	0.262
6/11/02	Lower	4	62.17	6	0.095	0.033
6/11/02	Upper	2	25.37	0	0.000	0.000
6/20/02	Lower	4	59.80	1	0.017	0.034
6/20/02	Upper	0	--	--	--	--
6/26/02	Lower	4	64.49	4	0.062	0.055
6/26/02	Upper	4	81.16	3	0.039	0.027
7/2/02	Lower	4	63.41	2	0.032	0.037
7/2/02	Upper	4	78.46	4	0.045	0.033
7/9/02	Lower	4	59.93	1	0.017	0.034
7/9/02	Upper	4	79.70	1	0.011	0.022
7/17/02	Lower	4	64.18	8	0.128	0.091
7/17/02	Upper	4	80.46	3	0.043	0.031
7/30/02	Lower	4	62.51	4	0.065	0.011
7/30/02	Upper	4	84.06	2	0.021	0.025
8/8/2002	Lower	4	60.78	2	0.033	0.038
8/8/2002	Upper	4	81.93	1	0.010	0.020
8/20/2002	Lower	4	65.19	2	0.032	0.038
8/20/2002	Upper	2	40.76	0	0.000	0.000
9/3/2002	Lower	4	73.22	5	0.075	0.042
9/3/2002	Upper	4	78.43	2	0.024	0.028
9/17/2002	Lower	4	63.84	0	0.000	0.000
9/17/2002	Upper	4	72.08	1	0.021	0.041

Date	Portion of Bay	No. of Transects	Area Observed (km^2)	No. of Turtles Observed	Mean Turtle Density (turtles/ km^2)	SD of Mean Density
10/1/2002	Lower	4	62.32	2	0.034	0.039
10/1/2002	Upper	4	66.09	2	0.034	0.041
10/28/2002	Lower	4	62.99	1	0.017	0.034
10/28/2002	Upper	0	--	--	--	--
All	Lower	68	1088.87	45	0.045	0.036
All	Upper	48	917.61	43	0.043	0.055

Table 5.3 Summary of 2003 aerial density estimates by survey day (strip transect analyses).

Date	Portion of Bay	No. of Transects	Area Observed (km^2)	No. of Turtles Observed	Mean Turtle Density (turtles/ km^2)	SD of Mean Density.
5/14/03	Lower	4	64.79	2	0.031	0.062
5/14/03	Upper	3	67.80	0	0.000	0.000
5/28/03	Lower	4	59.18	0	0.000	0.000
5/28/03	Upper	1	12.08	0	0.000	0.000
6/5/03	Lower	4	66.10	6	0.083	0.089
6/5/03	Upper	4	89.29	15	0.166	0.241
6/11/03	Lower	4	67.56	9	0.139	0.113
6/11/03	Upper	2	25.79	0	0.000	0.000
6/27/03	Lower	4	63.25	11	0.166	0.130
6/27/03	Upper	4	73.02	15	0.248	0.291
7/9/03	Lower	4	61.80	6	0.064	0.055
7/9/03	Upper	4	80.12	5	0.057	0.076
7/16/03	Lower	4	77.43	2	0.018	0.036
7/16/03	Upper	2	33.78	2	0.073	0.103
7/24/03	Lower	4	61.14	2	0.037	0.043
7/24/03	Upper	4	73.59	2	0.028	0.034
8/12/2003	Lower	4	61.85	7	0.118	0.107
8/12/2003	Upper	4	84.28	3	0.036	0.044
8/26/2003	Lower	4	60.43	6	0.076	0.073
8/26/2003	Upper	4	81.27	6	0.082	0.051
All	Lower	40	643.53	49	0.063	0.058
All	Upper	32	621.02	50	0.086	0.082

Table 5.4 Summary of 2004 aerial density estimates by survey day (strip transect analyses).

Date	Portion of Bay	No. of Transects	Area Observed (km^2)	No. of Turtles Observed	Mean Turtle Density (turtles/ km^2)	SD of Mean Density
5/13/2004	Lower	4	59.18	6	0.108	0.090
5/13/2004	Upper	2	38.41	2	0.044	0.062
5/19/2004	Lower	4	62.02	2	0.032	0.037
5/19/2004	Upper	2	30.53	2	0.067	0.012
5/25/2004	Lower	4	64.47	4	0.059	0.046
5/25/2004	Upper	4	85.67	3	0.033	0.043
6/1/2004	Lower	4	64.04	7	0.106	0.050
6/1/2004	Upper	4	83.86	1	0.014	0.028
6/22/2004	Lower	4	61.87	2	0.032	0.037
6/22/2004	Upper	0	--	--	--	--
6/29/2004	Lower	4	61.55	1	0.017	0.034
6/29/2004	Upper	0	--	--	--	--
7/6/2004	Lower	4	62.04	1	0.016	0.032
7/6/2004	Upper	4	74.06	0	0.000	0.000
7/13/2004	Lower	4	59.69	3	0.051	0.065
7/13/2004	Upper	4	87.97	1	0.012	0.023
7/20/2004	Lower	4	73.15	0	0.000	0.000
7/20/2004	Upper	4	79.78	0	0.000	0.000
8/10/2004	Lower	4	66.39	7	0.104	0.051
8/10/2004	Upper	4	77.84	0	0.000	0.000
8/24/2004	Lower	4	64.96	2	0.030	0.035
8/24/2004	Upper	2	40.35	0	0.000	0.000
10/13/2004	Lower	4	62.03	1	0.017	0.034
10/13/2004	Upper	0	--	--	--	--
All	Lower	48	762.01	36	0.054	0.039
All	Upper	30	598.47	9	0.021	0.023

Table 5.5 Annual survey summaries for the Lower Chesapeake Bay (strip transect analyses)

Year	Number of Surveys	Total Area Observed (km^2)	Average Area per Flight (km^2)	Total Turtles Observed	Average Turtle Density (turtles/km^2)	SD Turtle Density (turtles/km^2)
1982	10	697.10	69.71	159	0.223	0.210
1983	12	835.95	69.66	284	0.341	0.346
1984*	10	629.00	62.90	207	0.329	
1985	11	777.00	70.64	173	0.223	0.267
1986	10	666.35	66.64	122	0.183	0.108
1987	11	771.75	70.16	145	0.188	0.188
1994	9	623.95	69.33	72	0.115	0.120
2001	11	701.20	63.75	63	0.090	0.048
2002	15	1088.87	64.58	45	0.046	0.034
2003	10	643.53	64.35	49	0.093	0.055
2004	12	762.01	63.45	36	0.048	0.038

*1984 data presented in Byles 1988; raw data missing from archives; cannot calculate SD

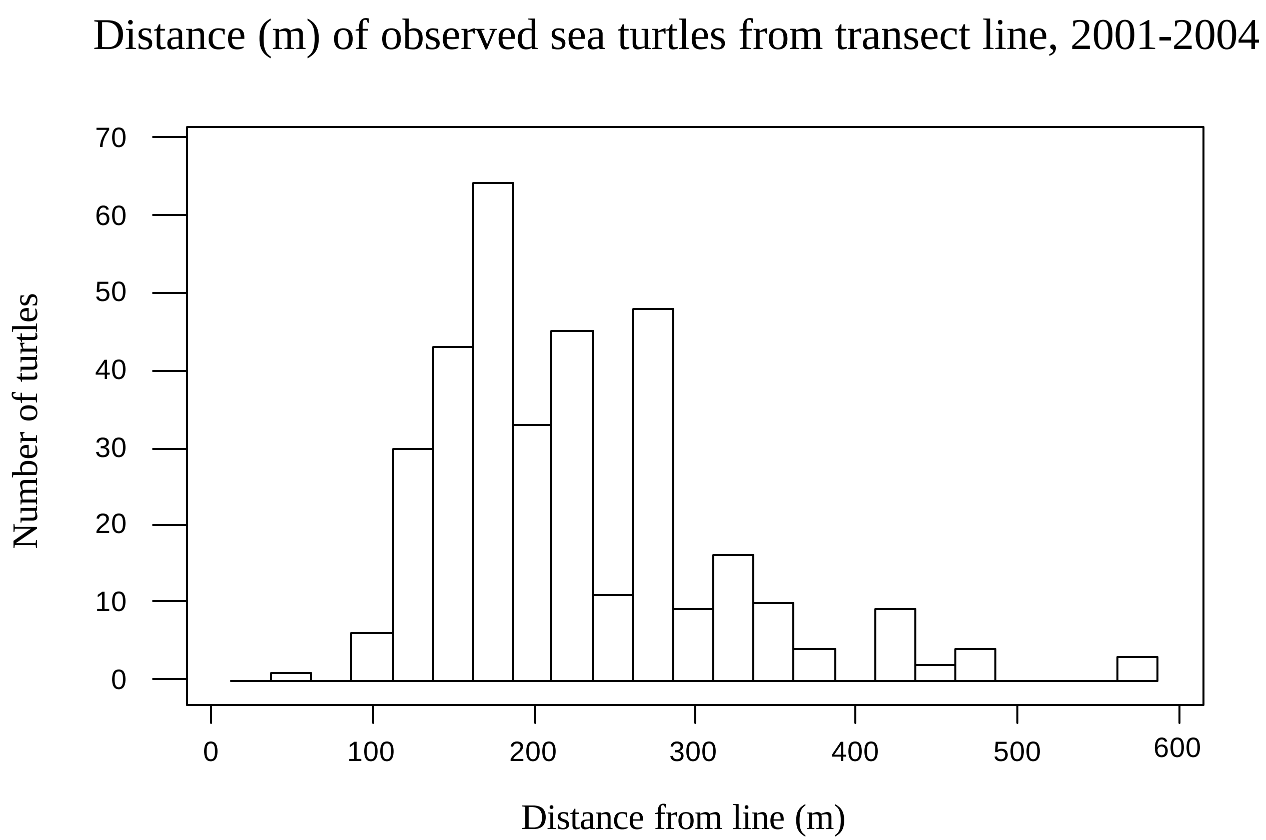


Figure 5.2 Distribution of turtle sightings perpendicular to transect line.

densities were highest in the spring of the year and were located mostly within the Lower Bay region. As the season progressed, more turtles were sighted within the Upper Bay. Apparent abundances declined after August (Figures 5.3-5.5). The majority of turtles initially sighted in the spring of 2003 were located within the Upper Bay region. This is possibly an artifact of survey timing.

Significant differences ($p<0.05$) were found in the number of turtles recorded due to observer, sea state and glare. Differences in turtles observed due to sea state and glare resulted in a negative bias, reducing the number of turtles observed.

2001-2004 strip transect densities--uncorrected:

In 2001, a total of 63 turtles were observed in the Lower Bay resulting in an average turtle density of 0.090 turtles/km^2 (+/- 0.048 turtles/km^2 SD) (Table 5.5). Minimum estimated sea turtle densities in 2001 (uncorrected for diving behavior) were greatest in June and early July, subsequently declining over the course of the season within the Lower Bay (Figure 5.3; Table 5.1). Peak Lower Bay densities were 0.155 turtles/km^2 (+/- 0.083 turtles/km^2 SD) in June (Table 5.1). A total of 34 turtles were observed in the Upper bay, resulting in an average Upper Bay density of 0.042 turtles/km^2 (+/- 0.040 turtles/km^2 SD) (Table 5.6). Highest average Upper Bay densities were also observed during June, with declining densities in July, a secondary peak in August (0.044 turtles/km^2 +/- 0.041 turtles/km^2) and declines in September (0.012 turtles/km^2 +/- 0.024 turtles/km^2) and October (0.00 turtles/km^2) (Figure 5.3; Table 5.1).

In 2002, mean Lower Bay densities were greatest in June and July, declining through August and October (Table 5.2; Figure 5.4). A total of 45 turtles were observed

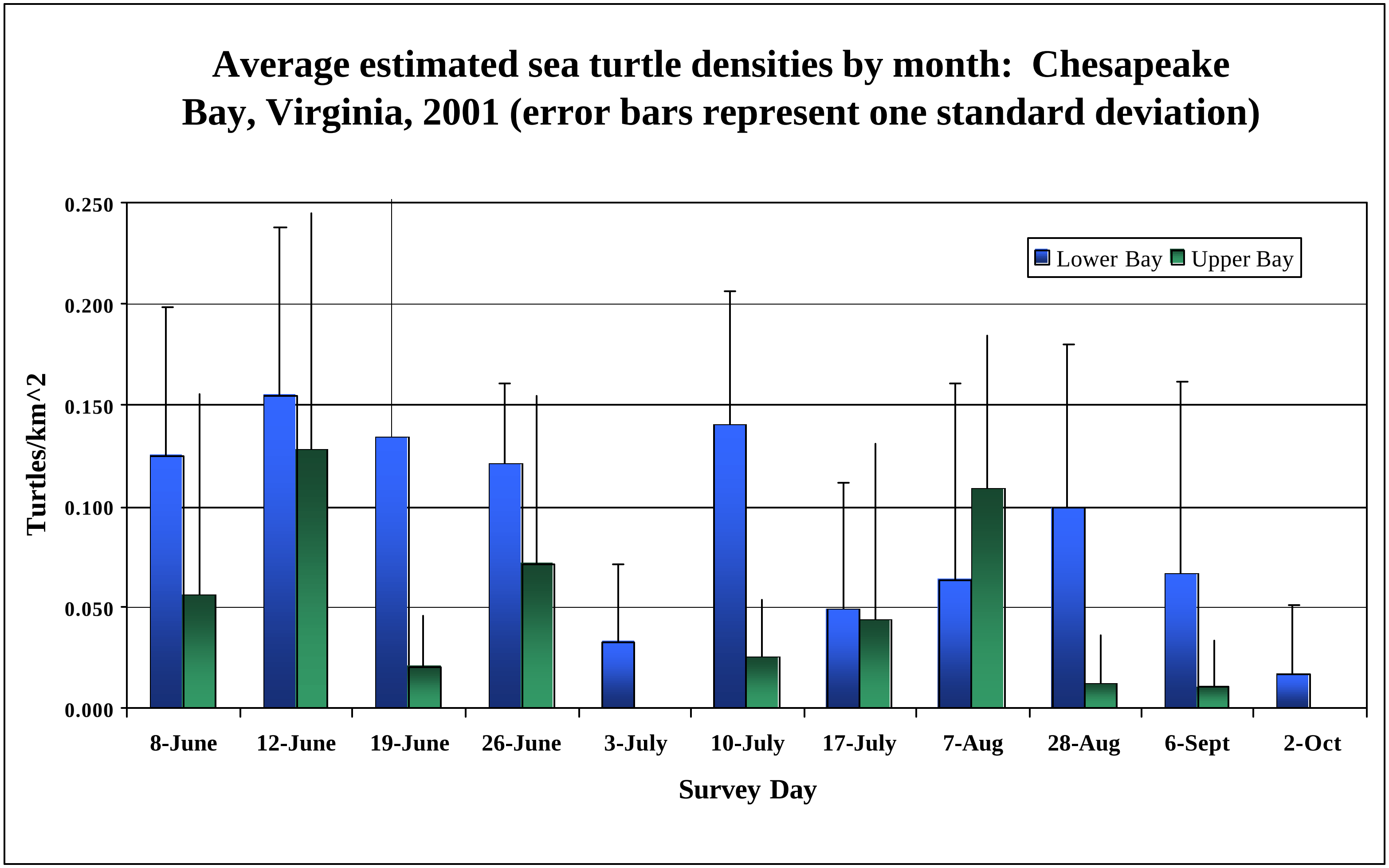


Figure 5.3 2001 sea turtle densities (strip transect analyses), Upper and Lower Bay

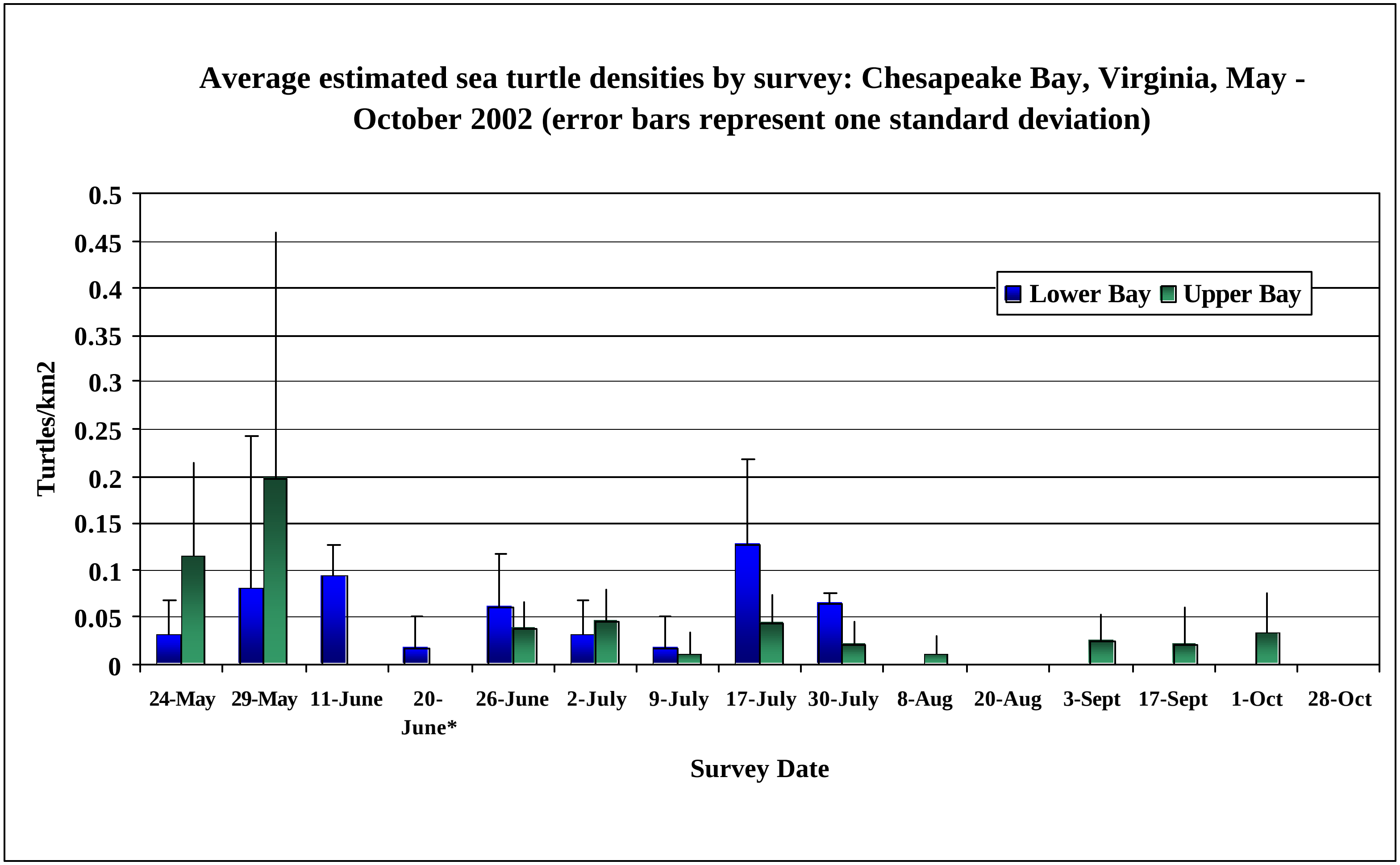


Figure 5.4 2002 sea turtle densities (strip transect analyses), Upper and Lower Bay

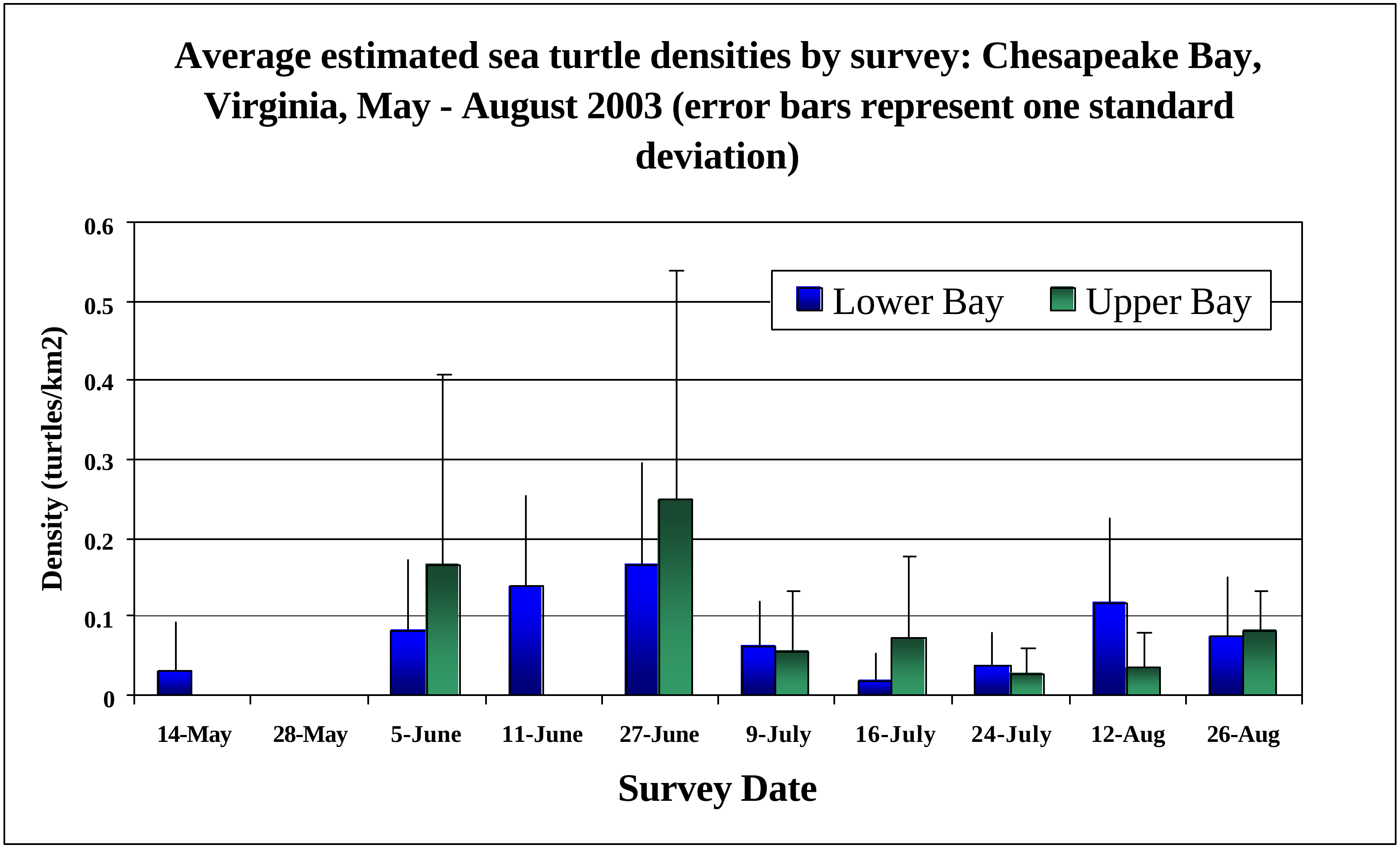


Figure 5.5 2003 sea turtle densities (strip transect analyses), Upper and Lower Bay

Table 5.6 Annual survey summaries for the Upper Chesapeake Bay (strip transect analyses), 2001-2004

Year	Number of Surveys	Total Area Observed (km^2)	Average Area per Flight (km^2)	Total Turtles Observed	Average Turtle Density (turtles/km^2)	SD Turtle Density
2001	11	767.62	69.78	34	0.042	0.040
2002	13	917.61	70.59	43	0.043	0.055
2003	10	621.02	62.10	38	0.079	0.071
2004	9	598.47	66.50	42	0.060	0.047

in the Lower Bay, resulting in an average turtle density of 0.046 turtles/km^2 (+/- 0.034 turtles/km^2 SD) (Table 5.5). Peak densities were observed in July (0.128 turtles/km^2 +/- 0.091 turtles/km^2 SD) and June (0.095 turtles/km^2 +/- 0.033 turtles/km^2 SD) respectively (Table 5.2). A total of 43 turtles were observed in the Upper bay, resulting in a mean annual density of 0.043 turtles/km^2 (+/- 0.055 turtles/km^2 SD) (Table 5.6). Upper Bay densities peaked in May (0.198 turtles/km^2 +/- 0.262 turtles/km^2 SD), exceeding peak Lower Bay densities (Table 5.2; Figure 5.4).

A total of 49 turtles were observed during Lower Bay surveys in 2003, resulting in a mean annual density of 0.093 turtles/km^2 (+/- 0.291 turtles/km^2 SD) (Table 5.5). Estimated sea turtle densities in 2003 were greatest in June within both the Upper and Lower Bay (0.166 turtles/km^2 (+/- 0.130 turtles/km^2 SD and 0.248 turtles/km^2 +/- 0.291 turtles/km^2 SD). Peak estimates were observed on June 27th within both regions (Table 5.3; Figure 5.5). A total of 38 turtles were observed in the Upper Bay, resulting in a mean annual density of 0.079 turtles/km^2 (+/- 0.071 turtles/km^2 SD) (Table 5.6). Peak Upper Bay densities exceeded peak densities observed in the Lower Bay (Table 5.3; Figure 5.5). Within the Upper Bay, highest densities in 2002 and 2003 were observed along transect lines located in the lower half of the study region.

In 2004, 36 turtles were observed within the Lower Bay, resulting in a mean annual density of 0.048 turtles/km^2 (+/- 0.038 turtles/km^2 SD) (Table 5.5). Lower Bay densities in 2004 were highest in May and June, declining through August, with a secondary August 10th followed by a subsequent decline (Figure 5.6; Table 5.4). Peak Lower Bay density occurred in early June: 0.106 turtles/km^2 (+/- 0.050 turtles/km^2 SD). A total of 42 turtles were observed within the Upper Bay, resulting in a mean annual

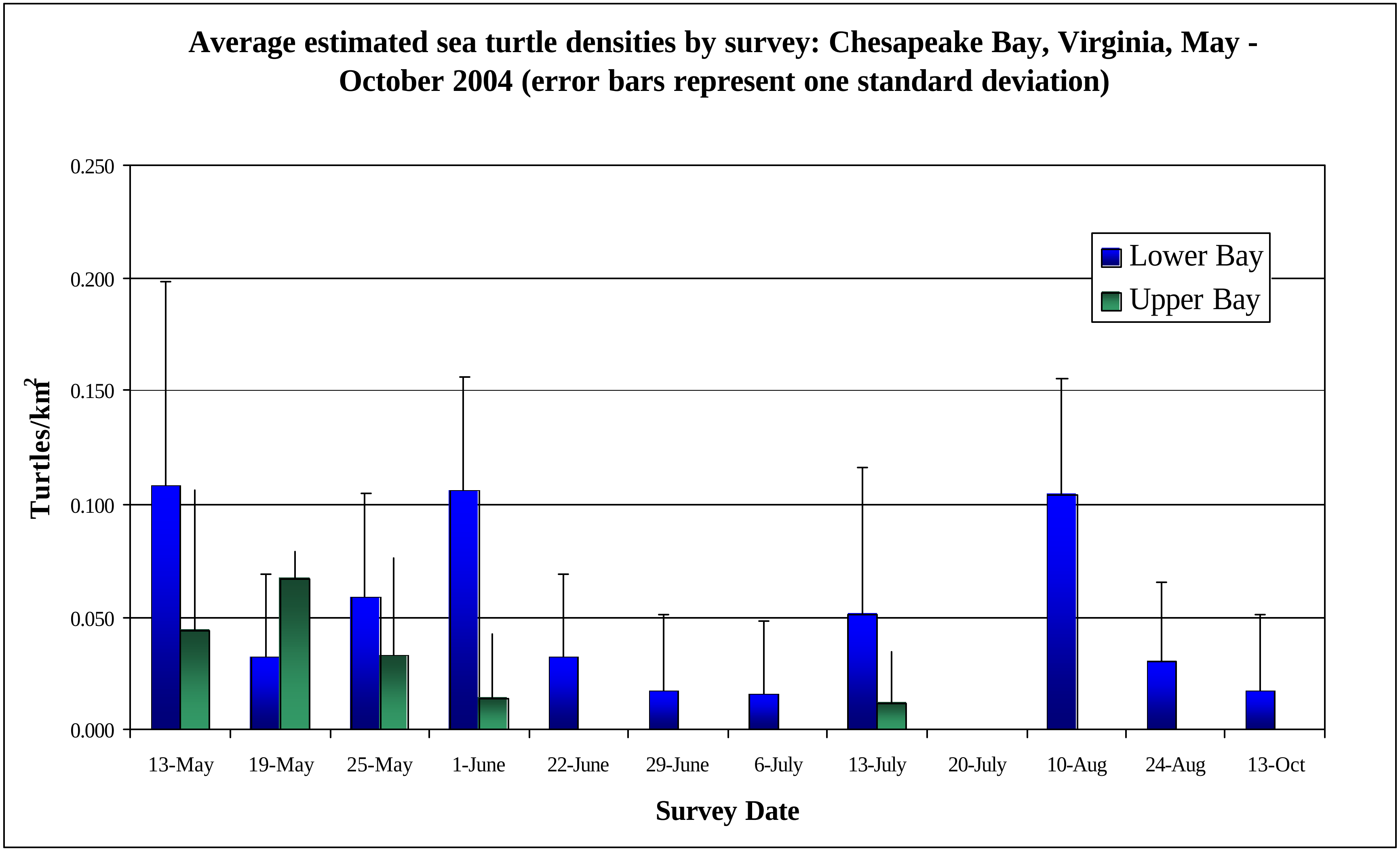


Figure 5.6 2004 sea turtle densities (strip transect analyses), Upper and Lower Bay

density of 0.060 turtles/km^2 (+/- 0.047 turtles/km^2 SD) (Table 5.6) for this region. Peak Upper Bay densities were observed late May: 0.033 turtles/km^2 (+/- 0.043 turtles/km^2 SD).

Based on negative biases associated with strip-transect analyses and seasonal sea turtle sightability, all density estimates derived from strip transect analyses must be considered as minimum estimates.

2001-2004 strip transect abundances—corrected for sightability:

Tables 5.7 and 5.8 provide estimates of sea turtle abundances, spatially extrapolated to the Lower or Upper Bay survey areas, and corrected for surfacing behavior. Estimates include Byles (1988) assumption of constant sightability (5%), 10% spring (May-June) sightability, and 25% sightability. In the Lower Bay, mean annual estimates ranged between 1,326 and 2,597 turtles assuming constant sightability (5%), 1,033 and 2,088 turtles assuming a springtime correction of 10% sightability, and 799 to 1,600 turtles assuming 25% sightability (Table 5.7). Mean annual Upper Bay estimates ranged between 1,480 to 2,805 turtles assuming constant sightability, 1,072 to 1,619 assuming 10% sightability, and 737 to 1,198 turtles assuming 25% sightability (Table 5.8).

Combined mean annual abundances for the entire Virginia portion of the Chesapeake Bay are presented in Table 5.9. Assuming constant sightability, total mean abundances for the entire Bay were between 2,850 and 5,479 turtles. Total annual abundances ranged between 2,506 and 3,471 turtles assuming a 10% sightability correction in May and June, and between 1,832 and 2,573 turtles assuming a 25%

Table 5.7 Mean annual abundances adjusted for 5%, 10% and 25% springtime sightability, Lower Bay (strip transect analyses).

Year	5% Correction	SD 5%	10% Correction	SD 10%	25% Correction	SD 25%
1982	**5820.69**	5488.12	**5487.81**	3557.81	**4527.51**	3288.29
1983	**8915.68**	9045.58	**5856.44**	4657.22	**3794.03**	2768.34
1984*	**8599.63**					
1985	**5840.36**	6980.44	**4600.90**	5036.94	**3765.30**	4558.94
1986	**4771.24**	2829.90	**3888.95**	2660.10	**3294.14**	2957.42
1987	**4913.96**	4902.07	**3431.49**	2874.16	**2432.07**	2261.07
1994	**2997.29**	3129.42	**2776.98**	3340.06	**2639.69**	3466.75
2001	**2597.21**	1385.43	**2088.06**	825.47	**1600.44**	1040.71
2002	**1325.79**	978.55	**1401.93**	898.99	**1266.29**	968.24
2003	**2674.30**	1579.95	**1997.31**	1130.49	**1540.91**	1243.09
2004	**1378.48**	1110.76	**1032.54**	812.80	**799.33**	801.49

* 1984 raw data missing from archives, cannot reconstruct springtime surveys

Table 5.8 Mean annual abundances adjusted for 5%, 10% and 25% springtime sightability, Upper Bay, 2001-2004 (strip transect analyses).

Year	**5% Correction**	**SD 5%**	**10% Correction**	**SD 10%**	**25% Correction**	**SD 25%**
2001	**1480.16**	1403.97	**1098.06**	1146.76	**840.46**	1138.50
2002	**1524.55**	1959.08	**1072.27**	1017.33	**767.36**	558.29
2003	**2804.50**	2526.26	**1619.00**	1390.71	**1197.92**	964.61
2004	**2127.23**	1659.05	**1473.25**	1050.76	**1032.36**	971.31

Table 5.9 Combined mean annual abundances, Upper and Lower Chesapeake Bay, 2001-2004 (strip transect analyses).

Year	5% Correction	SD 5%	10% Correction	SD 10%	25% Correction	SD 25%
2001	**4077.37**	2789.40	**3160.33**	1842.80	**2367.80**	1599.00
2002	**2850.34**	2937.62	**3020.93**	2289.70	**2464.21**	1932.85
2003	**5478.80**	4106.21	**3470.55**	2181.25	**2573.27**	2214.40
2004	**3505.71**	2769.80	**2505.79**	1863.56	**1831.69**	1772.80

sightability correction. Abundance estimates per survey day and adjusted for sightability are presented in Appendices D and E.

Historic vs. recent estimates:

Ten to twelve surveys were flown annually in the Lower Bay between 1982 and 1987. Nine surveys were flown in 1994. The Upper Bay was inconsistently surveyed in the 1980's and data were insufficient for comparison. Total area surveyed per year was comparable to that surveyed between 2001 and 2004 (Table 5.5). In the 1980's, between 122 and 284 turtles were observed per survey; 72 were observed in 1994. Mean annual turtle densities ranged between 0.183 turtles/km^2 (+/- 0.108 turtles/km^2 SD) in 1986 to 0.341 turtles/km^2 (+/- 0.346 turtles/km^2 SD) in 1983 (Table 5.5). In 1994, mean annual density was 0.115 turtles/km^2 (+/- 0.120 turtles/km^2 SD). Assuming constant sightability, historic Lower Bay abundances ranged between a low of 2,997 turtles in 1994 and 4,771 turtles in 1986, to a peak of 8,916 in 1983 (Table 5.7). Adjusted for seasonal sightability, 1994 estimates drop to between 2,777 (10% sightability) and 2,640 turtles (25%). Estimates in the 80's drop to between 3,431 and 5,856 (10%) or 2,432 and 4,527 (25%) (Table 5.7). Abundance estimates per survey day and adjusted for sightability are presented in Appendix F.

There were significant differences in densities between the 2001-2004 surveys and surveys in the 1980's (p=0.0000). Significant differences were observed in abundances corrected for sightability (10% and 25%) among decades (p=0.0000) and for seasonal densities (May/June; July/August; September/October) between survey decade (p=0.0004 to 0.011). Fewer turtles were observed during the 2001-2004 surveys than in the 1980's or 1994. Surveys in the 1980's often resulted in large spikes in turtle observations during one or two early season surveys (Appendix F). These spikes were absent in survey observations from 2001-2004 (Figures 5.7 and 5.8). Early season spikes in turtle observations are represented as 5th percentile outliers in boxplots of densities vs. survey year (Figure 5.8). Removing these outliers still resulted in significant differences ($p=0.0000$) among decades with lower densities observed in 2001-2004 (Figure 5.9).

A conservative comparison of median densities and abundances between observations from the 1980's and 2001-2004 result in a three-fold reduction of turtles since the 1980's. Comparisons of uncorrected density medians from the 1980's (0.170 turtles/km^2) vs. 2000's (0.056 turtles/km^2) result in a 67.1% decline in turtle densities (Figure 5.10). A comparison of median abundances corrected for 10% springtime sightability from the 1980's and present (3,181 and 1,105 turtles respectively) result in a 63.5% decline; and a 67.6% decline results when comparing median abundances adjusted for 25% sightability (2,633 and 853 turtles). A less conservative comparison of mean densities between decades (0.230 vs. 0.060 turtles/km^2 respectively) results in a 73.9% reduction in turtle densities.

Removing the early season outliers from the 1980's dataset still result in significant declines: comparisons of median density estimates between the 1980's and present (0.122 and 0.056 turtles/km^2 respectively) result in a 54.1% decline (Figure 5.11); differences in median abundances corrected for 10% sightability (3,048 and 1,105 turtles) result in a 63.7% decline; and differences in median abundances corrected for 25% sightability result in a 59.9% decline.

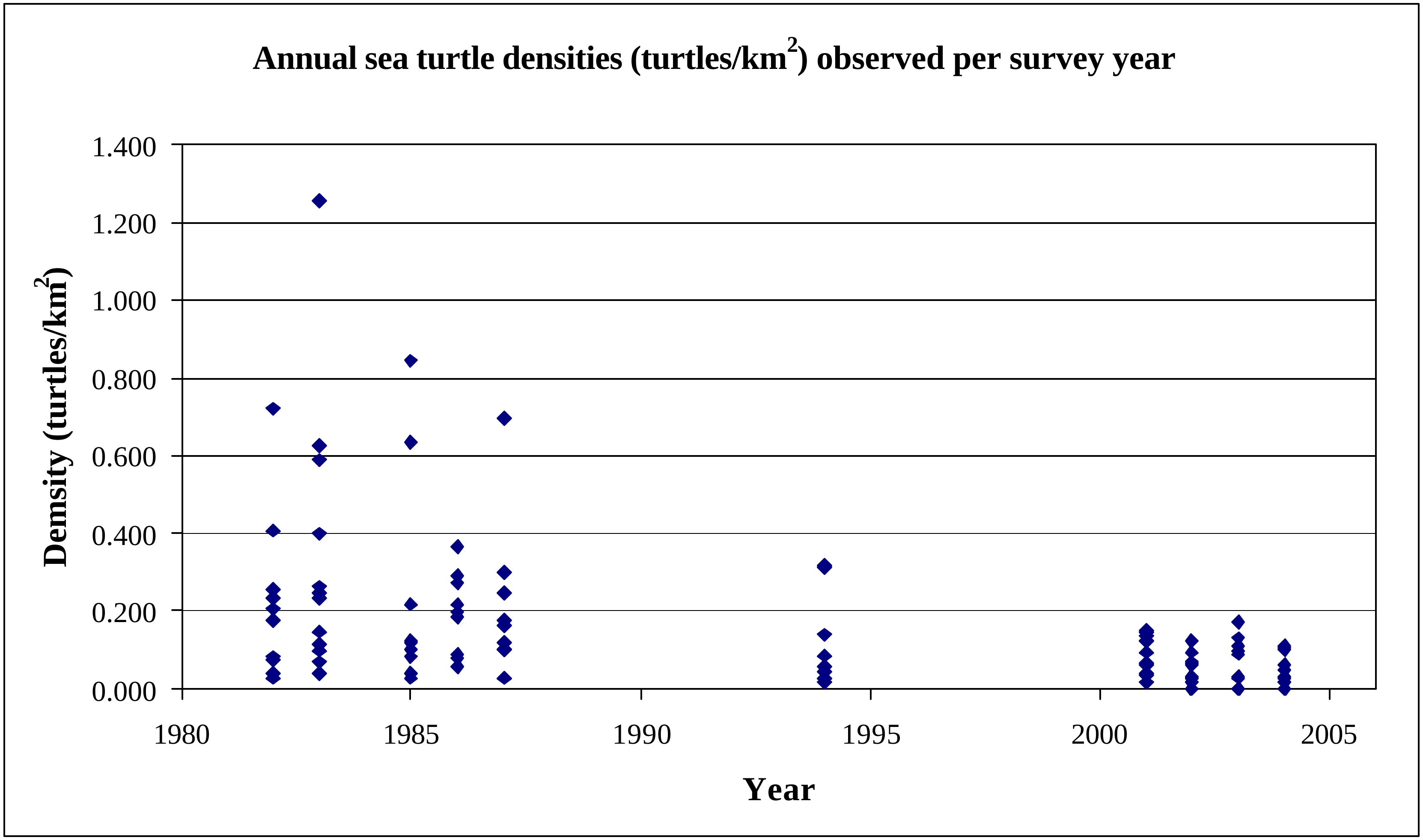


Figure 5.7 Sea turtle density estimates (turtles/km^2) observed per survey year, uncorrected for seasonal behavior in the Lower Chesapeake Bay, Virginia, 1982-1987, 1994 and 2001-2005.

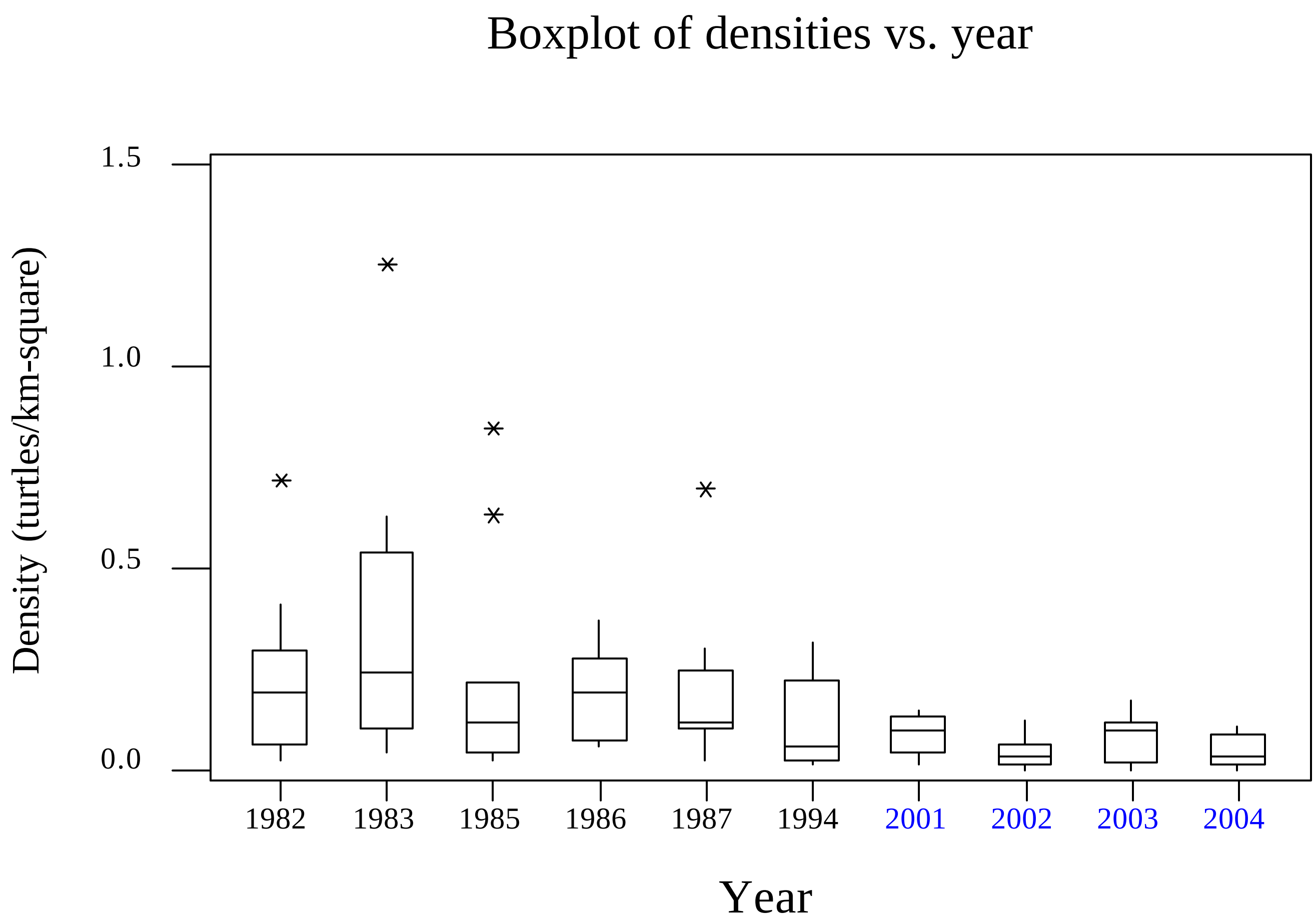


Figure 5.8 Boxplot of sea turtle densities (turtles/km^2) uncorrected for seasonal behavior in the Lower Chesapeake Bay, Virginia, 1982-1987, 1994 and 2001-2005. Boxes represent 75th percentile; vertical lines represent 95th percentile. Horizontal line represents median and asterisks represent the 5% outliers.

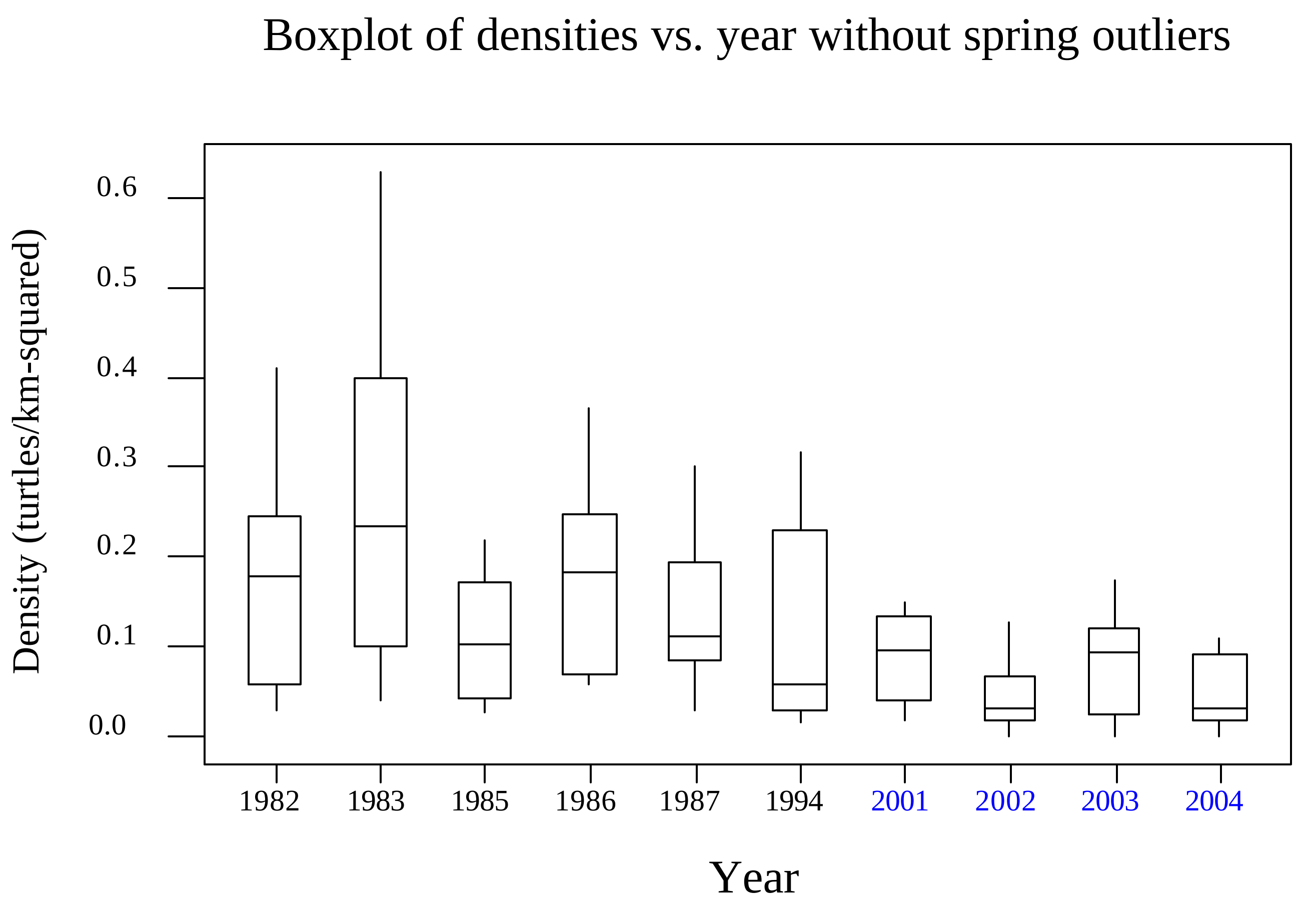


Figure 5.9 Boxplot of sea turtle densities (turtles/km^2) without spring outliers and uncorrected for seasonal behavior in the Lower Chesapeake Bay, Virginia, 1982-1987, 1994 and 2001-2005. Boxes represent 75th percentile; vertical lines represent 95th percentile. Horizontal line represents median.

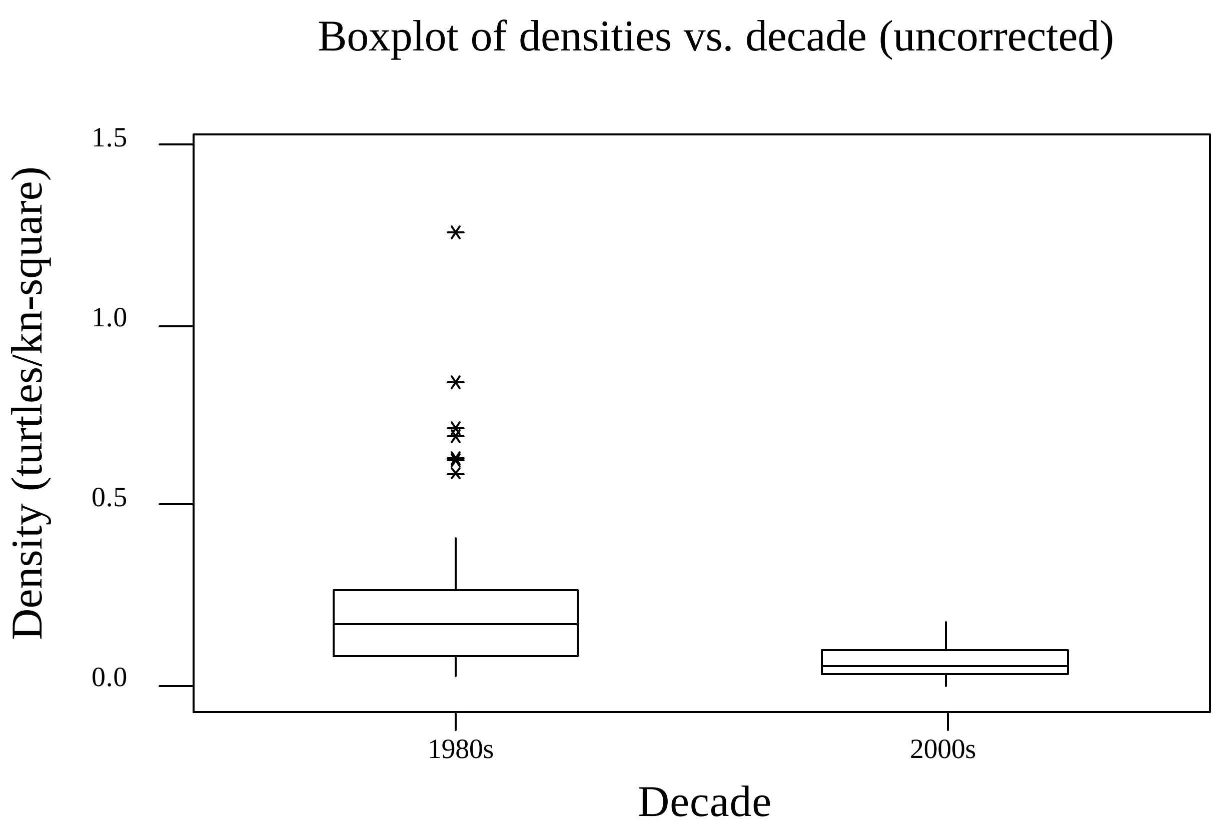


Figure 5.10 Boxplot of sea turtle densities (turtles/km^2) uncorrected for seasonal behavior in the Lower Chesapeake Bay, Virginia by decade (1980's vs. 2000's). Boxes represent 75th percentile; vertical lines represent 95th percentile. Horizontal line represents median and asterisks represent the 5% outliers.

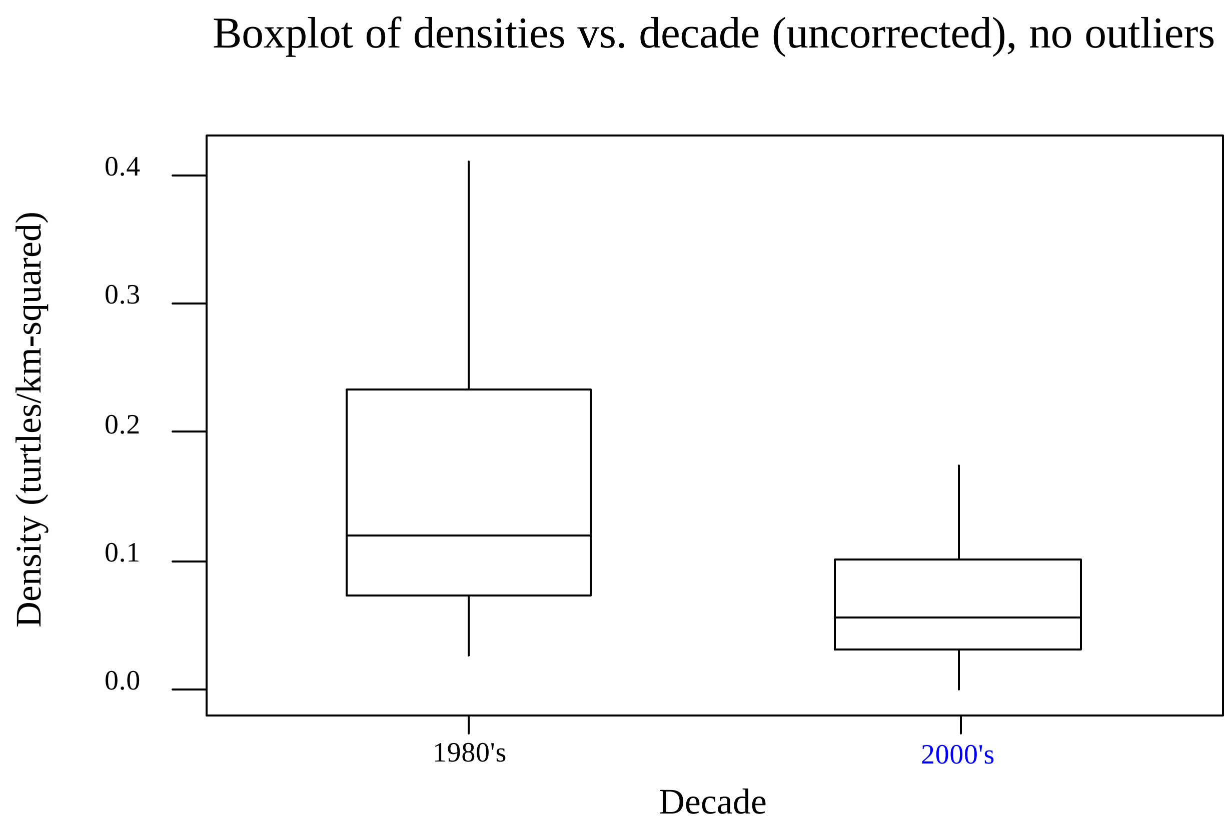


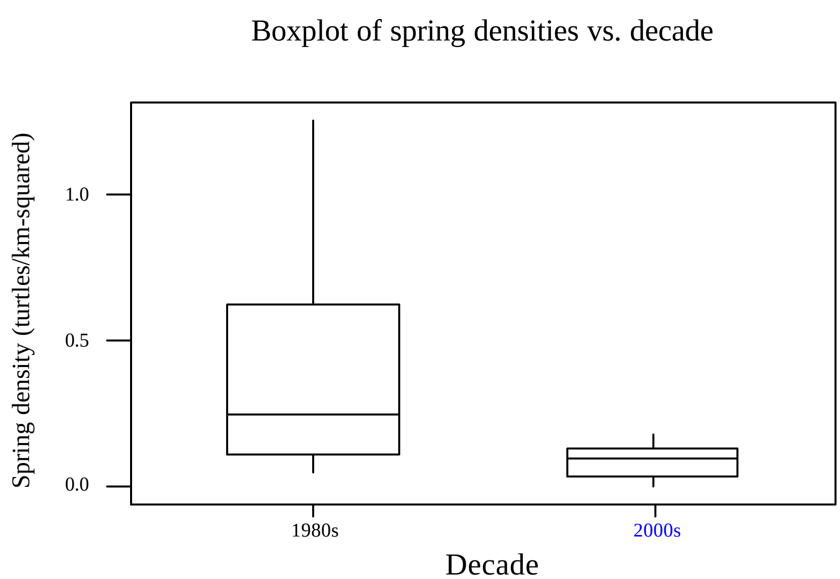
Figure 5.11 Boxplot of sea turtle densities (turtles/km^2) without spring outliers and uncorrected for seasonal behavior in the Lower Chesapeake Bay, Virginia by decade (1980's vs. 2000's). Boxes represent 75th percentile; vertical lines represent 95th percentile. Horizontal line represents median and asterisks represent the 5% outliers.

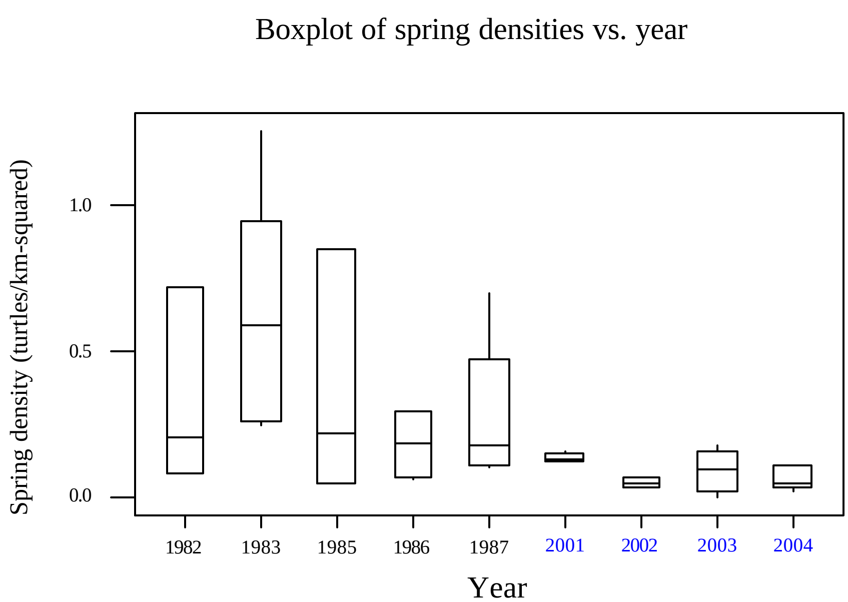
Significant differences ($p<0.05$) were also found when comparing spring densities (May-June) among decades, as well as comparing summer densities (July-August) among decades. Significantly fewer turtles were observed in both the spring and the summer from 2001-2004 compared to surveys in the 1980's (Figures 5.12-5.15). A comparison of median densities (0.248 and 0.091 turtles/km^2 respectively) in the spring result in a 63.2% reduction in densities from the 1980's to the 2000's. A 74.9% reduction in densities occurred during the summer residency period from the 1980's (0.179 turtles/km^2) to present (0.045 turtles/km^2).

Peak density observations in the 1980's were back-calculated to solve for surfacing behavior. Assuming constant abundance, turtles would have spent 37.4% (1986) to 49.3% (1985) of their time on the surface to account for the high springtime densities observed in the 1980's. Mean predicted surfacing behavior (or sightability) for all 1980's surveys was 45.0%. These predicted surfacing rates were significantly higher ($p<0.05$) than predicted estimates from the 2001-2004 surveys (21.5% and 28.2%; Chapter 4). A comparison of these means resulted in a 43.7% difference in mean predicted sightability over the past two decades, assuming annual abundances remained constant during each season.

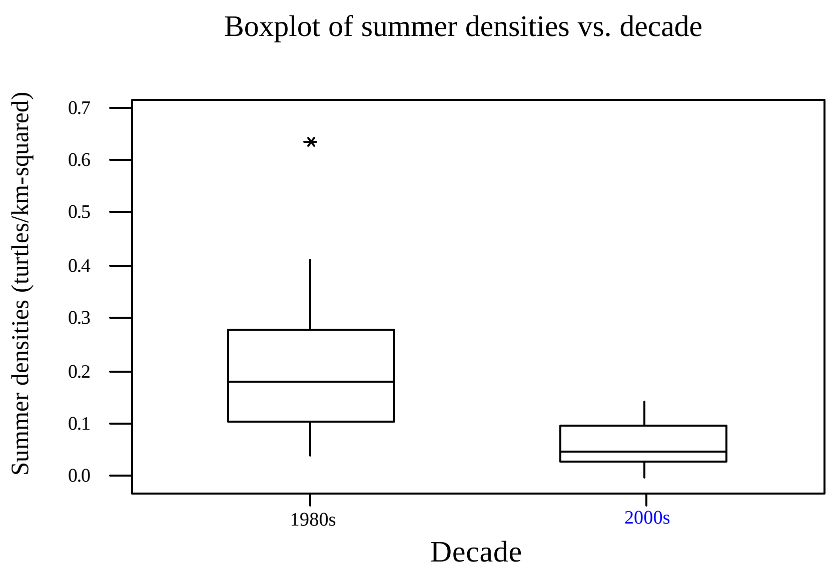
2001-2004 line transect estimates:

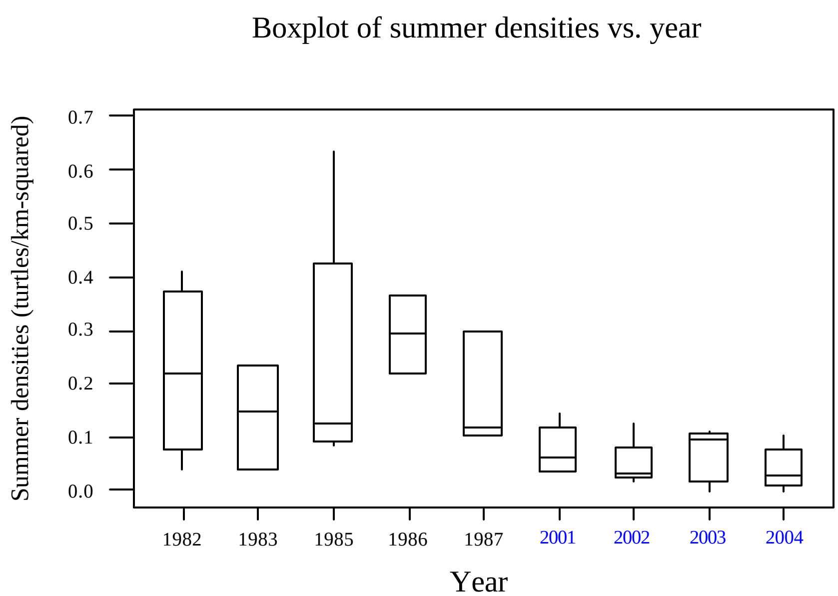
Due to small sample sizes, turtle sightings were pooled across years and regions (Lower and Upper Bay), resulting in the probability density function: $f(0)= 0.746\ e^{-2}$ with a standard error (SE) of $0.128\ e^{-2}$ (Figure 5.17). The resulting effective strip half width





Figures 5.12 and 5.13 Boxplots of springtime turtle densities (turtles/km^2) uncorrected for seasonal behavior in the Lower Chesapeake Bay, Virginia by decade (1980's vs. 2000's) and year. Boxes represent 75th percentile; vertical lines represent 95th percentile. Horizontal line represents median.





Figures 5.14 and 5.15 Boxplots of summer turtle densities (turtles/km^2) uncorrected for seasonal behavior in the Lower Chesapeake Bay, Virginia by decade (1980's vs. 2000's) and year. Boxes represent 75th percentile; vertical lines represent 95th percentile. Horizontal line represents median.

was 134.12 m (22.96 SE). Pooled sampling resulted in a line transect density of 0.093 turtles/km^2 (0.18 turtles/km^2 SE). Total estimated number of turtles (across all four survey years, Upper and Lower Bay) was 13,791 (2659.6 SE) or approximately 3,448 in any given year.

Fisheries observations:

With the exception of the 2003 surveys, gillnet activities were minimal during the months of May through July and did not increase significantly until late September or October (Mansfield et al. 2002a; 2002b; 2003). In 2003, gillnet activities were concentrated in May and June, with few or no nets observed in July. No data are available for mid- to late-September 2001, or fall of 2003 due to due to airspace closures over the southern Chesapeake Bay and Hurricane Isabel. Fall gillnet effort was highest within the northern transects of the Lower Bay region, or within the Upper Bay. No more than one to nine nets were observed per survey. Menhaden boats were observed primarily within the Upper Bay region, however no more than four boats were observed during any given survey (Mansfield et al. 2002a; 2002b; 2003). In 2002, only one menhaden boat was observed, located in the Upper Bay.

During any given survey, crab pots were observed throughout the Bay, blanketing Bay shorelines out to a depth of approximately ten meters. Due to pot density, it was not possible to record every single crab pot along a transect. Crab pot distribution generally complied with the Marine Protected Area and Corridor for the Bay's blue crab spawning stock, or "crab sanctuary" (VMRC 2003). Recreational and commercial fishing boats were also observed throughout the Bay. Recreational fishing vessels were predominantly

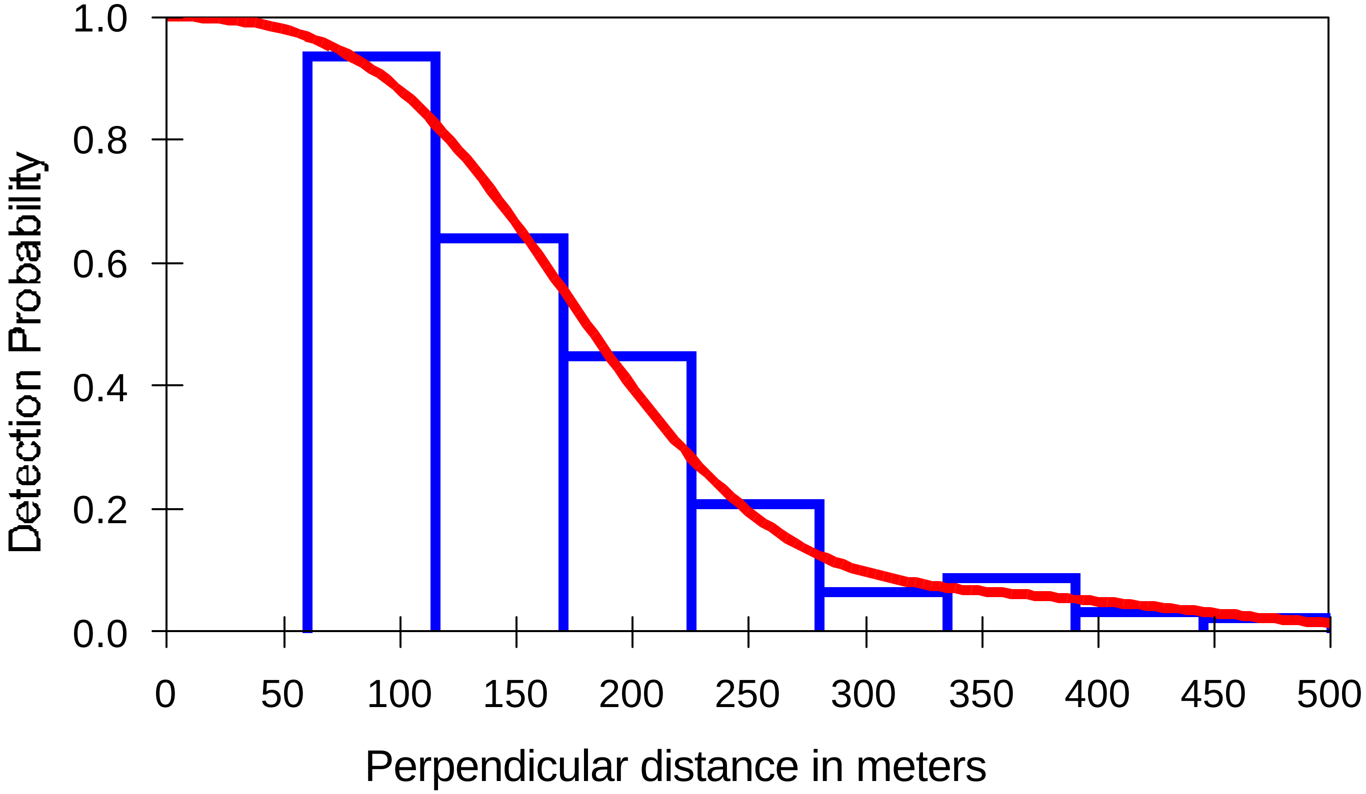


Figure 5.16 Distribution of perpindicular sighting distances modeled with a half-normal cosine model resulting in a probability density function f(0)= 0.746 e^{-2} with a standard error (SE) of 0.128 e^{-2} . Data were left truncated to 60 m, to account for the unobservable area under the airplane.

hook and line fishers often found in association with converging water masses/fronts. Commercial fishing boats, not including menhaden boats, were primarily comprised of crabbers and located mostly outside the “crab sanctuary”, within the 10-meter depth contour of the Bay. Most commercial vessels were observed later in the summer—from mid-July through August (Mansfield et al. 2002a; 2002b; 2003).

Marine mammals were also observed during surveys. All marine mammals observed were a species of dolphin, most likely the bottlenose (*Tursiops truncatus*). Most were sighted during the first half of the summer. Highest concentrations occurred in the Lower Bay region. Marine mammal sightings ranged from one individual up to groups of five or more (Mansfield et al. 2002a; 2002b; 2003).

DISCUSSION

Strip transect methods risk a negative bias in density calculations: this method assumes that all animals are seen and recorded within the survey strip. Turtles observed just outside the study swath must also be eliminated from the analysis. Thus, strip transect methods may only provide minimum density and population estimates. Similarly, line transect analyses are based on the assumption that all objects are observed at the transect line, or at an adjusted observable distance from the line. It is likely, however, that some turtles were missed. This would result in $g(0)<1$ and a negative bias in density calculations. Underestimating an endangered/threatened turtle sub-population is less detrimental than overestimating the population. Abundances generated by aerial population surveys are also prone to several sources of error including observer error, and the effects of sea state and glare. Aerial correction factors for surfacing behavior were calculated only for loggerhead sea turtles—potentially biasing population estimates that would include Kemp's ridleys (aerial surveys did not distinguish between species) (Chapters 2 and 3). However, Kemp's ridleys represent less than 10% of Virginia's annual strandings (unpub. VIMS data). The juvenile Kemp's ridleys common to Virginia's waters are also smaller (20-45 cm CCL) on average than local loggerheads (50-80 cm CCL), reducing the probability of being sighted aerially. Using large correction factors (5% to 10% or 25%) to account for turtles not observed below the sea's surface may result in some bias if a particular survey season is colder or warmer than average. Thus, for the purposes of this study, extrapolated population estimates should be considered conservative and should serve as a relative index of abundance in relation to the work presented in the 1980's. More tracking data are needed to refine the application of 10% or 25% sightability corrections to springtime density estimates.

Pooled line transect results were comparable to the strip transect estimates across years and regions. Attempts to sub-sample the dataset by region, year or season were confounded by small observational sample sizes. Among sub-samples, in order to achieve a $f(x)=0$, the data had to be artificially constrained, resulting in a detection model error. An $f(x)<0$ negates the assumption that all turtles are observed on the transect line (Buckland et al 1993). Hazard rate models with cosine adjustments were also tested. These models tended to provide a better 'shoulder' at $f(x)=0$, a desirable characteristic of line transect models (Buckland et al. 1993). However, all hazard rate models tested resulted in an artificially constrained dataset and therefore were rejected.

The Lower Bay area surveyed in 2001-2004 was larger than that surveyed in the mid-1980's by approximately 146 km^2. If similar densities were observed among decades, extrapolating density estimates out to a larger survey area should result in relatively larger abundance estimates. Despite this potential bias, this study documented a 200-300% decline in densities over time, which should be also considered conservative. Mean population estimates historically reported for the 1980's and 1994 ranged between 3,000 turtles to 9,700 turtles in the Lower Bay alone. Unfortunately, few data were reported or recorded for the Upper Bay in the 1980's. It is likely that Upper Bay densities in the 80's would result in much higher overall Bay estimates.

The distribution of sea turtles observed in 2001-2004 was relatively consistent with that observed during previous VIMS turtle surveys in the 1980's. The highest densities were observed during the spring months, typically within the Lower Bay. This corresponds to the time when turtles are first migrating into Virginia's waters. The peak in aerial densities was observed later in 2003 than in 2001, 2002, or 2004; however, springtime water temperatures were much cooler in 2003 than the other seasons. 2003 also resulted in high turtle densities, possibly due to colder temperatures affecting sightability. It may be possible to develop a predictive model for regional detection probabilities, or sightability, using temperature profiles of the water column and bathymetry to adjust observed sea turtle density estimates. Using 5%, 10% or 25% corrections for sightability provides gross estimates of standing stocks and is subject to compounded bias. These behavioral corrections should be refined through more tracking work.

High spring spikes in observed densities may a result of a) a concentration of turtles moving into the Bay during the initial weeks of their residency period, after which they are found more evenly distributed within the Upper and Lower Bay; b) differences in surfacing behaviors in the spring months vs. warmer summer months; and/or c) some turtles entering into the Bay as a stop-over place to feed along their migration route to northern summer foraging habitats. Results presented in Chapters 2 and 4 support the hypothesis of seasonal changes in surfacing behavior, or sightability. However, spikes in spring densities data observed in the 1980's, reflected as outliers in Figures 5.8 and 5.10, supports the hypothesis that there may be some turtles entering the Bay briefly before continuing their northward migration. Predicted values for springtime surfacing behavior in the 1980's, further support this hypothesis. Bay temperatures in the 1980's would have to have been very cold to account for high predicted surfacing times. Historic VIMS Ferry Pier data do not support this: annual spring temperatures ranged between 19°C and 27°C among past and present survey years, with no significant differences among decades ($p<0.05$). Average observed spring time at surface among loggerheads (Chapter 2) was an annual maximum of 25%. Thus it is likely that there is some percentage of turtles in the spring that briefly enter the Lower Bay before migrating farther north. It is also likely that the number of these transient animals have declined significantly since the 1980's.

This decline may be due to either a decline in the number of turtles migrating north of Cape Hatteras, North Carolina each spring, and/or to fewer turtles utilizing the Chesapeake Bay en route to northern foraging grounds. There has been a documented decline in blue crab (*Callinectes sapidus*) stocks since the 1980's, a primary prey item of loggerheads found within state waters (Lipscius and Stockhausen 2002; Seney and Musick in press). This may deter some turtles from entering the Bay during the spring. Seney (2003) documented a shift in diet among loggerheads from mostly blue crabs and horseshoe crabs (*Limulus polyphemus*) in the 1980's to include more fish by the late 1990's and 2000's.

Offshore aerial surveys along from Cape Hatteras to Maryland have not been conducted consistently in over 10 years. Future research should include conducting offshore and coastal surveys for comparisons with historic estimates. Should offshore turtle abundances show similar declines, it is likely that the effects of such a decline would not be observed on nesting beaches for at least 10 to 15 years.

It is also likely that a spring influx of transient turtles accounts for the difference in estimated declines reported for percent decline among spring densities (63.2%) versus among summer densities (74.9%) over the past two decades. Early spring transient turtles may mask actual population trends. A similar bias may be due to annual variations in sea temperatures affecting sightability. Predicted and observed summer (July-August) sightability estimates were consistently between 5% and 10% (Byles 1988; Chapter 4). Temperatures in the Bay are fairly stable and well mixed during these months. Summer density estimates may provide a better understanding of changes in population over time since the effects of migratory behavior and of colder temperatures on turtle sightability are minimized. Turtles are well established in their foraging grounds during these months. Thus, it is likely that Virginia has experienced up to a 75% decline in resident foragers since the 1980's.

Management Implications:

Observed turtle distributions suggest that fishery-based management strategies should prioritize the Lower Bay fisheries over Upper Bay fisheries in the early spring.

Considering migratory traffic along Virginia's coastal waters, fisheries management strategies should also prioritize the waters north of Cape Hatteras, North Carolina to Maryland. The decline in sea turtle densities over the past two decades is significant and should be monitored through continued aerial survey work in both the Upper and Lower Bay regions. Offshore aerial surveys should also be reestablished to compare current estimates with Keinath's estimates in the early 1990's (Keinath 1993). Population models for sea turtles in the Atlantic rely heavily on data collected from the reproductive output of adult females on nesting beaches. Significant data gaps exist in these models for the juvenile life stages of all species of sea turtles (TEWG 2000; Heppell et al. 2005). Assuming localized declines in juvenile estimates in the Chesapeake Bay will affect the larger Atlantic populations, it is likely that these declines may not manifest on nesting beaches for several years. Considering recent increases in annual sea turtle strandings, and movement patterns described in Chapters 2 and 3, it is recommended that the waters north of Cape Hatteras, including Virginia's coastal waters and the mainstem Virginia portion of the Chesapeake Bay be considered as either essential habitat or as an area of special concern for sea turtle conservation.

CHAPTER 6

CHARACTERIZATION OF VIRGINIA'S POUND NET FISHERY

ABSTRACT

The purpose of this study was to determine the current distribution of pound nets in the Chesapeake Bay and to assess whether pound nets are a current threat to sea turtles in Virginia's waters. In the 1980's up to 33% of Virginia's sea turtle mortalities were attributed to entanglement in large mesh (>12 inch stretch) pound net leaders. Under the assumption that the pound net fishery has remained a primary source of sea turtle mortality in Virginia, the National Marine Fisheries Service implemented a series of rules between 2001 and 2004 limiting the effort of this fishery in Bay waters. However, effort, net distribution and leader mesh size have not been characterized for this fishery since the mid-1980's. During the fall of 2000, and the 2001-2002 sea turtle residency seasons, all pound net stands in the mainstem Chesapeake Bay were characterized as to mesh size and distribution.

The pound net fishery has declined more than 50% since the 1980's, with a significant reduction in large mesh (90%) and string leaders (92%) in the Bay. By 2001 and 2002, there were less than 70 active nets in the Bay, including only three to six active string leaders and 10 or fewer active large mesh leaders. This is compared to over 170 large mesh leaders and 38 string leaders observed in the mid-1980's in the Western Bay alone. Yet, sea turtle mortalities in Virginia have risen 200% to 300% in the last 20 years. Based on surveys results and available data, it can be concluded that pound net effort has not remained constant over time. The decline in both effort and the number of large mesh or string leaders currently in use have resulted in a reduced threat of pound nets to sea turtle populations in Virginia's waters. Pound nets can no longer be considered a primary threat to sea turtles in Virginia.

INTRODUCTION

Pound nets have been fished in Virginia's waters since the late 1800's and historically are one of the primary commercial fisheries in the state (Reid 1955; Chittenden 1991). Pound net stands are fixed, semi-permanent structures that consist of wooden poles driven into the sediment. These poles serve as a framework for mesh nets that are attached to the poles, typically forming three distinct segments: the leader, the heart and the pound head (Mansfield et al., 2001a) (Figure 6.1). This gear type is considered passive and non-selective; pound nets typically do not target any particular species of fish (Chittenden 1991). Nets are set perpendicularly from shore. Behaviorally, fish that encounter leaders in the water column will swim into deeper waters to get around the obstacle. By doing so, the fish are herded into the heart and eventually through a trap into the pound head.

Virginia's pound net fishery is a limited entry fishery. In recent years, the number of licenses issued has been capped at 161 for the mainstem and lower tributaries of the Chesapeake Bay (Code of Virginia: 4 VAC 20-600-30). To receive or renew a license, each stand must actively fish a minimum of one day within a licensed year (4 VAC 20-20-50 B and D). The method of fishing these nets has varied little in the past century (Reid 1955; Chittenden 1991). Depending on weather, nets are usually harvested daily at slack tide in the morning hours between 4am and 9am (Chittenden 1991). Soak time of nets is 24-hours a day for as long as the net is active.

Pound heads are bowl-shaped, small-meshed nets similar to a live-well that are open at the surface. Mesh sizes of pound heads and most hearts typically do not exceed two inches stretch—larger mesh sizes would allow commercially viable catch to escape

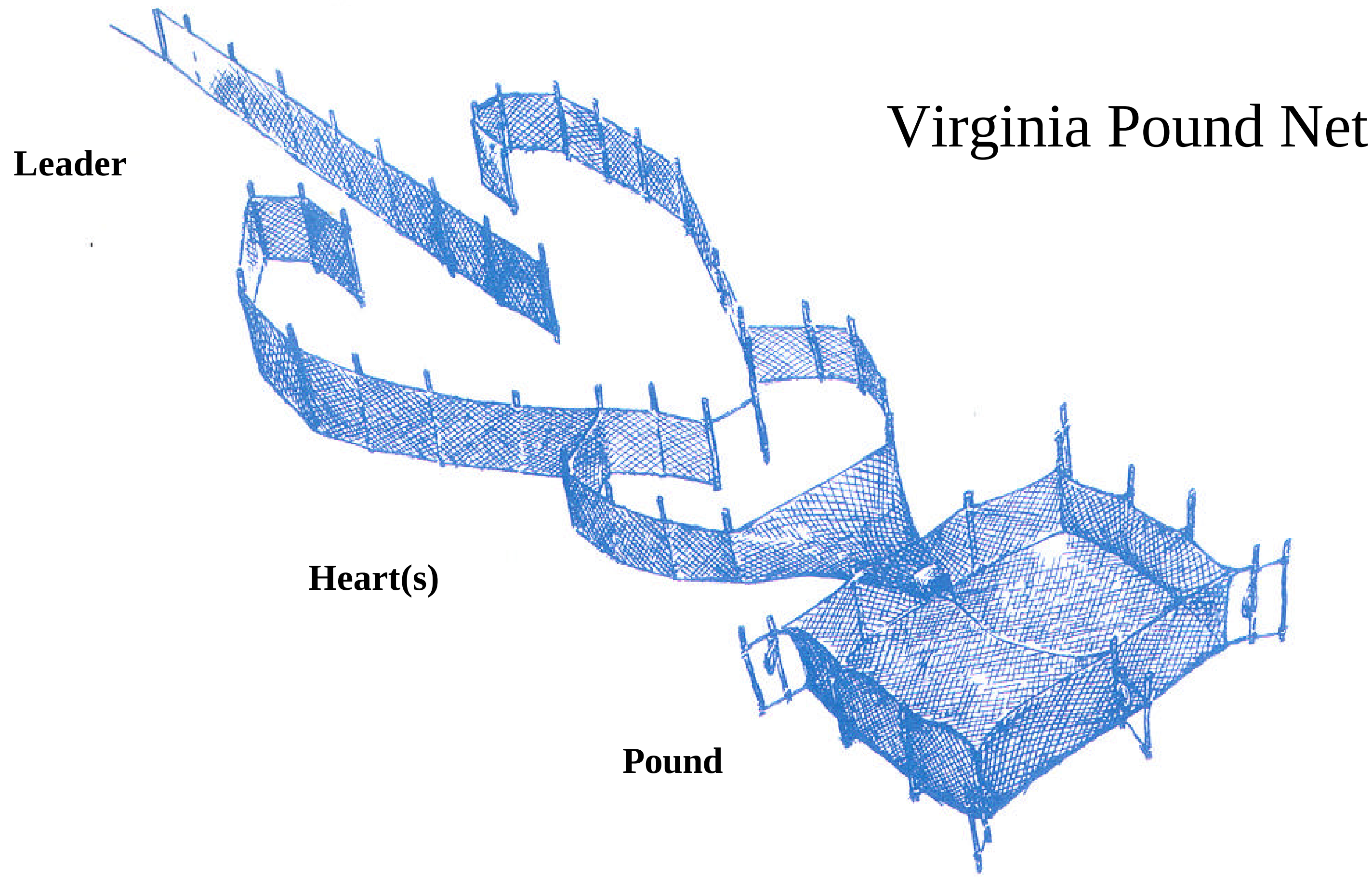


Figure 6.1 Typical Virginia pound net (adapted from Austin et al. 1998; Mansfield et al. 2001; 2002a; 2002b)

(Meyer and Merriner 1976). Leaders within the Chesapeake Bay vary widely in terms of both mesh size and type. Leader types include mesh and string leaders set to poles, or meshed leaders set to buoys. Larger mesh sizes and string leaders are used primarily on nets set in areas experiencing high tidal velocities. This reduces the accumulation of floating detritus or jellyfish that may damage nets over time.

A study conducted by VIMS in 1980-1981 concluded that between 3% and 33% of the sea turtle mortalities in Virginia could be attributed to pound net leaders (Lutcavage 1981; Lutcavage and Musick 1985; Bellmund et al. 1987). Turtles that entangle in leaders are at risk of drowning. This work determined that larger mesh leaders (defined as >12 inch stretch) and string leaders were more likely to entangle turtles than smaller mesh leaders (< 12 inch stretch) (Lutcavage 1981; Musick et al. 1985; Lutcavage and Musick 1985; Bellmund et al. 1987). Subsequent work conducted in 1983-1984 examined sea turtle mortalities in relation to leader mesh size. A combined total of 211 pound nets were observed in 1983 (n=113) and 1984 (n=98) within the Western Chesapeake Bay (Bellmund et al. 1987). Between these years, 173 of the nets examined were large mesh nets (defined as >12 inch stretch) and 38 had string leaders (Bellmund et al. 1987). The type of net that contributed most to sea turtle mortalities in the mainstem Bay were string leaders followed by large mesh (> 12 inch stretch) leaders (Bellmund et al. 1987). Turtle entanglement was insignificant in smaller mesh (<12 inch stretch) leaders (Bellmund et al. 1987). In the early to mid-1980’s there were over 300 active pound nets in the entire mainstem Chesapeake Bay.

Sea turtle mortalities in Virginia have risen 200% to 300% in the last 10 to 20 years (Musick and Mansfield 2004). Due to this recent increase in strandings, the NMFS

Northeast Region has targeted the pound net fishery as both a known and primary source of sea turtle mortality (Ryder et al. 2003; NMFS 2004a). Based on historic leader bycatch estimates collected by VIMS over 20 years ago, NMFS made the assumptions that pound net fishing effort and the relative hazard of this fishery to sea turtles have not changed over time. However, the pound net fishery has not been assessed since the mid-1980's, resulting in a significant data gap for both pound net effort and relative threat to sea turtles over the past 15 to 20 years.

The primary objectives and hypotheses of this study were to:

1. Determine the current distribution of pound nets in the Chesapeake Bay and assess whether pound nets with large mesh leaders still pose a significant threat to sea turtles in Virginia;

   H_{01} There is no difference in pound net effort over time (1980's to 2002);

   H_{02} There is no difference in the relative hazard (leader mesh size) of pound nets to sea turtles over time (1980's to 2002);

METHODS

Baseline in-water fisheries surveys were conducted from September 13 to October 31, 2000, May 2001 and 2002. The study area was divided geographically into five regions: Western Bay, Eastern Shore-Bay, Eastern Shore-Ocean, Virginia Beach-Ocean and Southern Bay (Figure 6.2). All pound nets within Virginia's mainstem Chesapeake Bay, and approximately five miles up-river of each major tributary, were located,

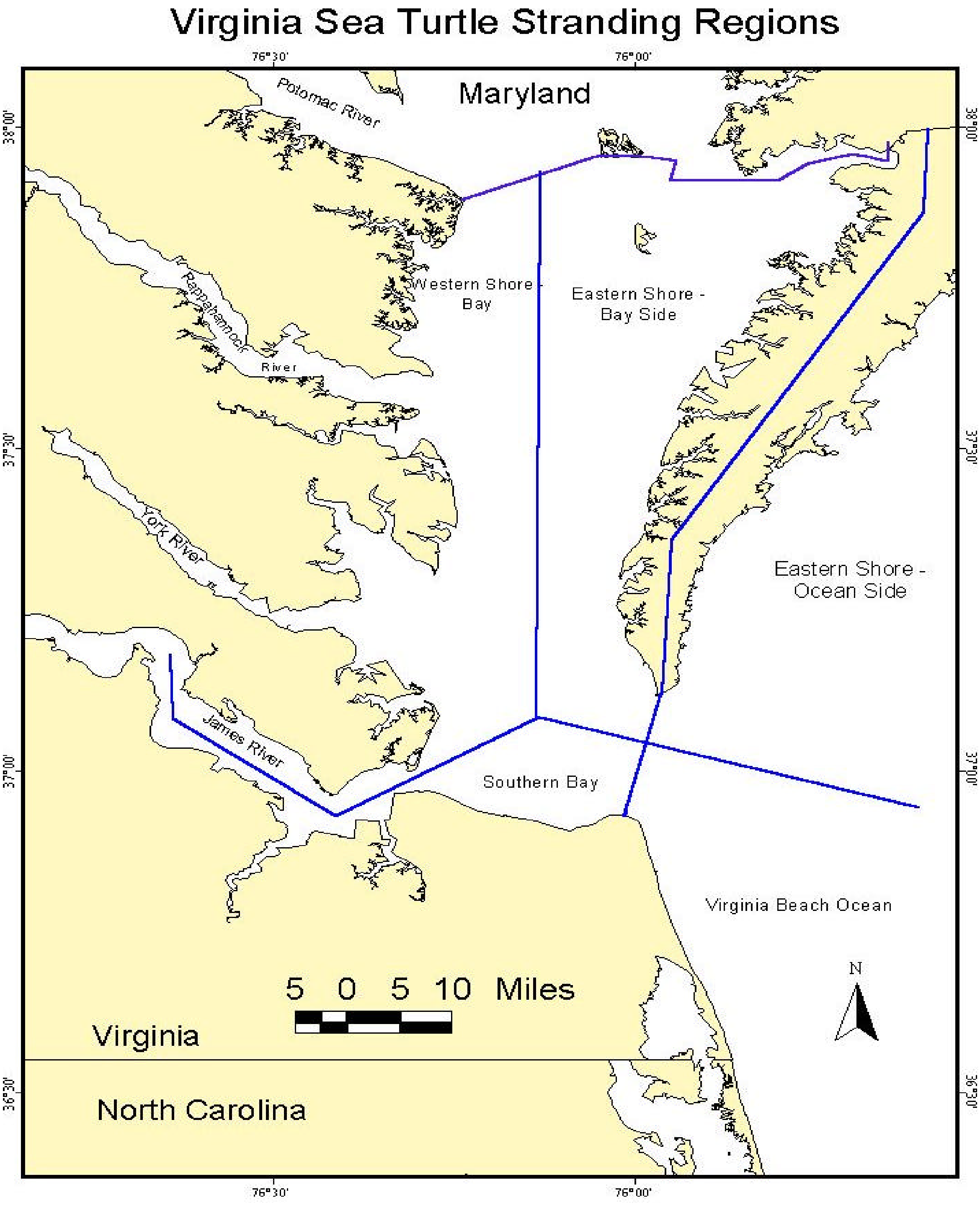


Figure 6.2 Subdivided study regions within the Chesapeake Bay, Virginia (adapted from Mansfield et al 2001; 2002a; 2002b)

recorded and targeted for follow-up fisheries and/or side scan surveys (Chapter 7) via shoreline aerial survey. The survey area corresponded to the known distribution of sea turtles within the Chesapeake Bay (Bellmund et al., 1987; Keinath et al., 1987; Byles, 1988). Flights were conducted at a speed of 130 km/hr and altitude of 152 meters. The latitude and longitude of all pound net stands were recorded and mapped in reference to local features.

Stands identified aerially were subsequently accessed by boat. The exact location of each stand, its fishing status (active or inactive as determined by the presence of nets), depth, latitude and longitude, and license information were recorded. Leader type and mesh size measurements were recorded for all active leaders. Mesh size was recorded in centimeters as both bar and stretch. In addition to pound nets located within Virginia's waters, stands located along the Virginia shore of the Potomac River were also recorded during the fall of 2000.

RESULTS

Stretch mesh measurements were typically found to be twice the length of bar measurements. However, the majority of the pound net leaders in the Chesapeake Bay are handmade and the mesh often did not form perfect squares, thus some stretch measurements did not result in exactly twice the bar measurements. Leaders were also often under strain from strong tidal currents or tight fits between poles, further reducing the ability of the measurer to fully stretch the mesh to the maximum stretched point. Thus, it was determined that bar measurements were the more reliable measurement to use when quantifying the mesh sizes of pound net leaders in the Chesapeake Bay.

Pound Net Characterization:

Three distinct types of leaders were observed within the Bay between 2000 and 2002: regular mesh leaders, string leaders and buoy leaders. Mesh leaders were most common and found throughout the Bay. Stringer leaders were found only along the Western Bay, particularly near the northern tip of Mobjack Bay and on nets near Reedville. Buoyed leaders were only found on the Eastern Shore Bay (Mansfield et al. 2001a; 2002a; 2002b). Some stands consisted only of a license posted on a pole and no nets at the time of survey. It was not unusual to observe pound nets with only pounds-heads, hearts, or leaders, or combinations of hearts and leaders only, pounds and leaders only, etc. The highest concentration of actively fishing nets was observed between Reedville and Smith Point along the Western Bay and just north of Kiptopeke State Park south to Fisherman's Island along the southern Eastern Shore Bay region (Figures 6.3-6.4).

Depths of the pound head for Western Bay nets ranged between 12 and 24 feet for mesh sizes less than 10 cm (3.9 in) bar. String leaders set within the Western Bay were found in deeper waters of 16 to 34 feet. Eastern Shore nets with mesh sizes less than 10 cm (< 4 in) bar were set in waters between two and 13 feet. Nets with mesh sizes larger than 10 cm bar (> 4 in) were in waters between 12 and 34 feet, with the largest mesh sizes (15 cm bar and greater; > 6 in) located within the deepest waters (Figure 6.5). Mesh sizes of the pounds were all approximately 3 to 4 cm bar (~1-2 inch) throughout the Bay. All hearts had mesh sizes of 10 cm bar (~ 4 in) or less. There were no large mesh (>15 cm or 6 in bar) hearts in the Bay. The only variation in mesh size was among the leaders.

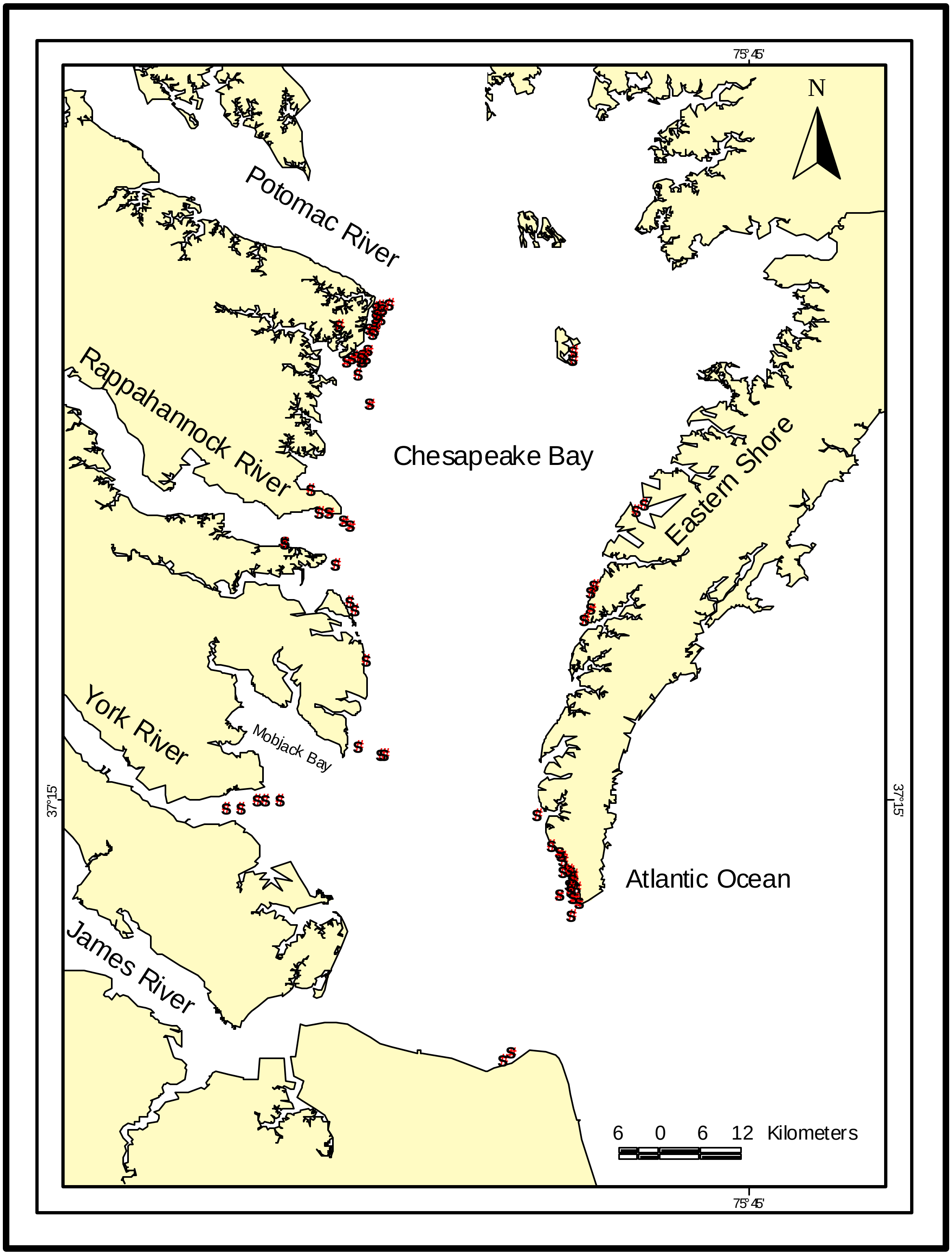


Figure 6.3 Pound net stand locations in the mainstem Chesapeake Bay, 2000 (adapted from Mansfield et al 2001)

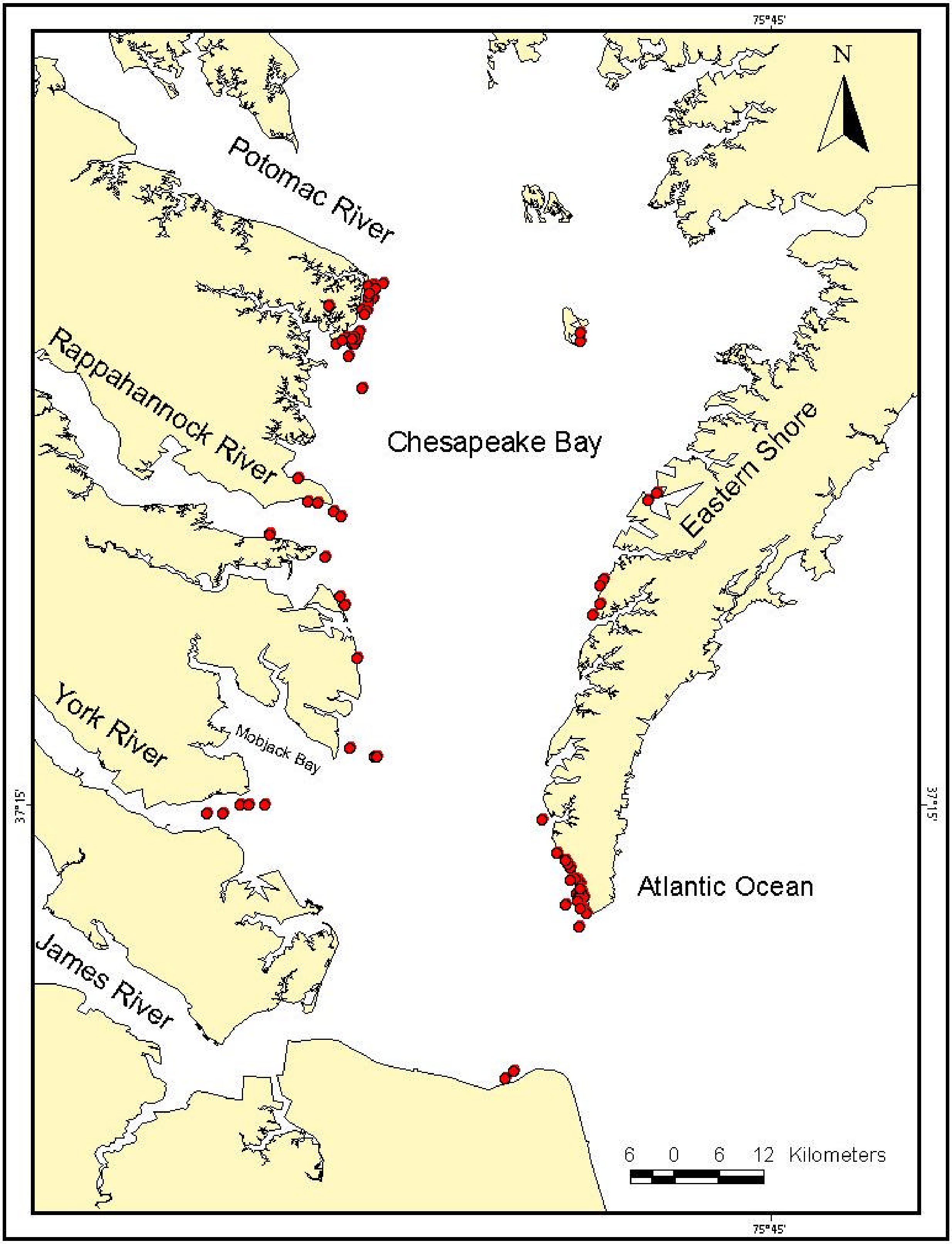


Figure 6.4 Pound net stand locations in the mainstem Chesapeake Bay, 2001 (adapted from Mansfield et al 2002a)

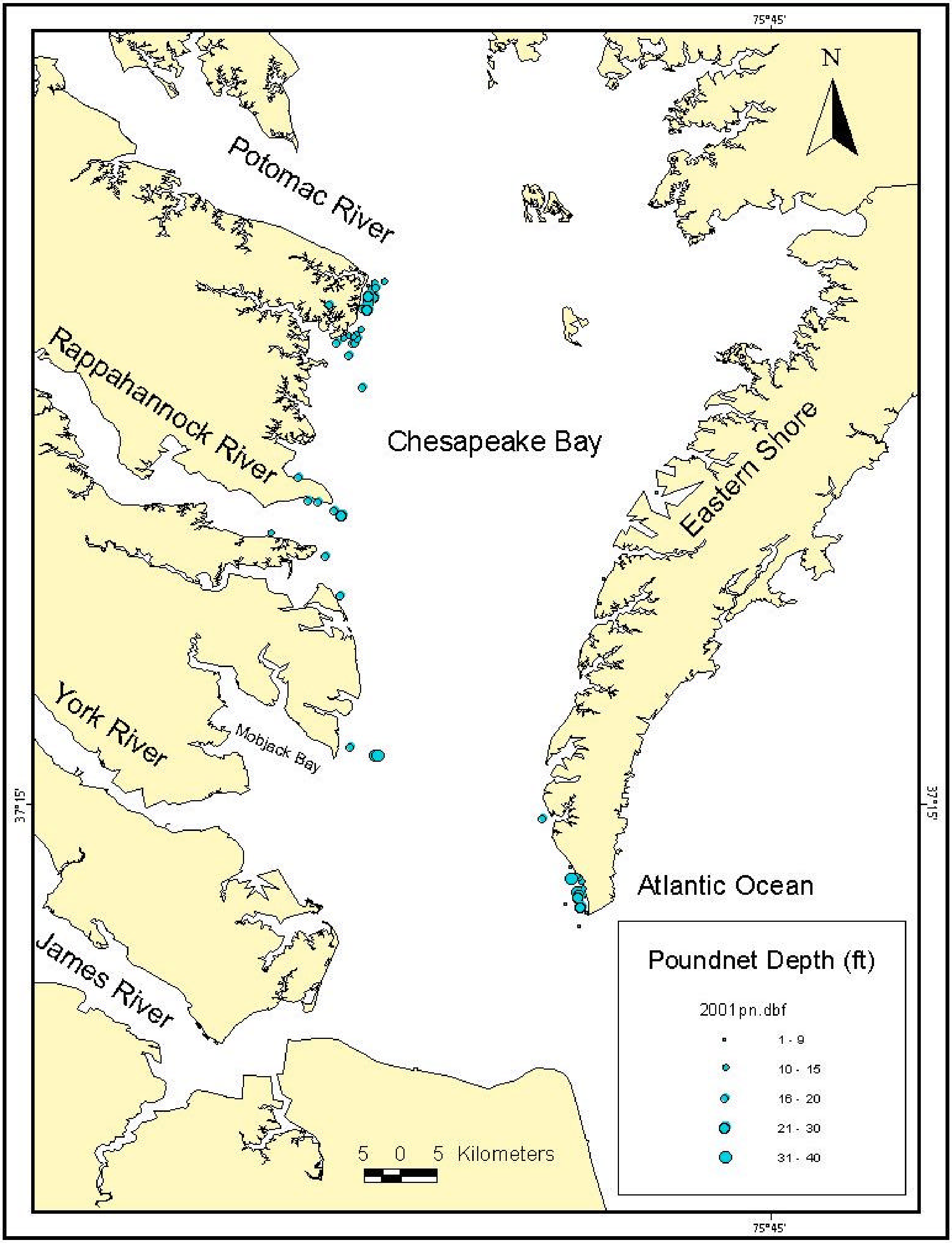


Figure 6.5 Locations of Virginia's active pound nets by depth, June-October 2001 (adapted from Mansfield et al 2002a)

A total of 82 pound net stands were recorded and surveyed within Virginia's waters during the fall of 2000. An additional 21 pound net stands were surveyed along the southern Virginia shore of the Potomac River, within Maryland's waters. The majority of Virginia stands (54) were located within the Western Bay region from the York River north to Smith Point at the mouth of the Potomac River (Figure 6.3). No stands were found within the Western Bay region south of the York River. Only two stands were located within the Virginia Beach-Ocean region, just west of the Chesapeake Bay Bridge Tunnel near Lynnhaven, Virginia (Figure 6.3). Twenty-six stands were located along the Eastern Shore-Bay with the concentration of stands found from Kiptopeke State Park, south to Fisherman's Island (Figure 6.3). No stands were located along the Southern Bay within the known distribution of sea turtles. An aerial flight along the ocean side of the Eastern Shore also indicated that no pound nets were set within this region.

In the Western Bay, 32 of the 54 pound net stands had leaders with nets. Of these, nine were stringer leaders, the rest mesh leaders. The majority of the leaders (24) had a bar measurement of less than 10 cm (4 in). Seven leaders had a bar measurement between 10 and 15 cm (4 to 6 in), and only one leader had a bar measurement greater than 15 cm (Figure 6.6). The two Lynnhaven nets had bar measurements of 8 and 10 cm (3 to 4 in). Along the Eastern Shore-Bay, 15 of the 26 pound net stands had leaders with nets. Of these five were buoyed leaders. Mesh sizes were somewhat larger along the Eastern Shore Bay with only four leaders having a mesh size less than 10 cm bar. Six leaders had bar mesh sizes between 10 and 15 cm, and five leaders had mesh sizes greater than 15 cm. Three of these nets had mesh sizes greater than 20 cm (7 to 8 in) bar (Figures 6.7). These larger meshed leaders were located towards the southern tip of the Eastern Shore,

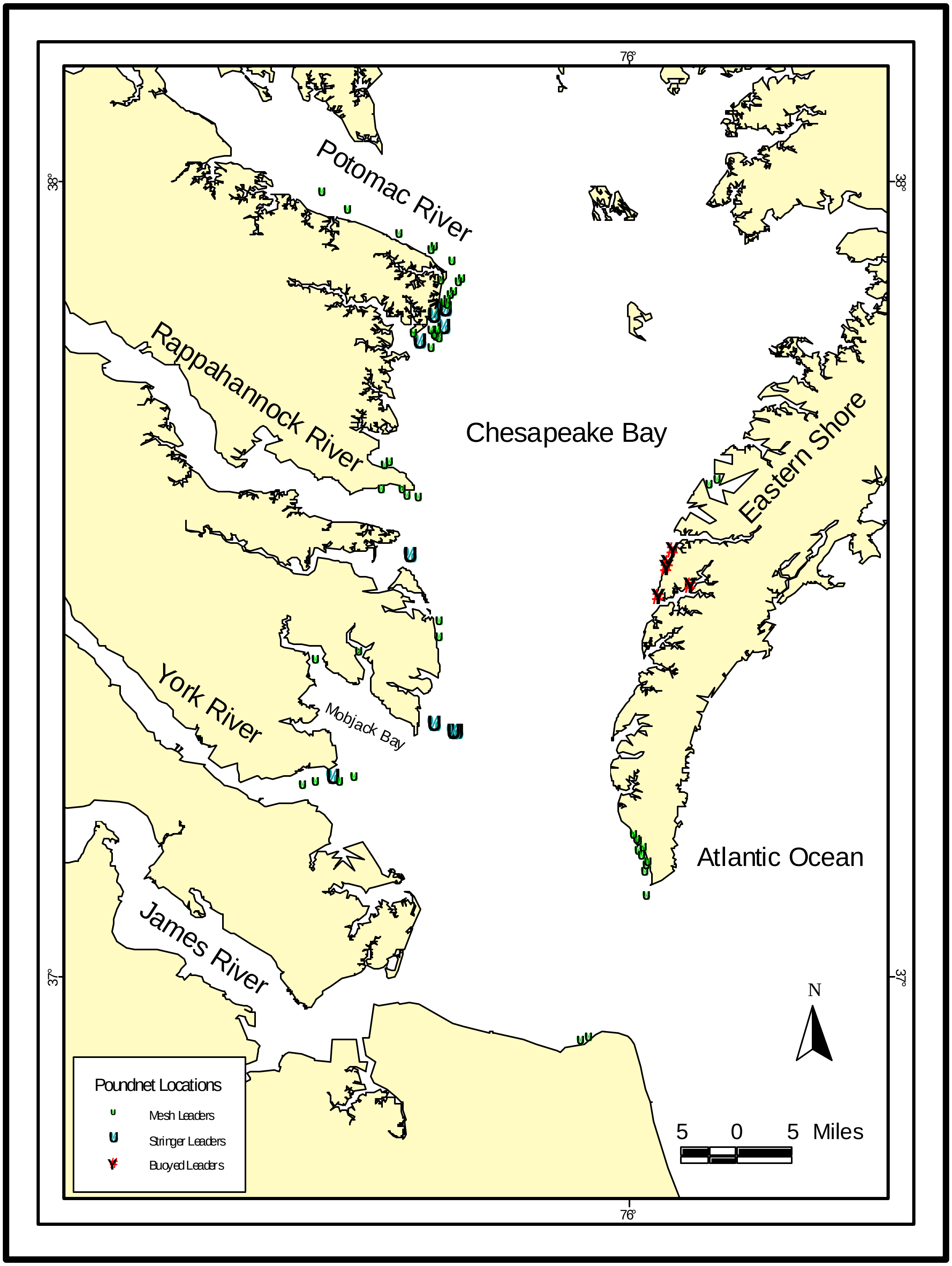


Figure 6.6 Pound net leader types mainstem Chesapeake Bay, 2000 (adapted from Mansfield et al 2001)

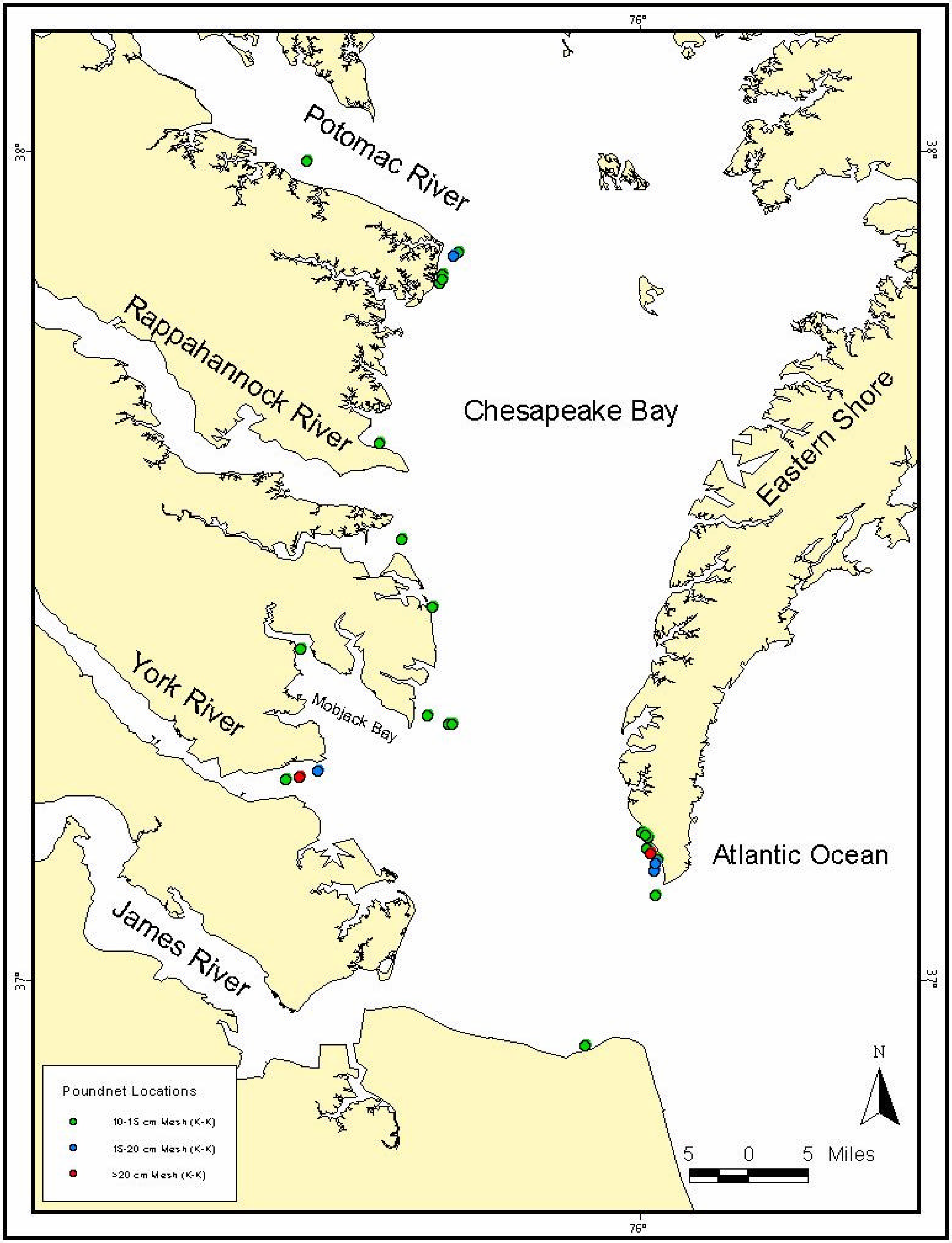


Figure 6.7 Pound net mesh size distribution in the mainstem Chesapeake Bay, 2000 (adapted from Mansfield et al 2001)

near the Bay mouth. Of the 21 pound net stands surveyed along the southern shore of the Potomac River, only six stands had active leaders. Five of these nets had a bar mesh size less than 10 cm. One net had a mesh size between 15 and 20 cm (Figures 6.7). No mesh size surveyed exceeded 25 cm (10 in) bar.

A total of 72 pound net stands were observed and monitored between June 1 and October 31, 2001 (Figure 6.4). Of these, 57 were actively fishing pounds (55 had active leaders) and 15 were either licensed or unlicensed stands. One of the active nets, located north of Mobjack Bay along the Chesapeake Bay's western shore, was unlicensed. The distribution of stands remained relatively unchanged between 2000 and 2001. In addition to the stands observed in 2000, two active stands were aerially observed off Tangier Island, though could not be accessed by boat due to rough seas. Two stands outside the CBBT, located in the vicinity of Lynnhaven, Virginia were also observed aerially (Figure 6.4). The Tangier Island and Lynnhaven nets were actively fishing the entire survey period. Fewer licensed pound nets were found in the mainstem Bay during the 2001 season than during the fall of 2000. This is due to a York River fisherman retiring in 2001.

The majority of pound net stands (n=40) were located in the Western Bay from Mobjack Bay north to Smith Point and the Maryland border (Figure 6.4). There were fewer stands within this region than in the fall of 2000 (n=54). No active/licensed stands were located south of Mobjack Bay. A total of 32 stands were located along the Eastern Shore Bay region, with the main concentration of activity found just north of Kiptopeke State Park south to Fisherman's Island (Figure 6.4). This represented an increase in stands observed in this area from the fall of 2000 (n=26). No stands were located along the Southern Bay stranding region. The pre-season shoreline survey (May 25, 2001) resulted in no observed pound nets outside the Bay along the Eastern Shore Ocean.

Leader type distribution was similar to that of 2000 (Figure 6.6). Mesh leaders (n=42) were distributed throughout the Bay, however, buoyed leaders were only found along the Eastern Shore Bay (n=7), located close to shore, with the end of the leaders often extending onshore. The number of buoyed leaders observed was slightly more than the number observed in 2000 (n=5). A total of six string leaders were found along the Western Bay region, three less than the number observed in 2000 (n=9). Three of the string leaders were located off of Newpoint Comfort and the northern tip of Mobjack Bay, one just south of the mouth of the Rappahannock River, and two between Reedville and Smith Point near the Maryland border.

Mesh size distribution was also similar to that observed in 2000 (Figure 6.7). The majority of leaders along the Western Shore (n=31) had mesh sizes of 10 cm (4 in) bar or less, including some nets with leader mesh sizes of 2.5 cm bar (1 in) or 5 cm (2 in) stretch. Only one leader had a mesh size between 10 and 15 cm (4 to 6 in) bar within this region. This represents a reduction in larger mesh leaders within the Western Bay from the fall of 2000 when seven leaders had mesh sizes between 10 and 15 cm bar, and one leader had a mesh size greater than 15 cm bar. However, compared to 2000, there was an increase in the smallest mesh sizes (less than 10 cm bar, < 4 in) within the Western Bay. Mesh sizes were somewhat larger along the Eastern Shore Bay. Ten leaders had a bar mesh size of 10 cm (< 4 in) or less (more than in 2000: n=4), three had mesh sizes between 10 and 15 cm bar (4 to 6 in), and three stands had mesh sizes greater than 15 cm bar (> 6 in). Compared to 2000, the total number of mesh sizes greater than 10 cm bar (> 4 in) declined (n=11) in 2001.

Full fisheries characterizations were not funded in 2002; however 63 active leaders were observed in the mainstem Bay, including ten large mesh leaders found along the Eastern Shore and only three string leaders located in the Western Bay.

DISCUSSION

It is necessary to place the pound net fishery into historical perspective when attempting to assess its impact on sea turtles. In the 1980's, between 3% and 33% of the sea turtle mortalities in Virginia were attributed to large mesh (>12 in stretch) leaders within the main-stem Bay (Bellmund et al. 1987). This fishery has declined more than 50% since the 1980's (Musick and Mansfield 2004). At that time, over 300 nets were active in the main-stem Chesapeake Bay, with over 170 large mesh nets and 38 string leaders present in the Western Bay alone (Bellmund et al. 1987). By 2001 and 2002, there were less than 70 active nets in the Bay, with only three to six active string leaders and 10 or fewer active large mesh leaders (Mansfield et al. 2001a; 2002a; 2002b). This represents an 90% decline in the use of large mesh leaders in the Bay and up to 92% decline in string leaders (Musick and Mansfield 2004). Despite this, the number of sea turtle strandings in spring has increased by 200% to 300% (Musick and Mansfield 2004).

Acting on the assumption that pound nets are the primary or sole source of sea turtle mortality in Virginia, NMFS has implemented a series of increasingly stringent rules limiting pound net fishing effort or methods (Chapter 7). Current distribution and mesh sizes of pound nets, along with available historic data indicate that pound net effort has not remained constant over time. The relative threat of pound nets has also declined over time with the reduction in both effort and the numbers of large mesh or string leaders currently in use. To date, the documented decline in pound net effort and reduced threat associated with large mesh or string leaders has not been addressed by NMFS (NMFS 2001; 2002a; 2002b; 2003; 2004a; 2004b; 2004c).

Chapter 7

Side Scan Sonar: A Tool for Assessing Sea Turtle Bycatch Mortality in Virginia's Pound Net Fishery

ABSTRACT

The purpose of this study was to evaluate the use of side scan sonar as a tool for determining the presence of sub-surface sea turtle entanglements in pound net leaders and to assess whether pound nets are currently a primary source of sea turtle mortality in Virginia's waters. Between 200 and 500 sea turtle strandings are recorded annually in Virginia. Sea turtle mortalities in Virginia have risen 200% to 300% in the last 10 to 20 years. In the 1980's up to 33% of Virginia's sea turtle mortalities were attributed to entanglement in large mesh (>12 inch stretch) pound net leaders. Significant numbers of strandings are recorded long the southern Bay shoreline of the Eastern Shore annually. This is also an area of high pound net fishing effort.

The National Marine Fisheries Service implemented a series of rules between 2001 and 2004 limiting the effort of the pound net fishery in Bay waters. These rules were based on the assumptions that the pound net fishery has remained a primary source of sea turtle mortality in Virginia over time, and that a significant number of unobserved sub-surface entanglements occur in leaders adjacent to the southern Bay beaches of the Eastern Shore in order to account for high stranding densities in this region (Ryder et al. 2003; NMFS 2004a). However, few data are available on the actual number sub-surface mortalities occurring due to sub-surface entanglement in pound net leaders. During 2001-2002 side scan sonar (900 kHz) was used during in-water fisheries surveys to assess whether sub-surface turtle entanglements were likely in Virginia's pound net fishery.

Ground-truth side scan sonar images of turtle carcasses indicate that sea turtles as small as 35.0 cm curved carapace length have an acoustic signature within the water column. Survey efficiency was very high: each net took approximately four minutes to

scan at a tow speed of 2.0 to 3.5 knots. Various species of algae, seagrass and other detritus were found to visually imitate or mask the signature of a potential sea turtle entanglement, however, no sub-surface sea turtle mortalities were found via sonar survey in 2001 or 2002. Entanglements recorded by federal and state enforcement officers in 2001 represented less than 2-3% of the annual strandings recorded in Virginia's waters, with the majority found in a few large mesh leaders.

These data, combined with a documented decline in effort and a reduction in the number of large mesh leaders fished in Virginia, indicate a reduced threat of pound nets to sea turtle population in Virginia's waters compared to the 1980's. Pound nets can no longer be considered the primary source of sea turtle mortality in Virginia.

INTRODUCTION

Two to five hundred sea turtle stranding deaths are recorded within Virginia's waters each year. The majority of these strandings are juvenile loggerhead (*Caretta caretta*) and Kemp's ridley (*Lepidochelys kempii*) sea turtles. Historically, between 50% and 60% of annual turtle deaths occur in May and June when the turtles first enter the Chesapeake Bay (Lutcavage 1981; Lutcavage and Musick 1985; Keinath et al. 1987; Coles 1999; Mansfield et al. 2002a; 2002b). Since 1991, strandings within the northeastern United States have increased 10% to 14% (TEWG 2000). In the last 20 years, Virginia's sea turtle strandings have risen 200% to 300% (Musick and Mansfield 2004).

Virginia's turtles are known to interact with a variety of commercial fishing gears including whelk and crab pots, pound nets, gill nets, longline and trawling gear (Musick et al. 1985; Bellmund et al. 1987). Bellmund et al. (1987) concluded that pound nets were a primary source of sea turtle mortality in Virginia's waters in the mid-1980's; however, pound net fishing effort has not remained constant over time in Virginia. Over the past three decades, the number of state pound net licenses issued per year has declined significantly, yet the number of sea turtle strandings has risen dramatically (Chittenden 1991; Mansfield et al. 2000; 2002a; 2002b; Chapter 6). Due to recent trends in Virginia's sea turtle strandings and the history of incidental takes associated with pound nets, understanding sea turtle mortality due to interactions with pound nets is a current priority of the National Marine Fisheries Service (NMFS) Northeast Region.

There are two types of sea turtle takes likely in pound nets: live takes within the pound head (Chapter 8) and lethal or injury-inducing takes due to entanglement in the leader (Lutcavage 1981; Lutcavage and Musick 1985; Musick et al. 1985; Bellmund et al. 1987). In the 1980's up to 33% of Virginia's sea turtle mortalities were attributed to entanglement in large mesh (>12 inch stretch) pound net leaders (Lutcavage 1981; Lutcavage and Musick 1985; Bellmund et al. 1987).

A number of pound nets, including some larger mesh nets, are set in the lower Chesapeake Bay, along the southern tip of the Eastern Shore where currents are strong (Mansfield et al. 2000; 2002a; 2002b). These nets may entangle turtles when they first enter the Bay in the spring. They may also entrain dead, floating turtle carcasses that drift into the Bay with the tides and currents. High numbers of sea turtle strandings are typically observed in the southern Bay tip of the Eastern Shore, particularly along the beaches of Fisherman's Island, Kiptopeke State Park and Sunset beach in Northampton County. This is also an area in close proximity to other commercial fishing activities including spring gill net fisheries (Terwilliger and Musick 1995). At the time of the spring immigration, many of the turtles are emaciated and weak and may have difficulty navigating around nets, especially those located in strong tidal regimes (Bellmund 1988; Byles 1988). Historically, strandings drop off substantially by the middle to end of June. Turtles tracked via radio telemetry in the summer and fall were able to forage around the nets with little threat (Musick et al. 1985; Byles 1988).

Nets that have long soak times, particularly pound net leaders, may entangle sea turtles below the observable surface waters. These mortalities are at risk of not being observed or included in bycatch estimates. In the 1980's, SCUBA surveys conducted by the VIMS during the peak stranding period (May and June) recorded turtle-leader interactions only within the upper two meters of water column (Musick et al. 1985).

Entanglements were observed to begin late May, slowly increasing through the first two weeks of June and peaking in late June (Bellmund et al. 1987). These surveys were conducted during the earlier portion of the residency season and did not evaluate sub-surface mortalities throughout sea turtle residency (Musick et al., 1985). Very few surface entanglements were observed after June. This indicates that turtles may be at risk of entanglement for only a fraction of their residence time in the Chesapeake Bay. Alternatively, if turtles are spending more time within surface waters in the spring, sub-surface entanglements may occur unobserved later in the residency season with a seasonal change to benthic foraging behavior (Chapters 2 and 4).

SCUBA studies are time consuming and place divers in low visibility, high current situations where researchers are at risk of becoming entangled in the same nets as turtles. One alternative method of assessing sub-surface bycatch is to use side scan sonar. Side scan sonar is used in a variety of applications from imaging objects along the sea floor or within the water column, to systematic searches for specific submerged targets (Fish and Carr 1990; 2001). Kasul and Dickerson (1993) explored the feasibility of using acoustic methods to detect sea turtles sub-surface. They cited unpublished data supporting the ability of side scan sonar (500 kHz) to detect turtle carcasses and carapaces placed on the seabed. Side scan sonar works on the principles of sound reflection. The tow fish (sonar) transmits a sound into the water column and detects objects based on the echoes that are returned/reflected (Kasul and Dickerson 1993). No work has been published evaluating the use of side scan sonar in detecting sea turtle carcasses entangled in netting and/or suspended within the water column.

To date, there is no sea turtle take limit established for the pound net fishery in Virginia. Therefore, no incidental takes are permitted within the state. In response to increased stranding counts in Virginia, the National Marine Fisheries Service (NMFS) Northeast Region implemented a series of rules between 2001 and 2004 limiting the effort of the pound net fishery in Bay waters. These rules were based on the assumptions that the pound net fishery has remained a primary source of sea turtle mortality in Virginia over time, and that the relative threat of this gear type to sea turtles has not changed over time (Chapter 6). To justify increasing rates of sea turtle strandings observed on Virginia Beaches, NMFS also made the assumption that a significantly large proportion of sub-surface entanglements must be occurring unreported, particularly within nets located along the southern Bay tip of the Eastern Shore (NMFS 2004a). Very few data exist on other potential sources of fishery induced mortality in Virginia. As a result, increasingly stringent pound net regulations have been imposed on the fishery in an effort to reduce strandings. However, a significant data gap exists regarding the likelihood of sub-surface entanglements in Virginia's pound nets.

The primary objectives and hypotheses of this study were to:

1. Evaluate the use of side scan sonar as a tool for determining the presence of sub-surface sea turtle entanglements in pound net leaders;

2. Assess whether pound nets are still a primary source of sea turtle mortality in Virginia's waters;

H_{01} There is no difference in bycatch rates of sea turtles in pound net leaders in the 1980's compared 2000 to 2002.

METHODS

Surface-based fisheries surveys of active pound net stands were conducted from September 13 to October 31, 2000. Fisheries and side scan sonar surveys were conducted from June 1 to October 31, 2001, and May 15 to June 30, 2002. All active pound nets within Virginia's mainstem Chesapeake Bay, and approximately five miles up-river of each major tributary, were surveyed. The study area was divided geographically into five regions: Western Bay, Eastern Shore-Bay, Eastern Shore-Ocean, Virginia Beach-Ocean and Southern Bay (Chapter 6: Figure 6.2). All sea turtle interactions were documented. Additional in-water fisheries surveys (surface-based) were conducted periodically by state stranding cooperatives, state enforcement agencies and NMFS observers. Observations of sea turtles entangled within surface waters were documented by the respective agency and reported to VIMS in 2001. Frequency of surveys conducted by each agency varied throughout the season.

A Marine Sonics Technology side scan sonar system was used to examine pound net leaders for sub-surface sea turtle entanglements. A 900 kHz side scan sonar tow fish was used, providing high-resolution digital sonar data, with a resolution of 0.1 meter that was processed in an on-board computer, providing real time data management and storage. The unit also allowed bottom sediment features and structures suspended within the water column to be viewed on a large format monitor. The system operated on a Microsoft Windows 98-based program for ease of data management while a side scan review program (Sea Scan PC Review 2.0) allowed for post-processing and viewing of all survey sites. Mosaic images were created for each net scanned.

In 2001, ground truth images were collected of various sizes and species of turtle carcasses set within a test net on the York River. The net was first scanned without the addition of turtle carcasses to provide a base-line or control image for comparison. Turtle carcasses were placed within the leader of the sample net at varying depths. These specimens, representing some of the smallest size classes common to Virginia (35 cm, 50.0 cm and 65.0 cm curved carapace length, or CCL), were scanned and compared to base-line scans of the net in order to document the acoustic signature of carcasses when suspended within the water column. Other objects commonly found in leaders that could potentially produce similar acoustic signatures were also tested, including garbage bags (Hefty ™ 50 gallon bags), seagrass and dead fish. Kasul and Dickerson (1993) tested for the acoustic signatures of horseshoe crabs (*Limulus polyphemus*), however, due to severe population declines within the Chesapeake Bay (ASMFC, 1998), the low numbers of crabs observed in nets during the 2000 survey, and their relatively small size compared to the majority of sea turtles found within the Chesapeake Bay, horseshoe crabs were not ground truthed for this study.

All pound nets in the main-stem Chesapeake Bay were scanned early in the sea turtle residency season to establish a base-line image of each net. Subsequent scans were compared to the archived base-line images of each net. The sonar was towed from a stern davit onboard the *R/V Coot* or *R/V Langley* at a depth of one meter, a speed of 2.0 to 3.5 knots and a distance of 10 to 20 meters from the net. Digital sonar data were collected of the water column beginning at a one-meter depth. Objects within the top meter of water column were observed visually from the research vessel. Gain settings varied based on depth of net and sea conditions; range settings were established at 20 meters. Depth and navigation permitting, scans were conducted along both lengths of the net—typically first along the up-current, followed by the down-current sides of each net. Leader poles were counted during scans, and the location, indicated by pole number, of any acoustic signature similar to that of a sea turtle was recorded. Potential sea turtle signatures were verified by returning to the target's location along the net and recording any objects visually present at surface or at depth. In 2002, objects at depth were also identified with a Sea Viewer Black and White 550 Sea-Drop underwater video system with halogen lighting.

Survey frequency was dependent upon contractual obligations and weather conditions. Due to the size of the bay and length of time necessary to travel between all gear locations, survey days were concentrated within sections of either the Western Bay or Eastern Shore Bay. Western bay nets were monitored at least bi-weekly. The southern Bay portion of the Eastern Shore from Cape Charles south to Fisherman's Island, was deemed as a high priority survey area by NMFS due to the concentration of both nets and strandings occurring in this region. Per the request of NMFS, survey effort was concentrated in this area and in 2002. Nets found along the southern Bay side of the Eastern Shore were monitored on a weekly to semi-weekly basis. Weather and sea state within a particular region were determining factors in deciding which nets could be surveyed within a given day. Some surveys had to be rescheduled due to less than optimal survey conditions.

RESULTS

Prior to Bay-wide surveys, the ability of the sonar to pick up sea turtle acoustic images from carcasses anchored in a leader was tested. Ground-truthed images indicate that sea turtles as small as 35.0 cm (13.8 in) CCL (Kemp's ridley juvenile) have an acoustic signature within the water column (Plates 7.1-7.3). These images, depending upon orientation of the specimen in the water column, were measured by imaging software within two to three centimeters of the known carapace length. Turtle images were also easily differentiated from solid objects, such as pound net poles/tree branches. The acoustic images of the turtles appeared 'mottled' due to variations in density (bone vs. muscle tissue) in comparison to objects of uniform density (pound poles). The garbage bags scanned did not result in a distinct acoustic signature and could easily be differentiated from the turtle carcasses (Plate 7.4). The images of other objects scanned (fish, seagrass) were cataloged for visual comparison and reference during subsequent surveys.

Between the dates of June 1 and October 31, 2001, and May 15 through June 30, 2002, all pound nets with active leaders (n=55 in 2001; n=63 in 2002) were scanned by sonar. Survey efficiency was very high: each net took approximately four to five minutes per side to scan at a tow speed of 2.0 to 3.5 knots. With one exception, a baseline image for each active pound net stand located within the main-stem Chesapeake Bay was recorded and digitally archived. One net (license 2002-187) was in very shallow water and could not be scanned by the sonar; however it was visually checked by boat. Another net (license 2002-188) was successfully scanned by sonar but the digital files were corrupted and could not be archived successfully. This net was subsequently observed by

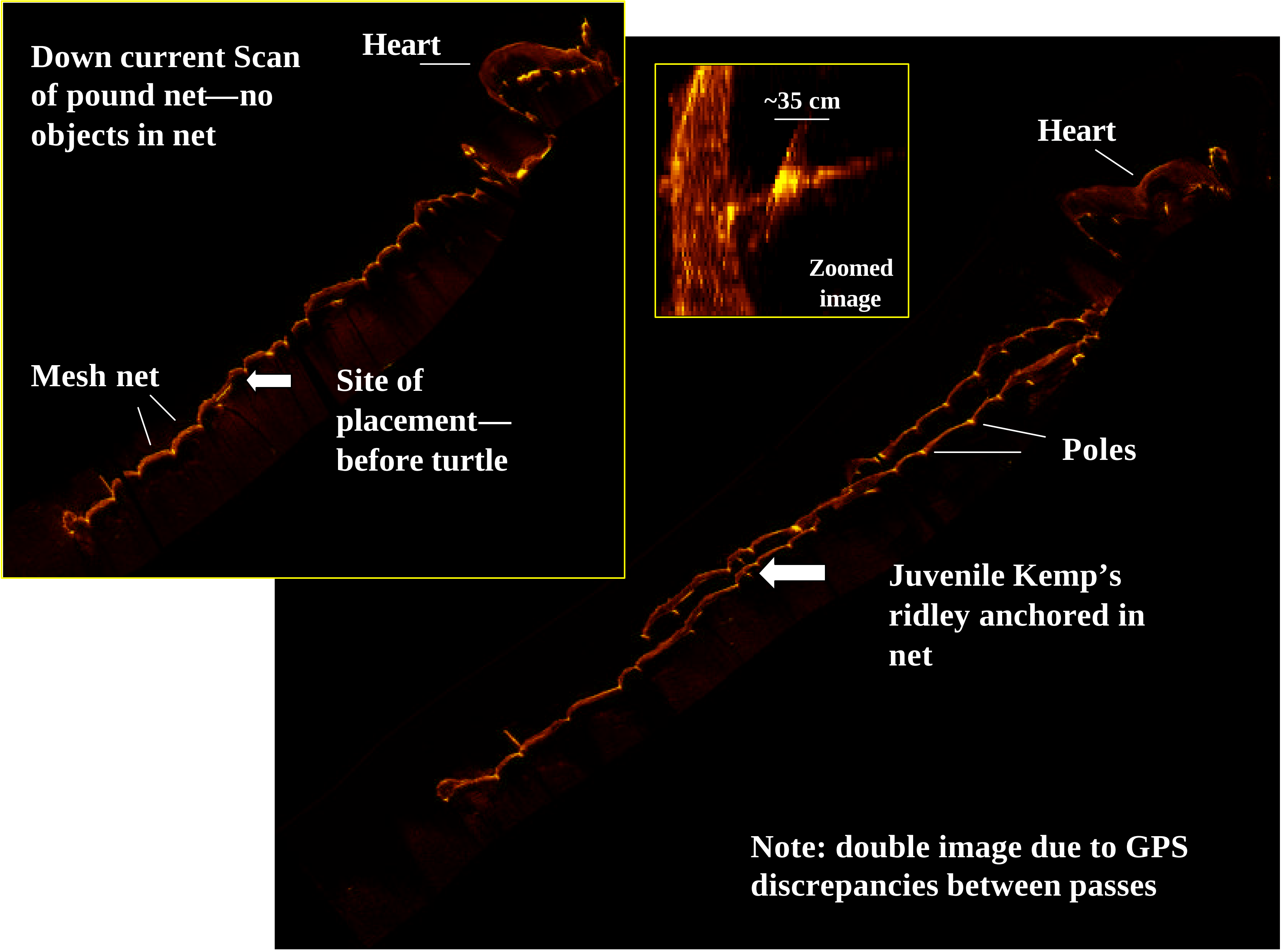


Plate 7.1 Ground-truth images of juvenile Kemp's ridley (35 cm CCL) by side scan sonar. VIMS pound net leader, York River, Virginia, 2001 (leader had 8 in stretch mesh)

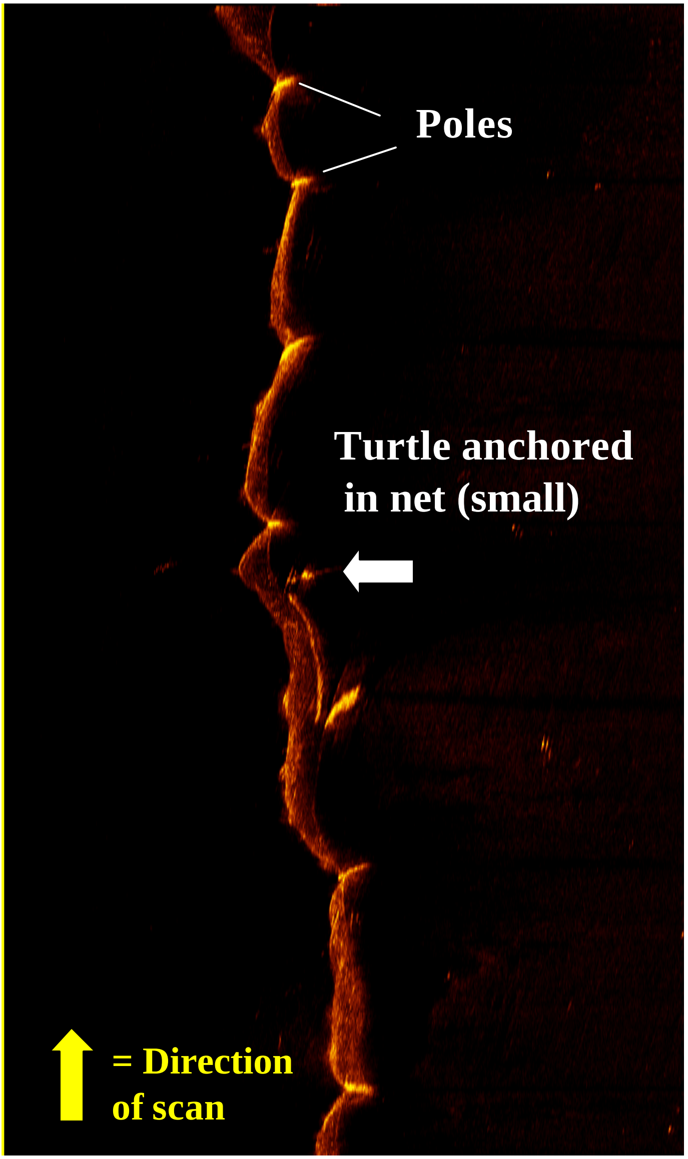


Plate 7.2 Ground-truth images of juvenile loggerhead (50cm CCL) sea turtle by side scan sonar. VIMS pound net leader, York River, Virginia, 2001

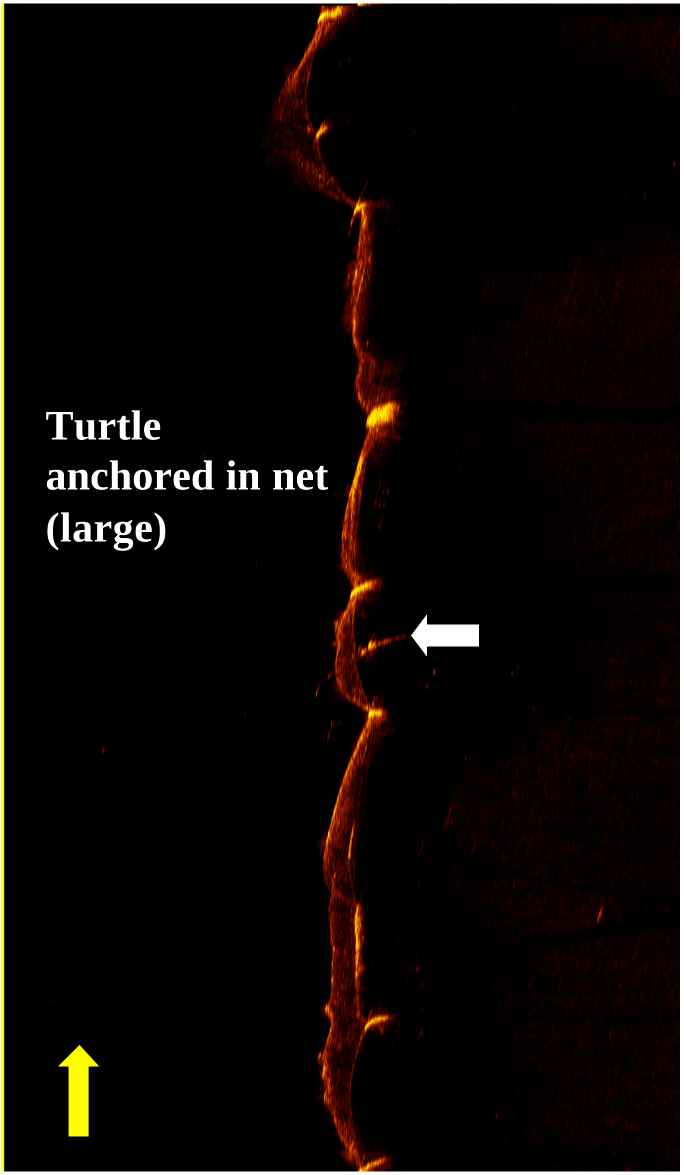


Plate 7.3 Ground-truth images of juvenile loggerhead (65 cm CCL) sea turtle by side scan sonar. VIMS pound net leader, York River, Virginia, 2001

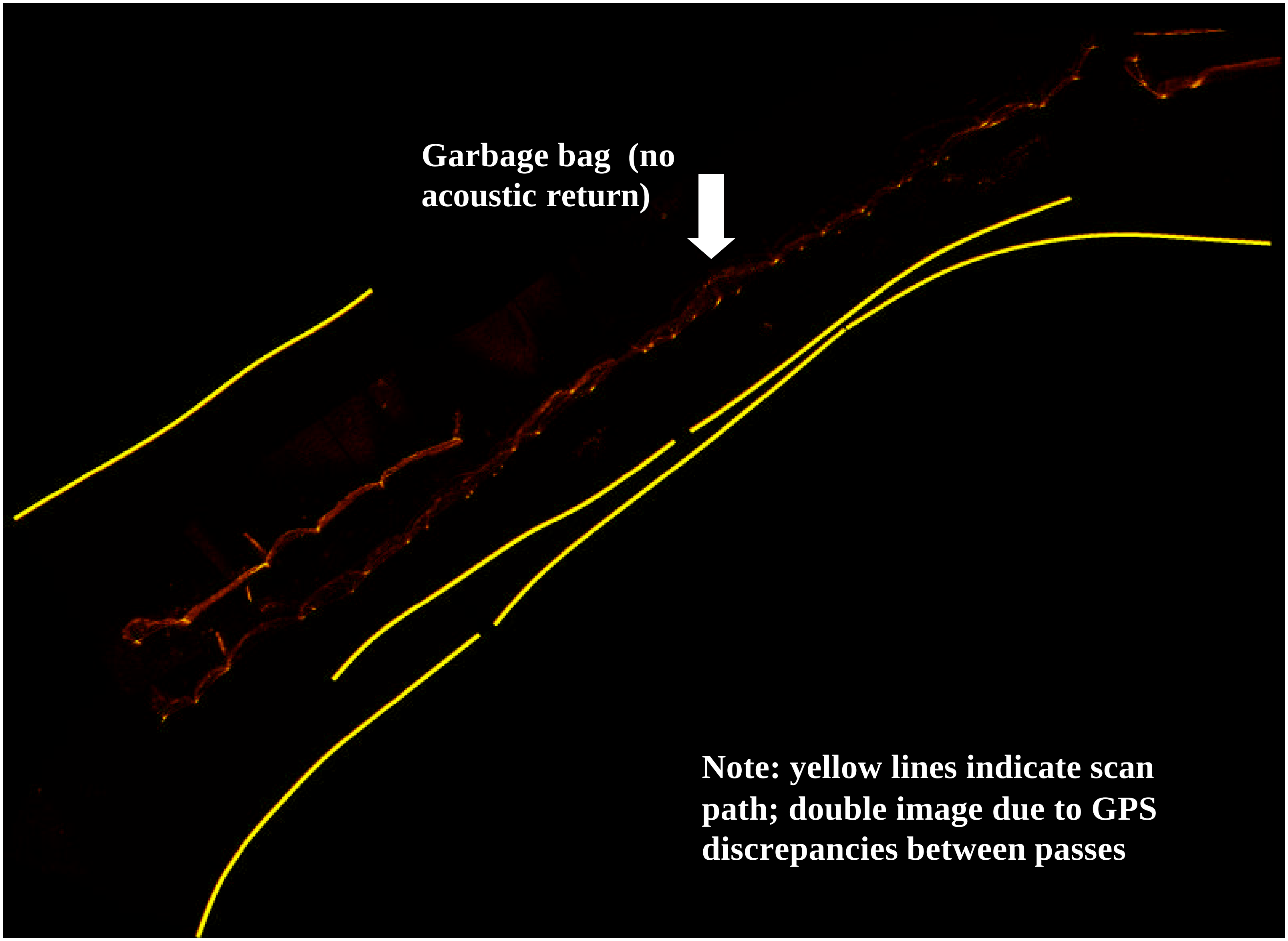


Plate 7.4 Ground truth images of Hefty tm garbage bags by side scan sonar. VIMS pound net leader, York River, Virginia, 2001

boat due to low tides at time of follow-up surveys. Both nets were located off of Fisherman's Island off the Eastern Shore.

In 2001, a total of 825 images were archived of the 55 active pound net leaders surveyed. For each net, between five and fifteen images were recorded per scan (the number of images archived varied based on tow speed and length of net). In 2002, a total of 1848 images (baseline and follow-up) were archived for the remaining 61 of the 63 active pound net leaders surveyed. For each net, between four and ten images were recorded per scan. Most nets were scanned at least twice (four nets in 2002 were scanned only once due to their nets being pulled early in the season) with Eastern Shore Bay nets and southern Western Bay nets observed at least three to six times. Survey frequency depended upon weather, sea state and need based on stranding events, as well as boat availability. Sea state was found to primarily affect sonar reception within shallow (3 to 5 feet) or surface waters. In 2002, the primary research vessel was grounded for ten days in May for repairs and the average sea state for the month of May was 2-3 feet throughout most of the Bay.

Scans of Bay pound nets indicated that various species of algae, seagrass and other detritus may imitate the signature of sub-surface sea turtle entanglements (Plates 7.5-7.8). The majority of the detritus, however, was found floating along the surface of the nets and video images of targeted objects allowed for visual verification and identification at depth. In one southern Eastern Shore net, seven juvenile sandbar sharks (*Charcharhinus plumbeus*) were observed entangled within the surface of a leader (Plates 7.9-7.10). These sharks were in waters less than a meter deep and were not picked up by

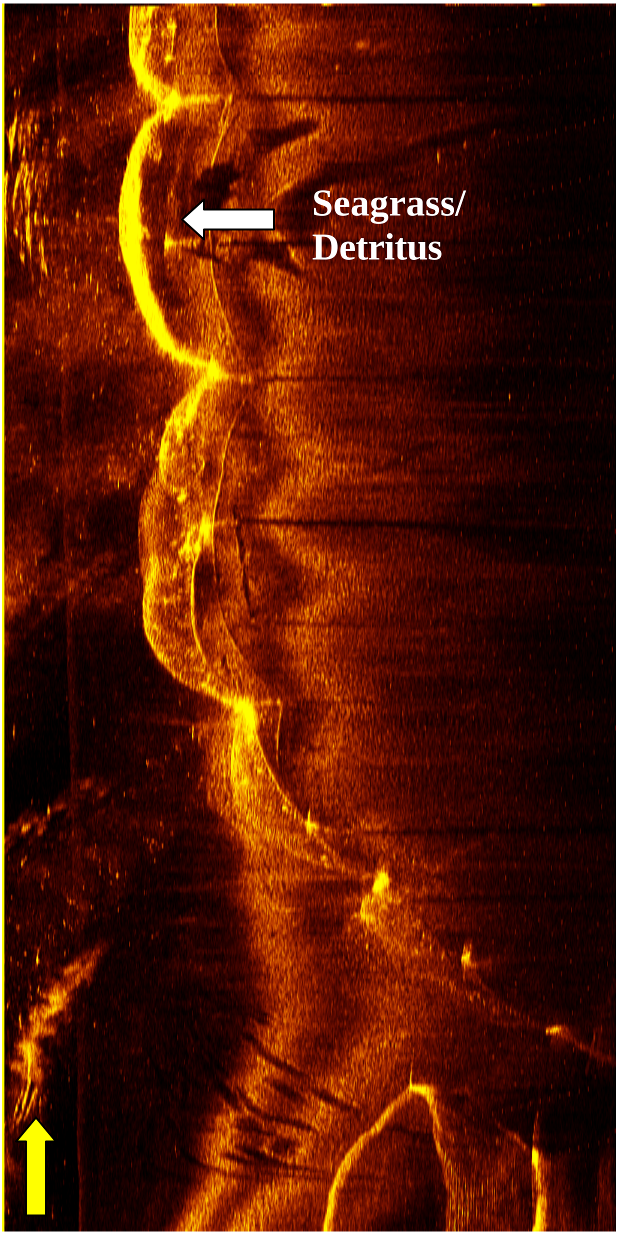


Plate 7.6 Surface photograph of seagrass and detritus accumulation in leader off of Eastern Shore Bay pound net, 2001 (leader had ~6-8 in stretch mesh).

Plate 7.5 Sonar image and of seagrass and detritus accumulation in leader off of Eastern Shore Bay pound net, 2001 (leader had ~6-8 in stretch mesh). 42 m scan length.

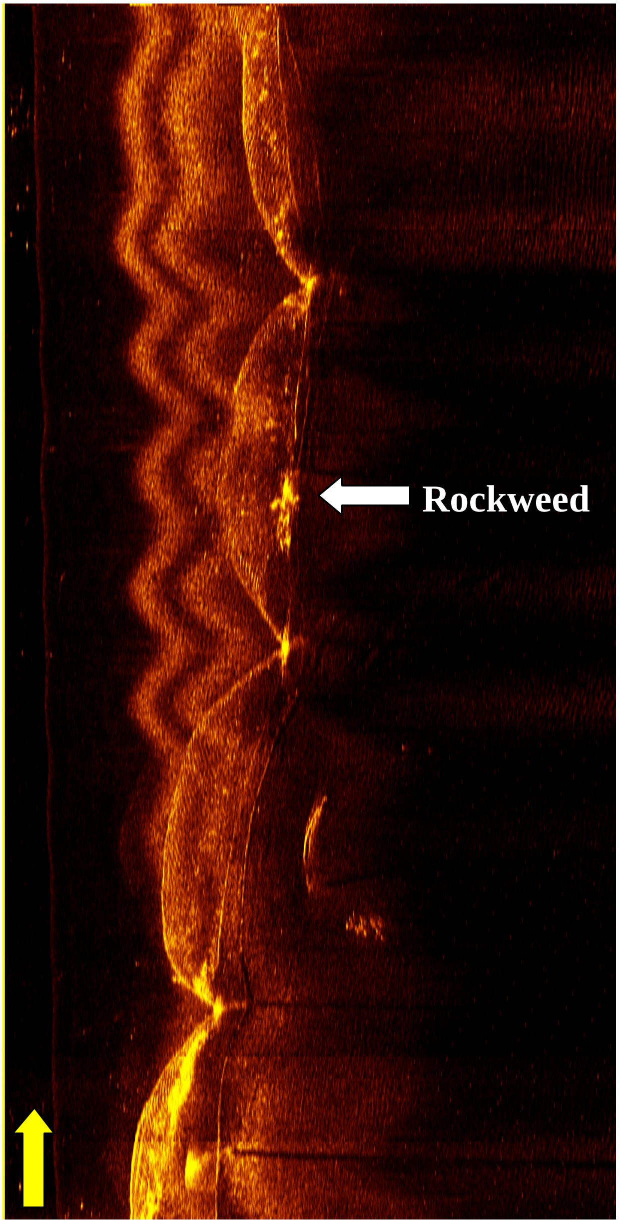


Plate 7.7 Sonar image of rockweed (*Pelvetia fastigiata*) accumulation in leader off of Eastern Shore Bay pound net, 2001 (leader had ~8 in stretch mesh). 42 m scan length.

Plate 7.8 Rockweed (*Pelvetia fastigiata*) from leader off of Eastern Shore Bay pound net, 2001 (leader had ~8 in stretch mesh).

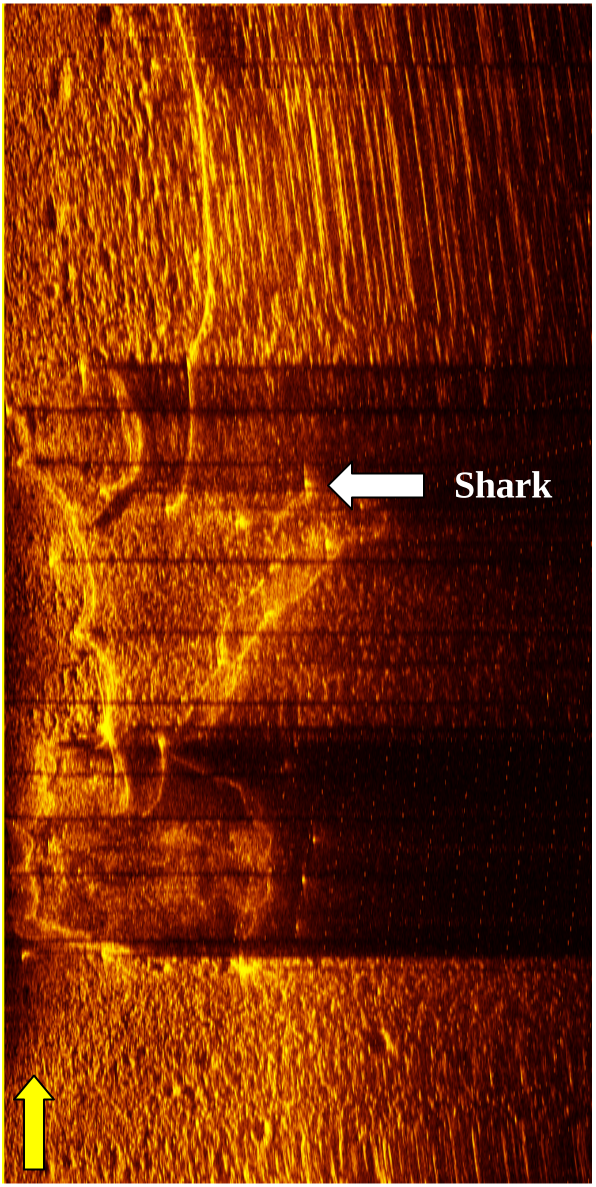


Plate 7.10 Surface photograph of shallow-water pound net with seven juvenile sharks caught in leader and heart off of Eastern Shore Bay pound net, 2002 (~12 in stretch mesh).

Plate 7.9 Sonar image of shallow-water pound net with seven juvenile sharks caught in leader and heart off of Eastern Shore Bay pound net, 2002 (~12 in stretch mesh). 42 m scan length.

the sonar (towed at one meter depth). The sonar also detected the presence of fish within a pound or schooling along a leader (Plate 7.11).

Pound net structure, relative mesh sizes and the presence of string leaders could be determined sub-surface through the use of sonar (Plates 7.12-7.14). Sonar surveys documented four nets in 2001 and six nets in 2002 that had different mesh size or string-mesh combinations at depth. Additional variations in leader type or mesh size were observed between the shallower ends of the leaders closest to shore, and the deeper ends farther offshore. Nets with missing portions of net or sub-surface holes in the net were also documented. From visual surface observations alone, it was not possible to identify these variations due to high turbidity and minimal light attenuation at depth (visibility=1 m).

Incidental Captures:

During the six-week survey period in 2000, only two sea turtles were observed to have interacted with the pound nets. Both animals were found on the same day in nets located along the Eastern Shore-Bay. One turtle had first become entangled in a gill net (approximately 4 in bar mesh size) before drifting into and snagging on a pound net leader pole. Another turtle had entangled in the large mesh leader (10 in bar) of an adjacent pound net. Constriction wounds indicated that the probable cause of death for each turtle was entanglement. Both animals were juvenile loggerhead sea turtles.

No sea turtle acoustic signatures were observed during baseline or follow-up surveys in either 2001 or 2002. In 2001, one turtle was found to have floated into a string leader off Newpoint Comfort however this turtle was floating at the surface, was severely

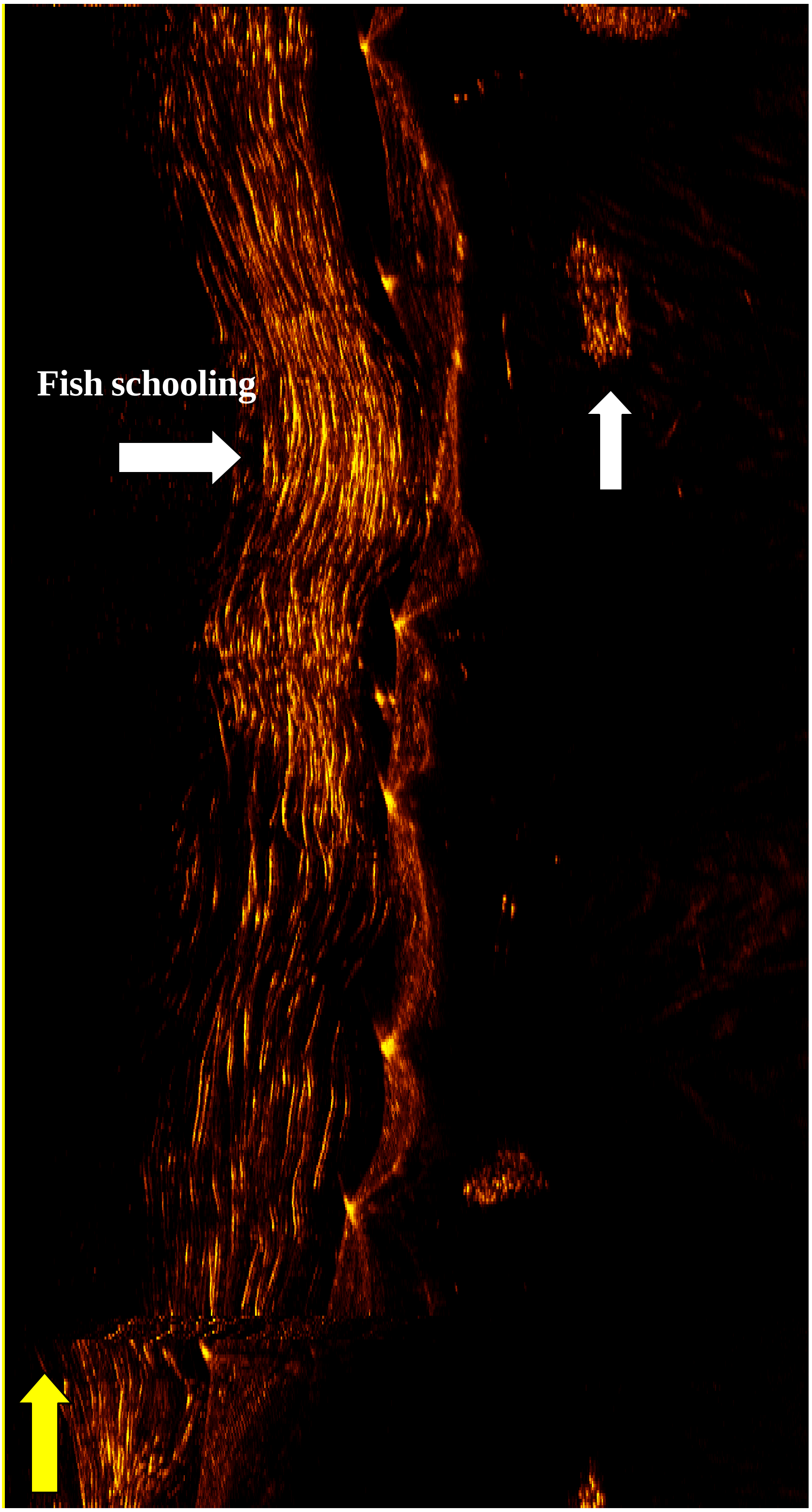


Plate 7.11 Sonar image of large school of fish up-current (to left) of pound net leader (smaller school present down-current), York River, Virginia, 2001 (~8 in stretch mesh). 42 m scan length.

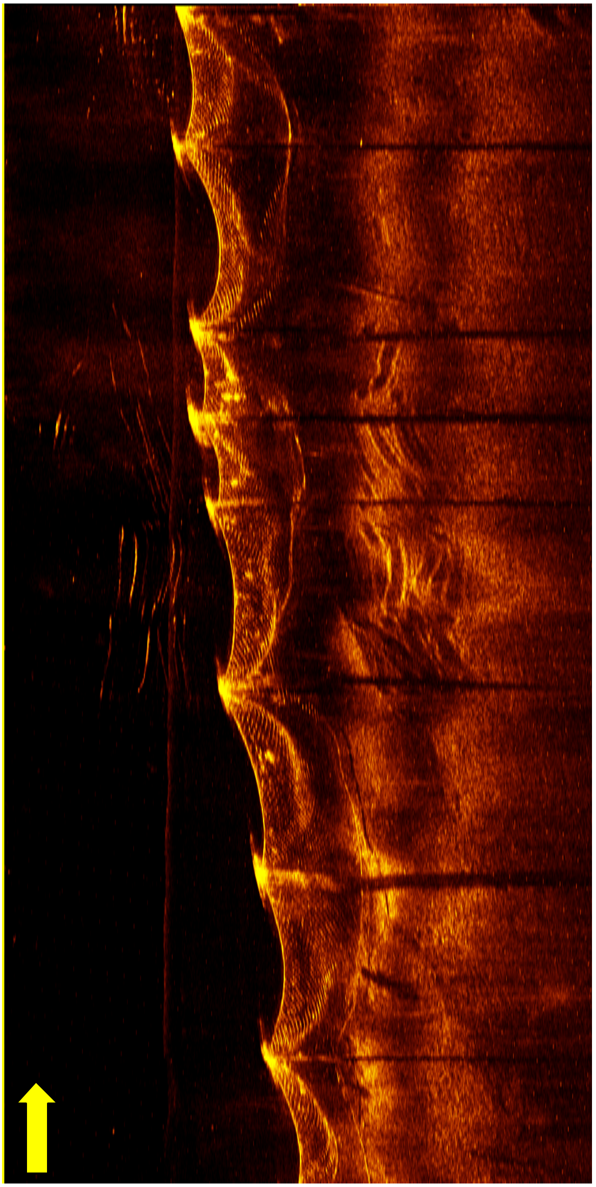


Plate 7.12 Sonar images of large mesh leader (~16 in stretch), Western Bay, 2001. 42 m scan length.

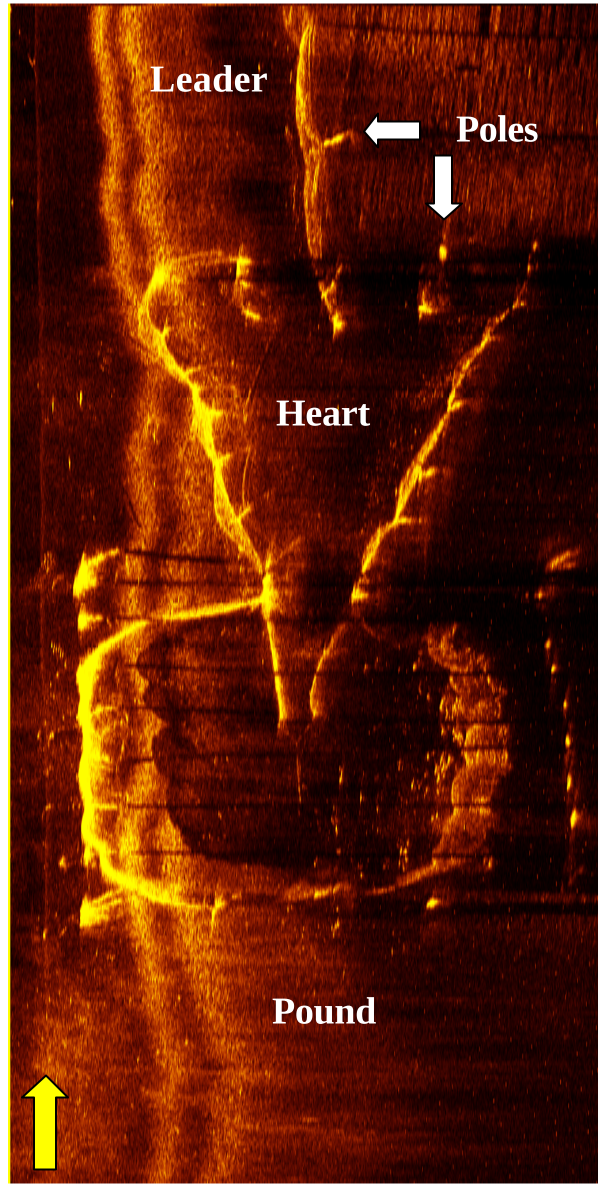


Plate 7.13 Sonar images of pound net leader, heart and head, Western Bay, 2001. 42 m scan length.

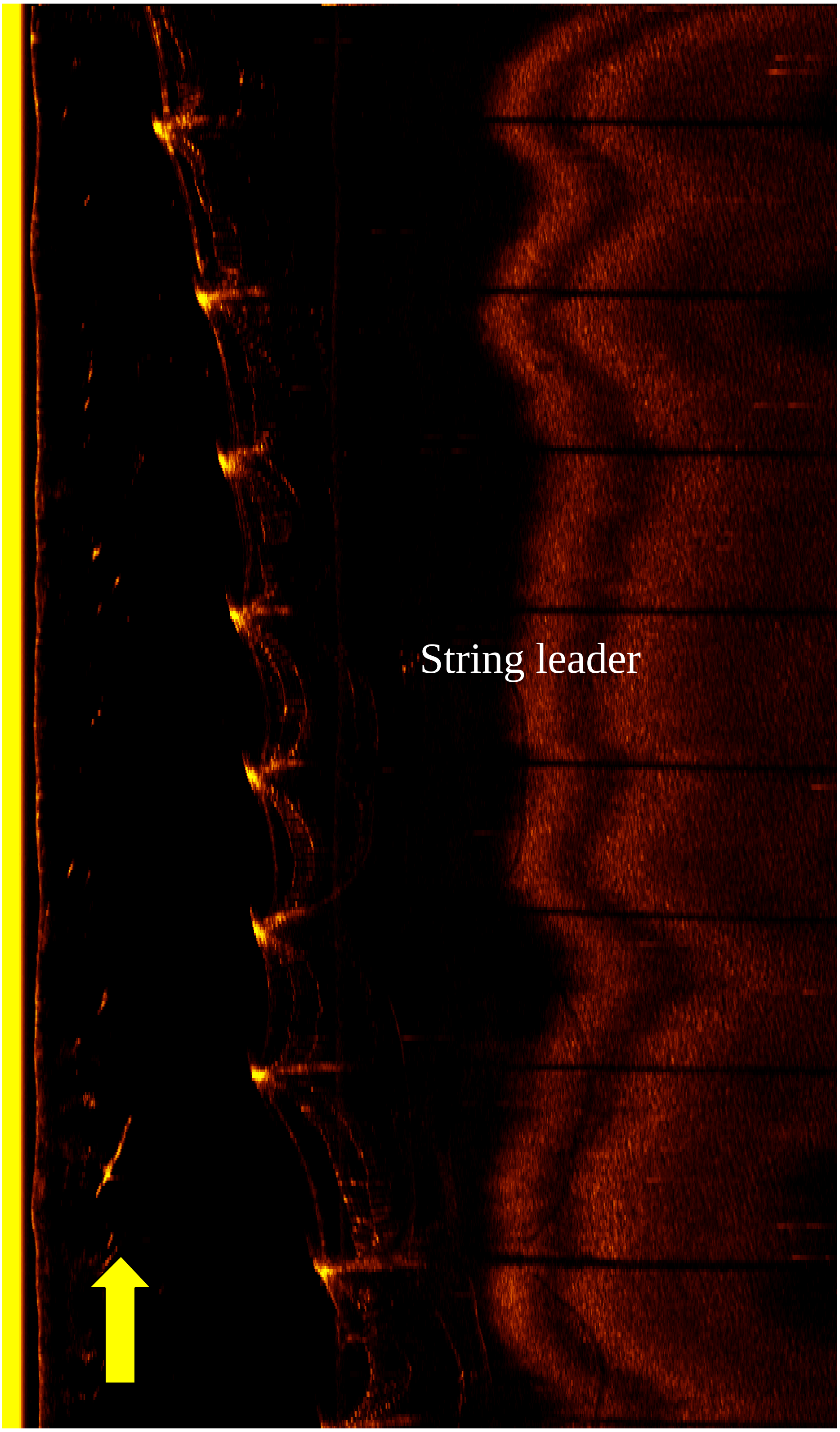


Plate 7.14 Sonar images of string leader, Newpoint Comfort, Virginia, Western Bay, 2001. 42 m scan length.

decomposed and appeared to have floated in post-mortem. Side scan images of this turtle were processed and measurements made via imaging software were within approximately two inches of the actual carapace measurements recorded.

While no sub-surface or surface entanglements were observed during the side scan surveys, ten loggerheads were found entangled in pound net leaders during random fisheries surveys conducted by state or local officials in 2001. All turtles were observed within the top two meters of the water column. Nine of these turtles were found in June, one in August. Three of these interactions were observed by stranding cooperatives, and the remaining seven interactions were reported to VIMS by law enforcement/Marine Patrol officers or pound netters. Only one of the ten turtles was alive at time of observation. Three turtles were severely decomposed and appeared to have floated into the leaders post-mortem. Thus, a conservative 1.8% of Virginia's strandings (n=395) could be directly attributed to pound net leaders in 2001.

On several occasions, various species of birds were observed to have entangled within a pound net. These interactions occurred within all parts of the net (pound-head, leader, and heart) regardless of mesh size. Species observed were the brown pelican (*Pelicanus occidentalis*) and cormorant (*Phalacrocorax spp.*). Cormorants were commonly observed to be swimming and fishing within the pound. When approached by boat, the birds would attempt to take flight, however, many did not have enough water for take-off and would frequently become entangled or struggle with the mesh of the pound. A dolphin (*Tursiops truncatus*) was also found in one of the Lynnhaven nets in 2001. The entanglement was reported to the Virginia Aquarium Stranding Program (state mammal stranding coordinators). Signs of struggle and entanglement were apparent on the carcass. Other bycatch included cownose rays (*Rhinoptera bonasus*) and juvenile sharks.

DISCUSSION

Virginia's pound net fishery is no longer the sole or primary source of sea turtle mortality in the Chesapeake Bay waters. The distribution of pound net stands in the mainstem Chesapeake Bay would suggest that if turtles are interacting with pound net leaders, the greatest possible interaction would occur within the northern Western Bay and Eastern Shore Bay regions where the pound net numbers are greatest (Chapter 6). Between 50 and 100 dead turtles may wash up per week on Bay beaches of the Eastern Shore during the peak stranding period. Sea turtle stranding densities are very low, however, along the Western Bay relative to the southern tip of the Eastern Shore. The Eastern Shore Bay is an area subject to strong tidal currents due to its proximity to the Bay mouth. A cyclonic eddy system located in the lower Bay was modeled to entrain particles along the beaches from Cape Charles to the Bay mouth (Hood et al. 1999). It is possible that floating sea turtle carcasses may also entrain in this region due to prevailing physical systems and current regimes.

This region and the waters on the ocean side of the Bay mouth also represent an area where several other fisheries are active, particularly during the time when sea turtles are first migrating into the Bay and when sea turtle stranding rates are highest. Mortalities induced by the pound net fishery in the 1980's may have been replaced by other local fisheries, including a spring gillnet fishery focused on both the seaside and lower bayside of Virginia's Eastern Shore and off Virginia Beach. It is possible that the large mesh gill nets used in the monkfish (*Lophius americanus*), black drum (*Pogonis cromis*) and smooth dogfish (*Mustelus canis*) fisheries pose a more current threat to sea turtles in Virginia's waters. Unfortunately, few consistent observer data are available for these fisheries.

The majority of the carcasses found along Eastern Shore Bay beaches are moderately to severely decomposed (Mansfield et al. 2002a; 2002b). This would suggest that high numbers of incidental captures occur one to two weeks prior to carcasses stranding on adjacent beaches. If pound nets were the sole or primary source of sea turtle mortality, then large numbers of incidental captures by leader entanglement should be observed. Yet, the 2000 through 2002 pound net surveys resulted in zero observations of sea turtle entanglements. During the 2001 season a total of ten turtles (out of 395 strandings) were randomly observed to have had some form of interaction with a pound net leader. Only one of these turtles was alive and observed entangled within a large mesh (>12" stretch) leader off the Eastern Shore (bayside). Most of these animals were severely decomposed, and in at least three instances, it was determined by the observer that the carcasses most likely had floated in post-mortem. It takes up to two weeks in Virginia's marine/estuarine environment before an average juvenile sea turtle becomes severely decomposed (Bellmund et al. 1987). A NMFS funded study performed by VIMS in 1984 monitored the condition of five sea turtles found to have recently died within pound net leaders. These turtles were examined regularly over a five-week period. During this time, none of the turtles became disentangled via natural means (Bellmund et al., 1987). It is probable that sub-surface entanglements of sea turtles would remain in place for some time.

Side scan sonar surveys have strong potential in assessing sub-surface entanglements of sea turtles within fixed gear fisheries. Though these surveys provide a relatively efficient way to observe for sub-surface entanglements, they are limited by weather and sea conditions and on the ability to verify object signatures within the nets. Successful surveys occurred when the sea state was relatively calm since suspended sediments (due to wave turbulence) are reflected acoustically by the sonar. A quantifiable acoustic signature may be difficult to obtain since target strength could change based on orientation of a turtle within the net. Side scan sonar works on the principles of sound reflection. The strongest returns/reflections are received from objects containing air/gas pockets (Kasul and Dickerson, 1993) and dense structures such as bone. Decomposition and bloat of an entangled turtle may also define the type of signature returned. Future side scan sonar studies should include cataloging signatures of turtles based on size, species, carcass orientation and decomposition stage. Side scan sonar is also limited to detection of probable targets vs. actual identification of the target. Sea turtles exhibit a large echo return due to their bony carapace. However, the possible masking of sea turtle signatures from seagrass, algae and other detritus may result in a false positive. As such, side scan sonar surveys are at risk of overestimating subsurface mortalities (Musick and Mansfield 2004). The risk of recording false-positives was moot for the 2001 and 2002 surveys as no sea turtle acoustic signatures were observed.

In addition to the survey results presented in this chapter, NMFS also observed the pound net fishery during the spring of 2002 and 2003. Between April 25 to June 1, 2002, NMFS observers monitored 70 pound net stands, making 648 observations resulting in only six potential sea turtle interactions (NMFS 2004a). Two turtles were found alive, four were dead; five were found in association with leaders with mesh sizes greater than 8 inch stretch (NMFS 2004a). Eight of the total nets (n=70) examined had large mesh leaders, suggesting that 83% of the observed turtle interactions occurred in a very small subset of actively fishing nets (Musick and Mansfield 2004). Between April 21 and June 11, 2003, 815 observations of 56 active nets were made by NMFS observers, resulting in reports of five dead entangled turtles, four of which were found in 11.5 inch stretch mesh and one in an 8 inch stretch net (NMFS 2004a). Unfortunately, NMFS conducted a non-random survey, concentrating its survey effort in areas known for high tidal velocities or on nets with prior entanglement histories (Musick and Mansfield 2004). These surveys were conducted during a fraction of the sea turtle residency period and often ended well before the documented peak in sea turtle strandings within a particular survey year (Figures 7.1-7.3). As a result, it is impossible to extrapolate these results to the entire fishery. At the very least, the 2002 observations would support the conclusions made in the 1980's that large mesh leaders pose the greatest risk to sea turtles.

In 2002, NMFS observers introduced a new category of take associated with pound nets: 'impingement'. NMFS defines an 'impinged' turtle as "a sea turtle being held against the leader by the current, apparently unable to release itself under its own ability" (NMFS 2004c). Two of the observed six turtles in 2002, and an additional 11 turtles in 2003 were reported as 'impinged' on leaders (NMFS 2004a). All turtles observed to be 'impinged' were reported to be alive and active with the exception of one turtle that was moderately decomposed at the time of observation (NMFS 2004a). All 'impinged' turtles were considered takes. Little effort was made to observe these turtles for any time beyond

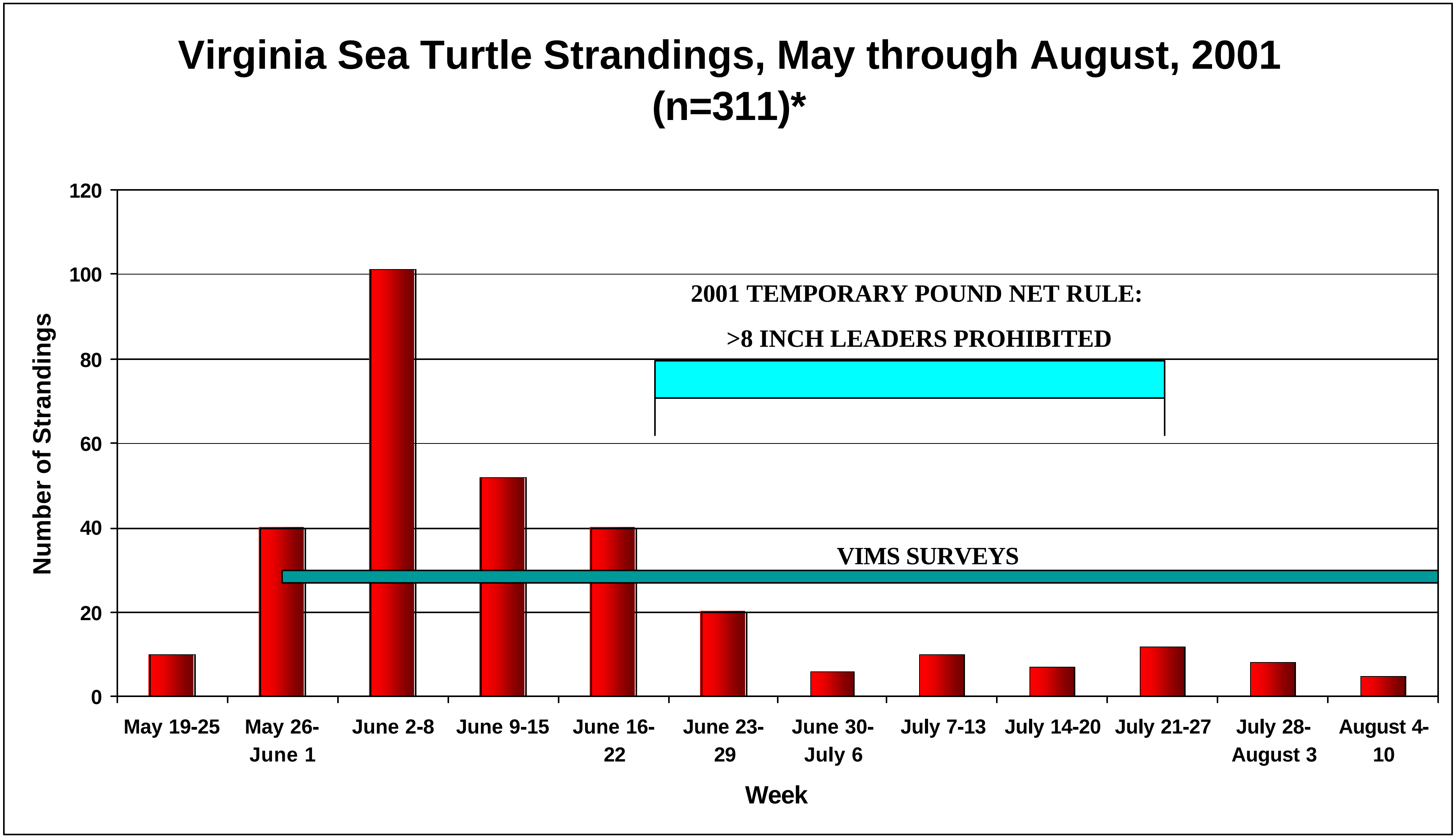


Figure 7.1 Virginia sea turtle strandings, May through August, 2001 (n=311) in reference to federal pound net rules and VIMS survey period.*Total 2001 strandings: n=381; first strandings not observed until mid-May; record year for strandings.

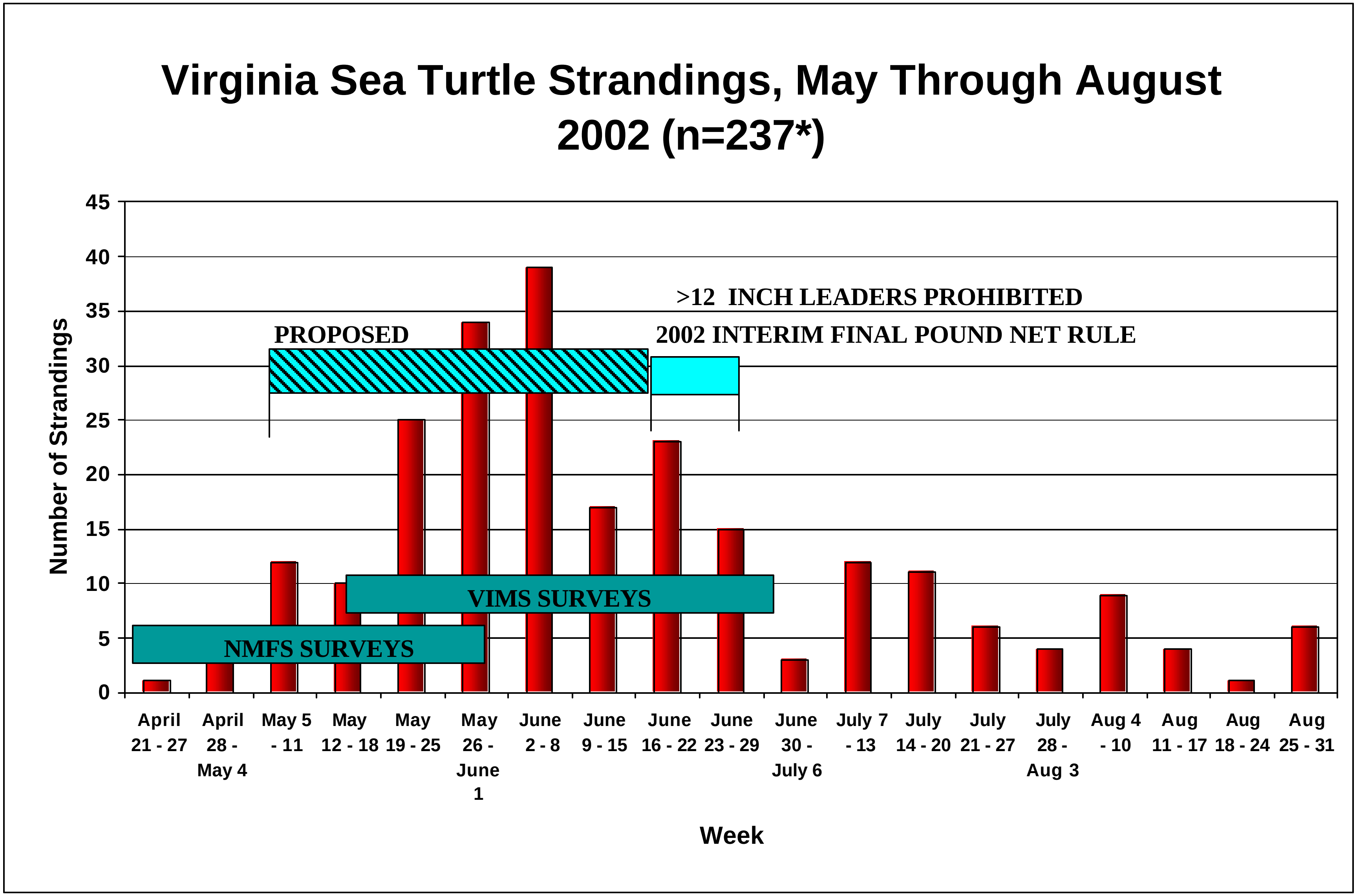


Figure 7.2 Virginia sea turtle strandings, May through August, 2002 (n=237) in reference to federal pound net rules and both VIMS and NMFS survey periods.*Total 2002 strandings: n=315; includes last ten days of April when first strandings were observed

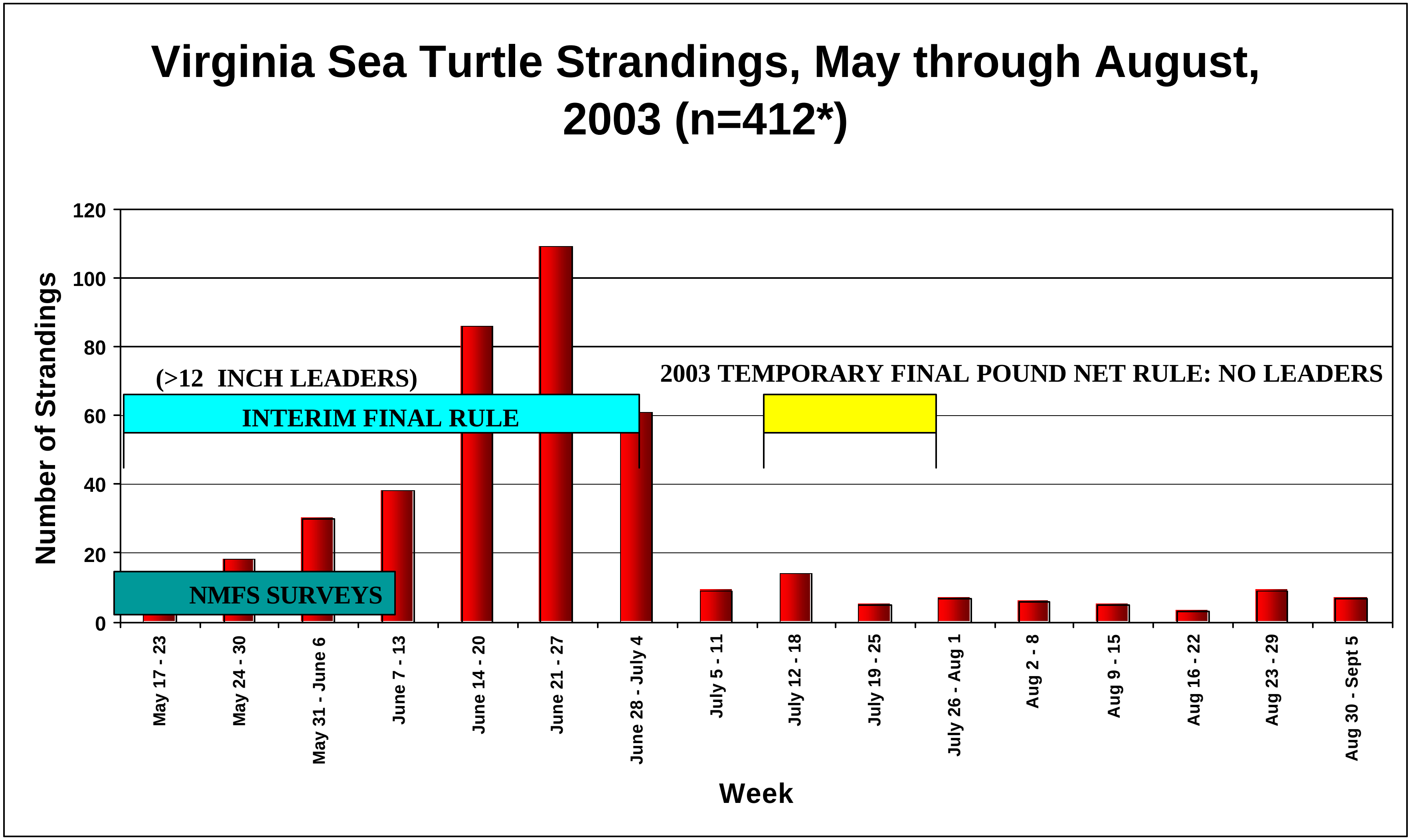


Figure 7.3 Virginia sea turtle strandings, May through August, 2003 (n=412) in reference to federal pound net rules and NMFS survey period.*Total 2003 strandings: n=529

the time necessary to scan the nets, yet NMFS has assumed that most ‘impinged’ turtles will die (NMFS 2004a).

This assumption neglects available data on turtle diving behavior. Byles (1988) found that some loggerheads in the Chesapeake Bay drift passively with the tides while foraging. Byles (1988) and Mansfield (2003; 2004; 2005; Chapter 2) showed that juvenile loggerheads and Kemp’s ridleys are capable of diving for periods over 40 minutes in duration during the day. While it is possible that turtles, when they first enter the Bay in the spring of the year, are weakened due to the energetic expenditures of migration and may be at greater risk of ‘impingement’ (Bellmund 1988; Byles 1988), it cannot be assumed that ‘impinged’ turtles will die without prolonged observations of these turtles. NMFS observers neglected to determine whether ‘impinged’ turtles could surface to breathe. It should also be noted that tidal cycles are by definition cyclic and current strength varies with tidal stage. It is possible that ‘impinged’ turtles may be utilizing these nets via behaviors yet to be defined. Regardless, the total number of ‘impinged’ turtles observed by NMFS is small relative to the total number of observations made during their survey periods and despite a biased survey effort in 2002.

Due to high labor intensity associated with this fishery, most nets that are set prior to, or early in the turtle residency season, remain active throughout the entire residency period. The majority (50% to 60%) of annual strandings in Virginia occur in May and June when the turtles first enter the Bay (Lutcavage 1981; Lutcavage and Musick 1985; Keinath et al. 1987; Coles 1999; Mansfield et al. 2002a; 2002b). Sea turtle strandings and incidental captures, however, drop of dramatically after the first two to three weeks of residency (Figures 7.1-7.3) (Lutcavage 1981; Lutcavage and Musick 1985; Keinath et al.

1987; Coles 1999; Mansfield et al. 2002a; 2002b). This is a pattern that has been observed since 1979 when the Virginia Sea Turtle Stranding Network was established. Unlike the NMFS surveys, the 2001 and 2002 VIMS surveys did span the entire period of each seasons stranding peak, including several weeks post-peak. Considering the lack of sub-surface entanglements observed during the side scan surveys, little change in strandings rates in reference to the progression of federal rules limiting fishing effort relative to the number of observed strandings, and constant fishing effort within a season among pound nets, it is not probable that significant rates in incidental takes are occurring within Virginia's pound net fishery.

Acting on the assumption that pound nets are the primary or sole source of sea turtle mortality in Virginia, NMFS has implemented a series of increasingly stringent rules limiting pound net fishing effort or methods. On June 21, 2001 NMFS implemented a temporary emergency pound net rule prohibiting string leaders and leaders with 8 inches or greater stretched mesh within the mainstem Chesapeake Bay for 30 days (NMFS 2001). This rule was enacted more than two weeks after the 2001 sea turtle stranding peak (Figure 5.18). On March 29, 2002, an interim final rule was proposed to prohibit string leaders and leaders greater than 12 inch stretch mesh from May 8 through June 30 of any given year (NMFS 2002a). This rule also required if one turtle were to be found entangled in a net with mesh sizes smaller than 12 in stretch, then additional action may be taken. This rule was not finalized or implemented until June 17, 2002 (NMFS 2002b), after the 2002 peak in strandings (Figure 7.1). The interim final rule was fully implemented in 2003, however, despite the reduction in pound net effort and/or large mesh leaders, 2003 experienced an historically high number of sea turtle strandings (n=529). The peak in strandings was observed during the time that the interim final rule was in place (Figure 7.2). In response, NMFS implemented an emergency modification to the temporary rule, prohibiting all leaders in the entire mainstem Chesapeake Bay from July 16 to July 30, 2003 (NMFS 2003). This emergency rule was implemented almost two weeks after the post-peak decline in sea turtle strandings (Figure 7.3). On February 6, 2004 NMFS proposed a rule to prohibit all leaders in the lower mainstem Chesapeake Bay between May 6 and July 15 of any given year (with the exception of nets from the COLREGS line to the Chesapeake Bay Bridge Tunnel (affecting only the Lynnhaven nets), and restricting all other nets in the mainstem Bay to leaders with stretch mesh sizes less than 8 inches (NMFS 2004b). The final rule was not in place until May 5, 2004, giving less than two days for fishermen to comply (NMFS 2004c). The 2004 stranding season resulted in a pattern of strandings that did not differ from previous years with 47.2% of the annual strandings occurring in late May to early June (n=161 of a total 341). Based on these data, it is apparent that the pound net fishery has little impact on sea turtle strandings in Virginia.

Pound nets can no longer be considered the primary or sole source of sea turtle mortality in the Chesapeake Bay. Results from the fisheries and side scan surveys presented in this chapter, along with available historic data show that pound net effort has not remained constant over time. The relative threat of pound nets has declined over time with the reduction in both effort and the numbers of large mesh or string leaders currently in use (Chapter 6). It is likely that there is a difference between surface and sub-surface bycatch rates in pound net leaders. Based on the results of this side scan sonar study, subsurface entanglements are not likely past the peak in seasonal strandings, nor are they as likely within the top two meters of the water column reflected by Bellmund et al.'s (1997) historic observations.

CHAPTER 8

SITE FIDELITY AND NON-LETHAL INCIDENTAL CAPTURE OF SEA TURTLES IN VIRGINIA'S POUND NET FISHERY

ABSTRACT

The purpose of this study was to determine whether turtles caught incidentally in heads of Bay pound nets exhibit fidelity to the area of capture. Fixed gear types, such as pound nets that remain in the same general location within a season or between seasons, pose a unique threat to sea turtles exhibiting fidelity to a particular habitat. A mark-recapture study was conducted using nets fished near the mouth of the Potomac River between 1980 and 2002. Five to seven nets were fished each year, incidentally capturing between 14 and 92 live sea turtles annually. A total of 436 individual turtles were caught in these nets between 1980 and 2002. Of these, 403 turtles were originally captured and tagged from these nets, representing 354 loggerheads (87.8%), 48 Kemp's ridleys (11.9%) and one (0.3%) juvenile green turtle (*Chelonia mydas*). Of the loggerheads, 333 (94.1%) were juveniles, 13 were adults (3.6%) and eight (2.2%) were of undetermined stage. Three Kemp's ridleys (6.25%) were adult-sized. Thirty-three turtles were originally captured and tagged by other fishermen in the Chesapeake Bay and were subsequently recaptured in the Potomac nets.

Among the total individual loggerheads captured and tagged for the first time in the study nets, (n=333), 74 were recaptured by the same fisherman, representing a 20.9% return to the original site of capture. A total of 116 recaptures of these turtles were reported including one to thirteen recaptures of the same turtles within a season and/or among seasons. These data suggest that some loggerhead sea turtles exhibit strong site fidelity to pound nets, with several individual turtles returning to the same net year after year during periods of one to eleven years. Of 48 individual Kemp's ridleys captured, only two were recaptured in the same nets.

Satellite telemetry was also used to track the movements of an adult female loggerhead captured multiple times in the Potomac River between 1999 and 2002. Monte Carlos random walk simulations indicate significant site fidelity to the mouth of the Potomac River ($p<0.0009$; $r^2<0.0199$). Kernel home range analyses indicate a concentrated seasonal home range for this turtle with a 73.9% overlap in the overall range (95% kernel contour) and a 39.5% overlap in the turtle's home range (50% contour) between Year One, Year Two and Year Three.

Strong site fidelity among loggerheads, including strong inter-annual site fidelity, indicate that some turtles actively interact with pound nets. However, once inside the pound head, the type of take associated with this behavior is typically non-lethal. Total incidental captures of turtles in Bay pound nets may be very high compared to actual bycatch mortalities from leader entanglements; allowable sea turtle take limits for Virginia's pound net fishery should incorporate both non-lethal incidental captures of sea turtles in pound heads and lethal takes in leaders.

INTRODUCTION

Pound net stands are fixed, semi-permanent, passive fishing devices that consist of a series wooden poles driven into the sediment that serve as a framework for mesh nets. There are typically three distinct segments to a pound net: the leader, the heart and the pound head (Mansfield et al., 2001a). Sea turtles interact with pound nets in two ways: turtles are known to swim into the pound head to feed, and/or may entangle within the leader mesh (Lutcavage 1981; Lutcavage and Musick 1985; Musick et al. 1985; Bellmund et al. 1987). Turtles caught within the pound head are usually captured unharmed and have been observed to eat various crab and fish species (Lutcavage and Musick 1985). Once inside a pound head turtles are trapped and must be released by the fisherman. The head itself is a bowl-shaped, small-meshed net similar to a live-well that is open at the surface, allowing trapped turtles to surface and breathe.

Fixed gear types, such as pound nets that remain in the same general location within a season and even between seasons, or nets that are set repeatedly within the same geographic area, may pose a unique threat to sea turtles. Juvenile loggerheads captured by pound net and radio-tracked were observed to forage along the bottom of tidal channels, moving passively with the tides (Byles 1988). Observed ranges of these animals (using minimum convex polygon analysis) varied between 10 and 80 km^2, with preferred home ranges between 5 and 15 km^2 (Byles 1988; Musick and Limpus 1997). Loggerheads subjected to displacement have been observed to return to their original capture site within a few days or weeks of relocation, exhibiting both homing and site fidelity behaviors (Byles 1988; Keinath 1993; Ryder 1995; Musick and Limpus 1997; Avens 2003; Avens et al. 2003; Avens and Lohmann 2004). Virginia loggerheads are known to exhibit strong site fidelity to both foraging grounds and specific pound nets; some turtles have been recaptured in the same sample nets multiple times within a season and/or within subsequent seasons (Lutcavage 1981; Musick et al. 1985; Byles 1988; Keinath 1993; Musick and Limpus 1997). These observations indicate that some sea turtles may utilize pound nets as a regular food source, and sea turtle behaviors, such as foraging site fidelity, may contribute to at least one type of take associated with Virginia's pound net fishery. To date, there is no sea turtle take limit established for the pound net fishery in Virginia waters. Therefore, no incidental takes are permitted within the state. This includes takes by entanglement and live takes within pound heads.

The primary objectives and hypotheses of this study were to:

1. Determine whether turtles caught incidentally by Bay pound nets exhibit fidelity to the area of capture;

H_{01} Turtles captured incidentally in pound heads exhibit random movements and distribution relative to their original capture location.

METHODS

Since 1979, the Virginia Institute of Marine Science has conducted a sea turtle mark-recapture program in cooperation with local pound net fishermen in the Bay. One Potomac River fisherman supplied consistent data on the incidental capture of sea turtles for 24 years: 1979 through 2002. Turtles were collected from pound heads in stands set at the mouth of the Potomac River between the months of May through November in any given year. This fisherman fished between five and seven pound net stands each season, the locations of which did not change significantly in the 24 years of this study (Figure 8.1). He also consistently fished these nets throughout the Virginia sea turtle season, with the exception of severe weather events that would prevent safe access to the sampling sites. All captured turtles were reported to VIMS, identified as to species and age class (adult or juvenile), flipper tagged with National inconel or monel tags, measured and weighed. Flipper tags were applied to front flippers in the second or third scale. A primary tag was assigned to each individual turtle and tag histories were managed in a Microsoft Access (2000) relational database. All turtles were released unless illness, injury or death prevented re-release into the wild. Recapture histories of all turtles were quantified and recapture rates per species was determined.

One individual turtle, SSB-919, was recaptured multiple times in the Potomac River sample nets between 1999 and 2002. An ultrasound confirmed the sex of this turtle. Upon initial capture within a given season, this turtle was either relocated from the Potomac River to the VIMS turtle facilities on the York River and released (2000-2002), or released directly from the Potomac River sample site (1999). Prior to release, the turtle was measured, weighed, outfitted with either satellite (1999, 2000 and 2001 recapture seasons) or radio/acoustic tags (2002 recapture season). Telonics, Inc. ST-14 platform terminal transmitters (PTTs) and VHF radio (Lotek RMMT_3) and acoustic (Lotek CAFT16_3) transmitters were used to track the at-sea movements of this turtle post-release. Tags weighed less than 1% of the turtle's body weight and PTT duty cycles were set to 24-hours a day continuous operation. Tags were attached using the methods described in Chapter 2.

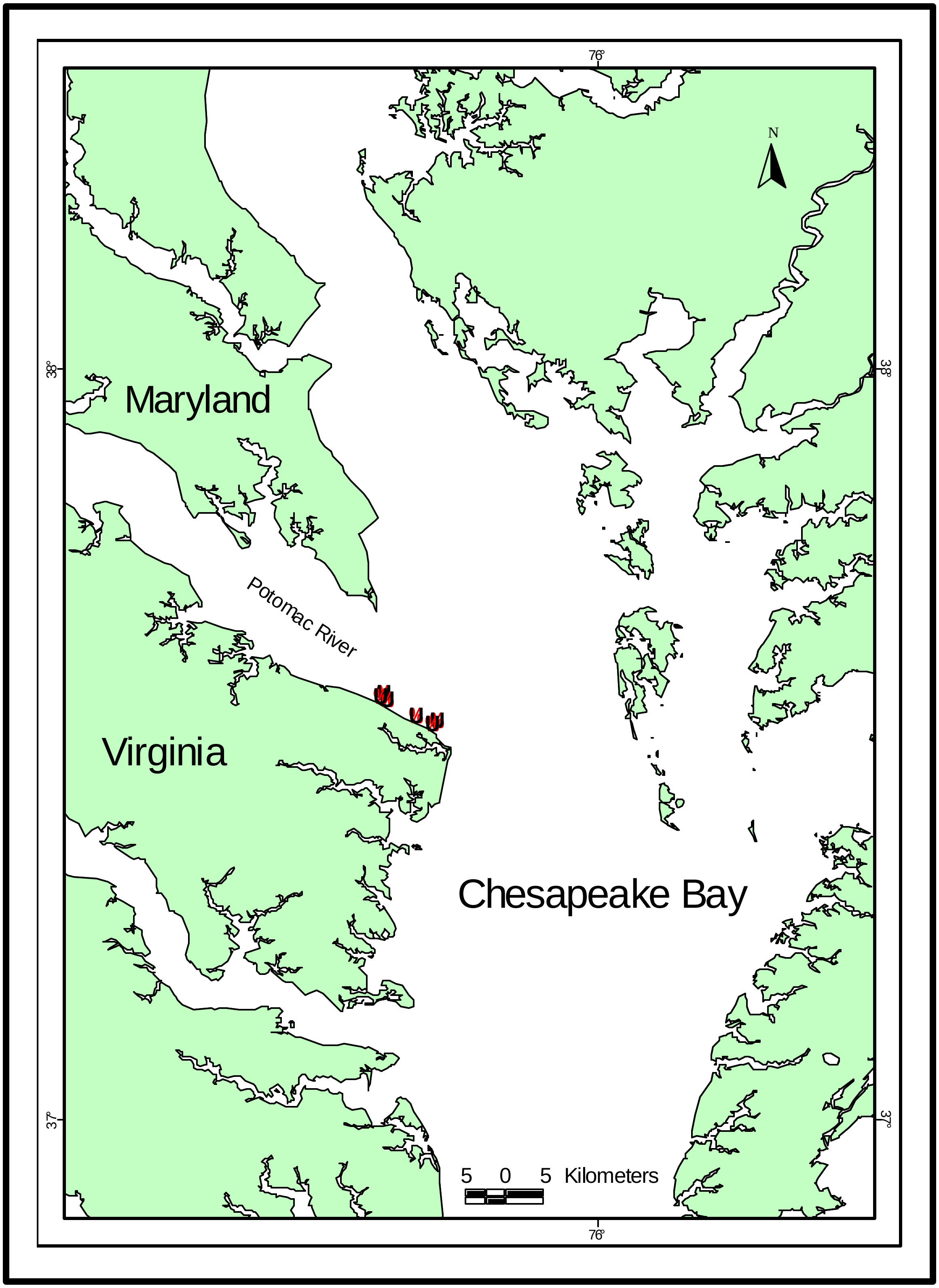


Figure 8.1 Location of Potomac River pound net study site and pound nets (in red)

Data from the PTTs were archived and filtered using the Satellite Tracking and Analysis Tool (STAT) (Coyne and Godley 2005). Data were filtered based on accuracy of transmission (LC 0-3, A and B were selected; Appendix C), likely swim speed between locations (<5 km hour), minimum turning angle (> 3°), likely distance between points (<50 km), locations received in time intervals greater than or equal to one hour, and topography (< 0.5 m). Tracks were reconstructed in STAT and mapped in reference to bathymetry overlays and bathymetric contours of 50 m derived from the General Bathymetric Chart of the Oceans (GBCO) using a one-minute spatial resolution (Coyne and Godley 2005). Location data were quantified to determine the range in depth of the water column that the turtle traveled. Calibrated sensor data from each PTT were converted for temperatures ranging between 5º C and 35º C via linear regression. Resulting formulae were used to convert transmitted sensor data to ambient temperatures.

Filtered location data were imported into ArcView 3.2 and reconstructed for spatial movement analyses (Mercator projection). Track data were analyzed for site fidelity using tests for Monte Carlo random walk simulations, comparing observed tracks with randomly generated walks (1000 replicates) using the Spatial Analyst and Animal Movement extensions (Hooge and Eichenlaub, 2001). Significance was based on $p<0.05$. Low r^2 values represent higher relative site fidelity (Hooge and Eichenlaub, 1997).

When sample size permitted, home ranges for tracks exhibiting significant fidelity to a particular area were determined using a fixed kernel density model. For comparison among turtle tracks, a fixed ad hoc smoothing parameter (H) of 5.0 was used (projection units in km) (Silverman 1986). This value provided the best spatial fit of all track data within the constraints of aquatic sea turtle distribution. Kernel output contours were set at

95% and 50% confidence levels. The 95% contour is typically used to determine the area the animal actually inhabits or uses, and the 50% contour is used to determine the "core area of activity" (Hooge and Eichenlaub 2001). Minimum sample size of location data required to estimate concentrated home ranges (50% kernel contour) was determined for each track using cumulative home range analysis. Cumulative home ranges were calculated using kernel densities estimated at daily intervals (day one, days one and two combined, days one, two and three, etc.) (McGrath 2005). These estimates were plotted over time to determine the asymptotic point at which the actual home range was achieved: a minimum two-week sample period was necessary to obtain the concentrated home range per individual. Site fidelity and kernel analyses were performed for the time the turtle was observed as resident within Virginia or neighboring waters, excluding any southern migratory movements.

RESULTS

A total of 436 individual turtles were caught in the Potomac River fisherman's nets between 1980 and 1999, capturing between 14 and 92 live sea turtles annually with The majority (87.8%; n=354) of turtles were loggerhead sea turtles, 11.9% (n=48) were Kemp's ridleys and one (0.3%) was a green. An average of 31.1 (+/- 19.6 SD) loggerheads was caught per year. The majority (94.1%; n=333) of the loggerheads were juveniles with only 3.6% (n=13) were adults. Maturity could not be determined for 13 individuals (3.6%). Of the total number of turtles captured (n=436), 403 turtles were originally captured and tagged from these nets; 33 turtles were originally captured and tagged by other fishermen in the Chesapeake Bay and were subsequently recaptured in the Potomac nets. Among the total individual loggerheads captured and tagged for the first time in the study nets, (n=333), 74 were subsequently recaptured by the same fisherman, representing a 20.9% return to the original site of capture. In addition to the initial tagging event, this fisherman has reported a total of 116 recaptures of these individuals, including multiple recaptures of the same turtles within a season and between seasons. Recapture frequency ranged between 1 to 13 recapture events occurring within a one to 11 year period. Mean recaptures per individual was 2.8 (+/- 1.8 SD). Of the 48 individual Kemp's ridleys captured, three turtles were adult-sized (>60 cm CCL) and only three individuals (6.3%) were recaptured in these nets. Among all species, the number of turtles reported as recaptured in a pound net (including those originally tagged by other fishermen) was 109, representing a minimum 25.0% return to this particular gear type. This represents a minimum estimate as reporting rates and effort varied widely among cooperative fishermen.

Carapace lengths of loggerheads, including turtles originally captured elsewhere, ranged from 45.3 cm to 114.6 cm CCL (n=331). Mean carapace length was 68.8 cm CCL (+/-13.2 cm SD) (Figure 8.2). Weights ranged from 9.07 kg to 140 kg (n=400), with a mean weight of 42.2 kg (+/- 23.7 kg SD). Sex was determined in only 24 individual loggerheads based on tail size, laparoscopy, ultrasound or subsequent stranding and necropsy. Fifteen turtles were determined to be female and nine determined to be males. The captured green turtle had a 37.2 cm CCL. Mean carapace length of all Kemp's ridleys (n=48) was 45.1 cm CCL (+/-10.4 cm SD) and ranged between 27.1 cm and 70.8 cm (Figure 8.3). Sex was determined for only two of these turtles. Both were identified as female including one that was subsequently recapture on a nesting beach in Rancho

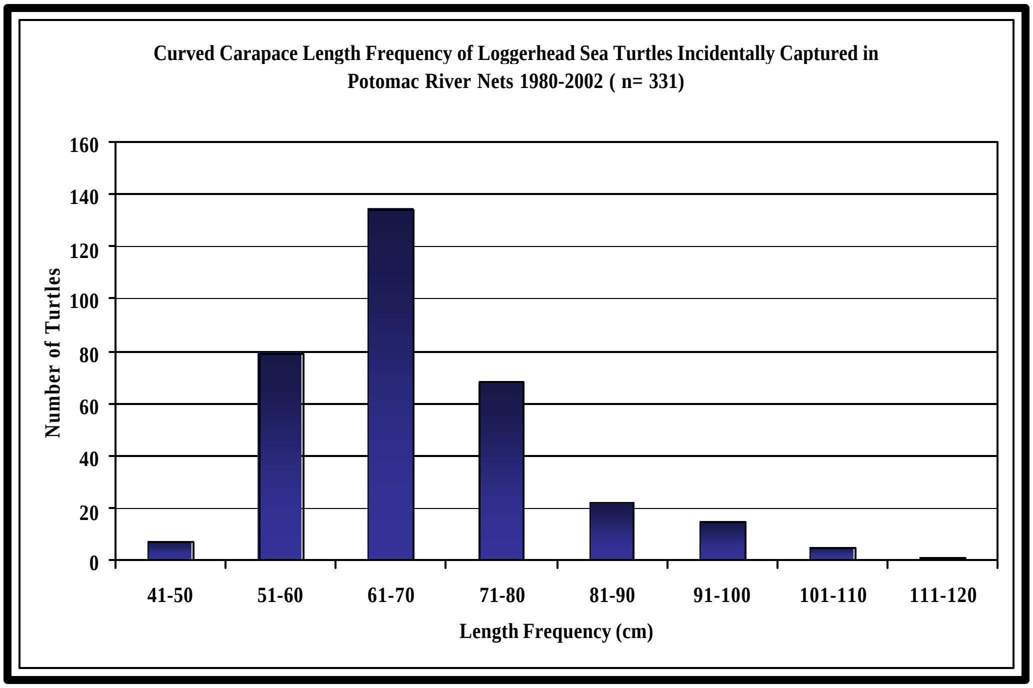


Figure 8.2 Length frequency distributions (cm) of loggerheads captured incidentally in Potomac River pound net study, 1980-2002.

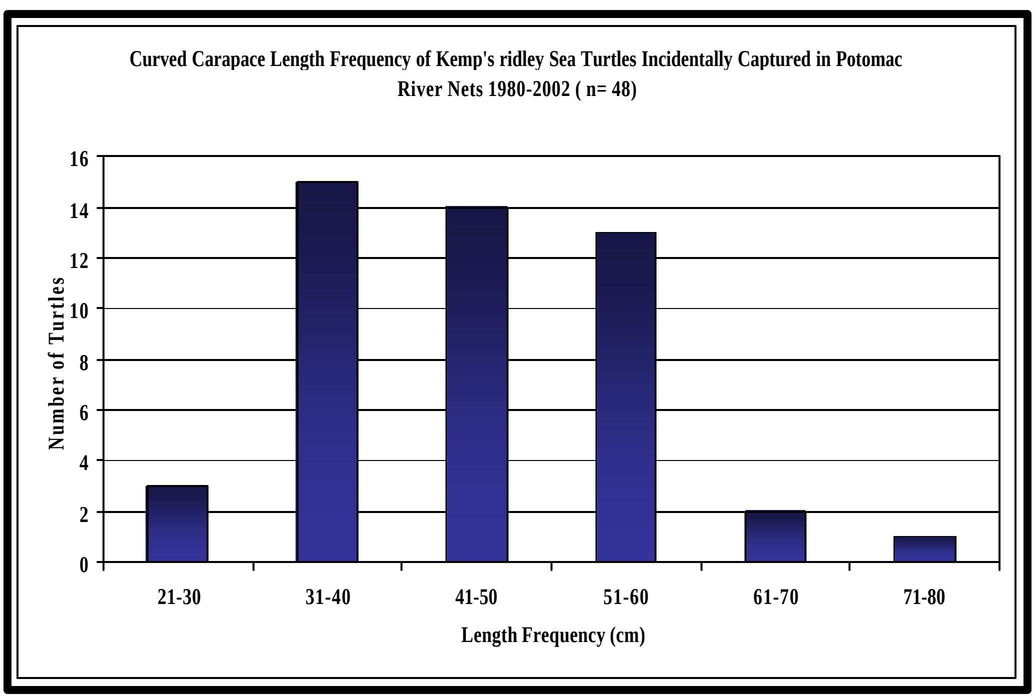


Figure 8.3 Length frequency distributions (cm) of Kemp's ridleys captured incidentally in Potomac River pound net study, 1980-2002.

Nuevo, Mexico. This turtle (PPX857) was originally captured in the Potomac River pound nets on June 7, 1989 with a CCL of 50.7 cm. PPX857 was observed nesting twice in 1996 (May 2 and May 28) on the beach at Rancho Nuevo, Mexico. Observed CCL during her nesting events was 70.0 and 71.3 cm respectively.

Of the 436 total turtles captured, 406 turtles were caught between the months of May through October. Incidental captures began in May and increased within the first two weeks of June. Captures peaked in the second half of June but then gradually tapered off until the fall when turtles began their southern migration out of the Bay. This peak followed the average peak in sea turtle strandings during the first two weeks of June within the Western Bay (Figure 8.4). The majority of turtles were seen only once and the ones that did return to the same nets did so over an average of three to four years. One turtle in particular was first captured and tagged in 1994. At the time of first capture, the turtle was already close to adult size (97.8 cm CCL; 90.7 cm straight carapace length [SCL]). Measurements during the 1999 season (99.7 cm CCL; 91.2 SCL) indicate SSB-919 had a slow growth between recapture events Minimal differences in CCL measurements were recorded among subsequent recapture years. This coupled with the relative size of the turtle suggests that SSB-919 had shifted its energetic budget from growth to reproduction. An ultrasound was performed, and the presence of well formed eggs and egg follicles within the infundibulum and oviduct confirmed that this turtle was an adult female. SSB-919 was recaptured a total of 13 times within the Potomac River pound nets between 1999 and 2002.

During all tracking seasons, SSB-919 returned to the Potomac River study site within seven to ten days post-release. Satellite tracking data for SSB-919 in 1999

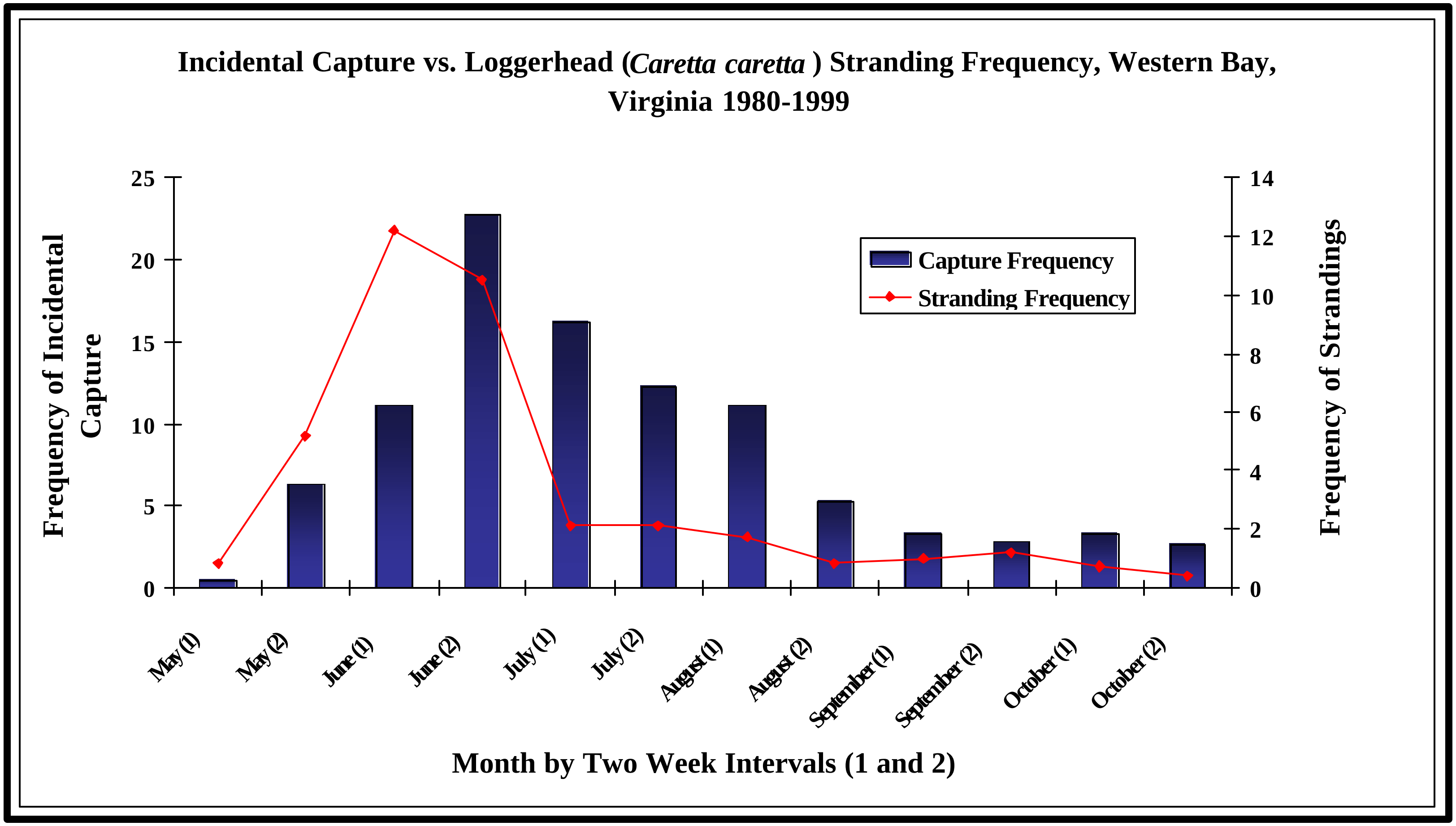


Figure 8.4 Incidental captures versus loggerhead stranding frequency, Western Bay, Virginia, 1980-1999. Mean western bay strandings (n= 2925): 139.3 (+/- 60.0 SD)

indicates that she remained in close proximity to the Potomac River nets during the time that she was resident in the Chesapeake Bay (Figure 8.5). She was caught multiple times in 1999 both before and after being tagged with a satellite transmitter, and showed significant fidelity to the mouth of the Potomac River ($p<0.0009$; $r^2=0.0199$). Year One (1999) kernel analyses indicated a range (95% confidence contour) of 1511.8 km^2 and a concentrated home range (50% confidence contour) of 411.7 km^2 (Figure 8.6). She was released with the satellite tag on August 10 and the tag remained active through October 21, 1999. At the time of tag failure, she was still in the Bay and within her home range. Ambient temperatures recorded by her tag were 15º C at the time of tag failure. The mean temperature recorded by her tag was 22.0° C (+/- 3.7° C SD) with a range in recorded temperature between 15.2° C and 26.6° C.

Her tracks during Year Two (2000) exhibited a similar behavioral pattern to Year One (Figure 8.7) including strong site fidelity ($p<0.0009$; $r^2=0.00476$) to the mouth of the Potomac River. The area associated with SSB-919's Year Two range (95% confidence contour) was 1600.8 km^2, including a 50% confidence contour of 392.5 km^2 (Figure 8.8). She was released with her tag on June 22, and the tag ceased transmitting on February 14, 2001. She maintained residence for over four months before she began her southern winter migration in November when ambient temperatures recorded by her tag and VIMS Ferry Pier data dropped to 13° C. SSB-919 over-wintered south of Cape Hatteras, North Carolina, at the edge of the Gulf Stream, along the continental shelf. The mean temperature recorded by her tag was 19.1° C (+/- 3.7° C SD) with temperatures ranging between 9.8° C and 25.9° C. At the time of tag failure, ambient temperatures were between 11° and 12° C.

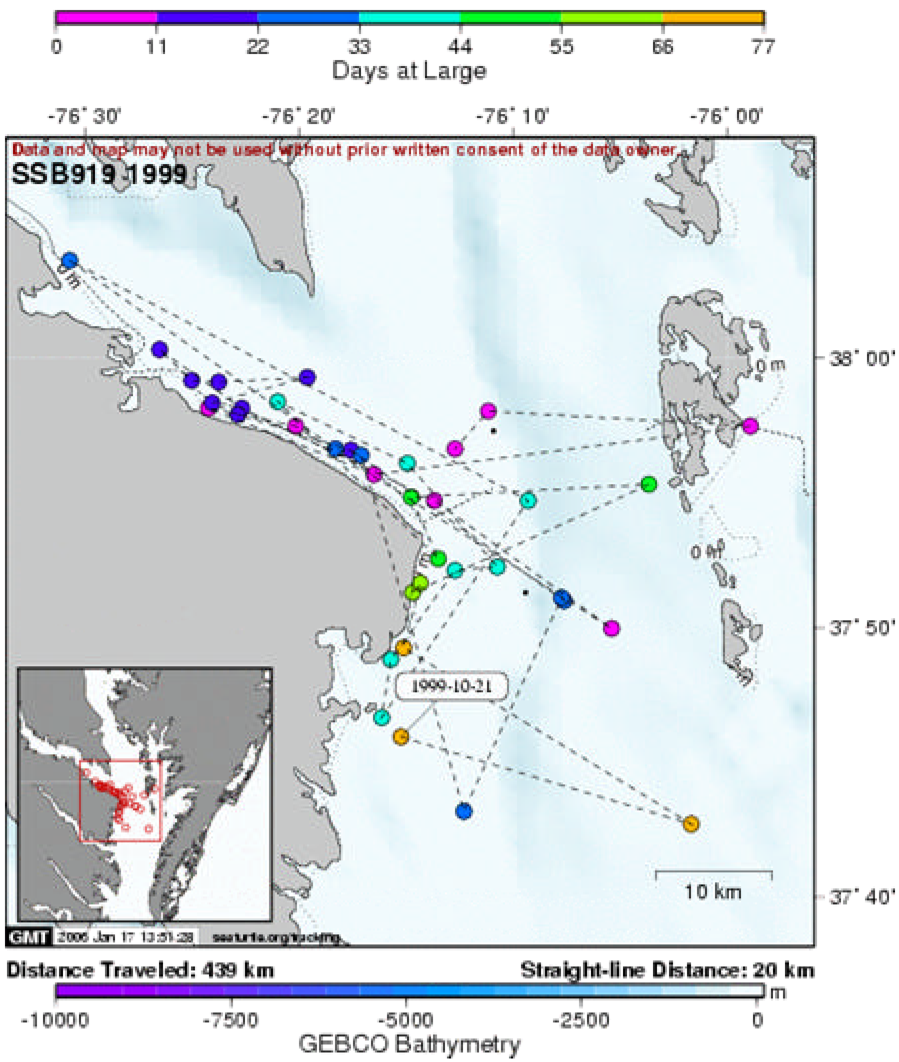


Figure 8.5 Year One satellite tracks of SSB-919 movements, August 10-October 21, 1999.

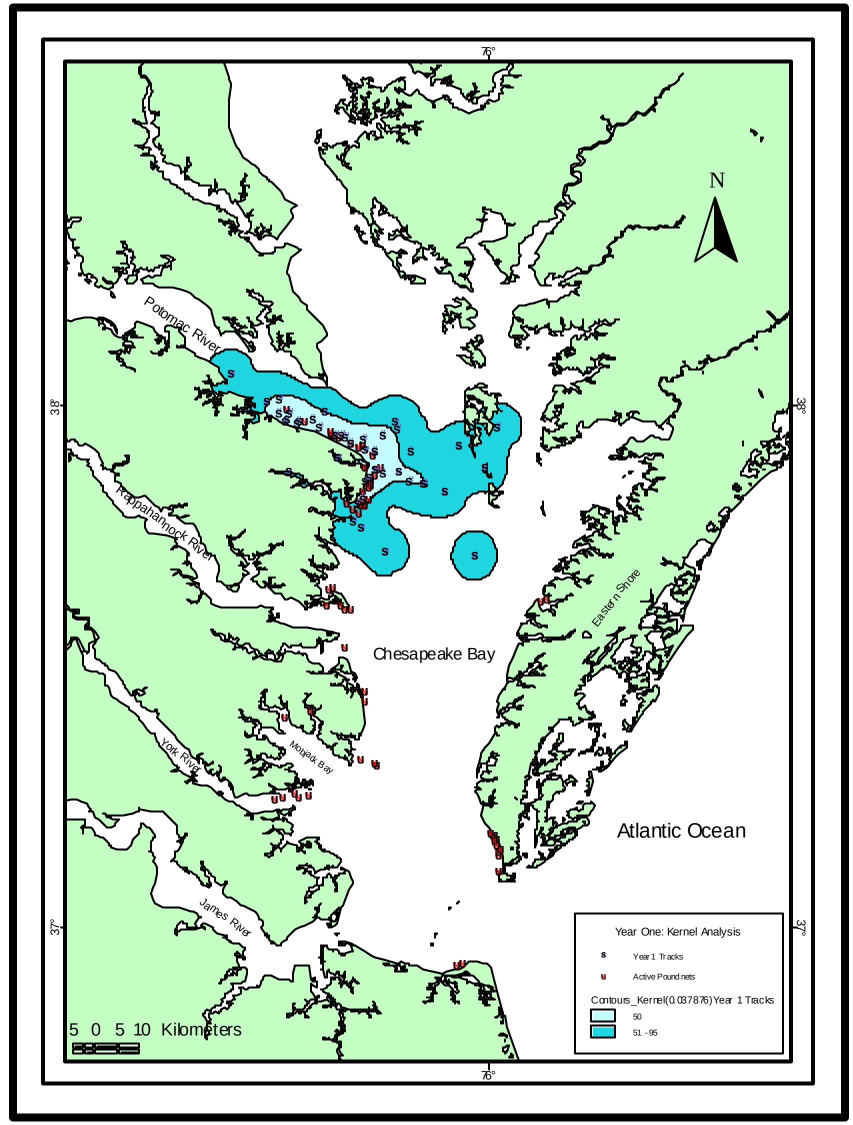


Figure 8.6 Year One Kernel analysis of SSB-919 movements, August 10-October 21, 1999.

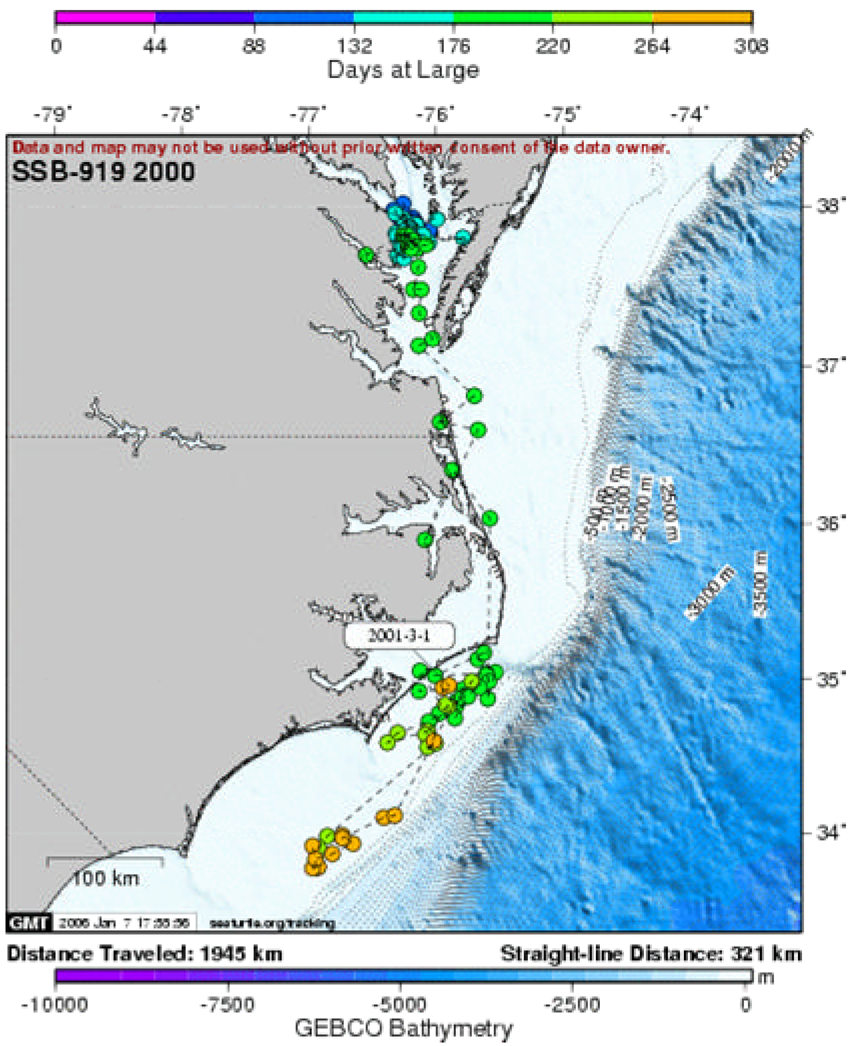


Figure 8.7 Year Two satellite tracks including fall migration excluding fall migration of SSB-919 movements, June 22, 2000 through February 14, 2001

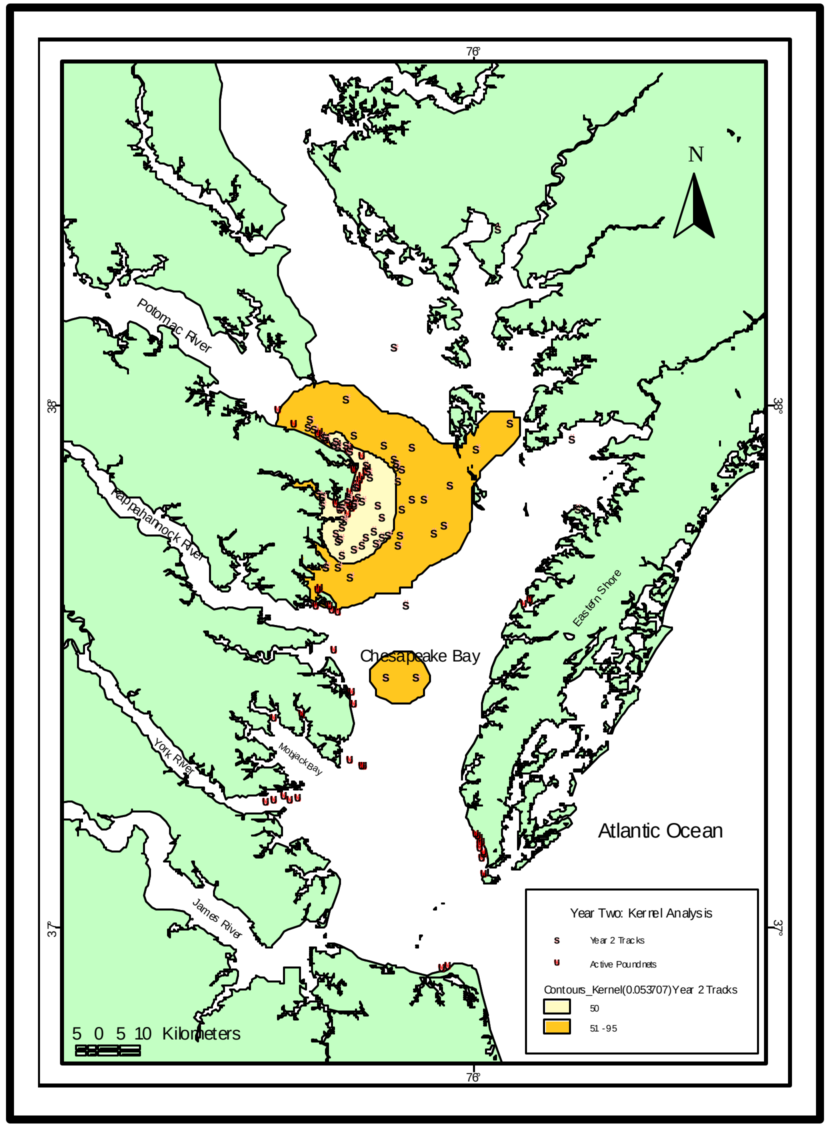


Figure 8.8 Year Two Kernel analysis excluding fall migration of SSB-919 movements, June 22, 2000 through February 14, 2001

Year Three (2001) tracks were recorded from SSB-919's release on September 18 through October 10, 2001 when the tag failed pre-maturely. The mean temperature recorded by her tag was 20.5° C (+/- 2.5° C SD) with temperatures ranging between 16.0° C and 24.3° C. At the time of tag failure, SSB919 was still within her home range and ambient temperatures were approximately 16° C. As in years One and Two, she exhibited significant site fidelity to the mouth of the Potomac River ($p<0.0009$; $r^2=0.0069$). However the tag transmitted inconsistently for a three-week period (n=17 locations). Kernel areas were much smaller than in years One or Two including in a range (95% contour) of 787.0 km^2 and home range (50% contour) of 148.1 km^2 (Figure 8.9). Between years One, Two and Three, the percentage of area overlap among the 95% confidence contours was 73.9%. Between the 50% contours, there was 39.5% overlap (Figure 8.10).

Table 8.1 lists the distribution of ARGOS location classes for each track year; most location classes were Class B. Mean travel speeds per track ranged between 1.6 km/hr (+/- 2.4 km/hr SD) to 2.0 km/hr (+/- 2.7 km/hr SD). She ranged up to 115 km from shore in 2001 when she traveled south of Cape Hatteras, however remained between 3.2 km and 2.3 km (+/-3.3 and 2.4 km SD respectively), offshore on average during her residency in the Bay (Table 8.2) Mean depths associated with her locations ranged between 6.7 m (+/- 4.1 m SD) and 18.2 (+/- 13.7 m SD) (Table 8.2).

In 2000 and 2001, SSB-919 was recaptured with her satellite transmitters still attached, despite cessation in transmission. The tags were still securely attached to her carapace with marine epoxy. Some bio-fouling was documented as was severe damage to

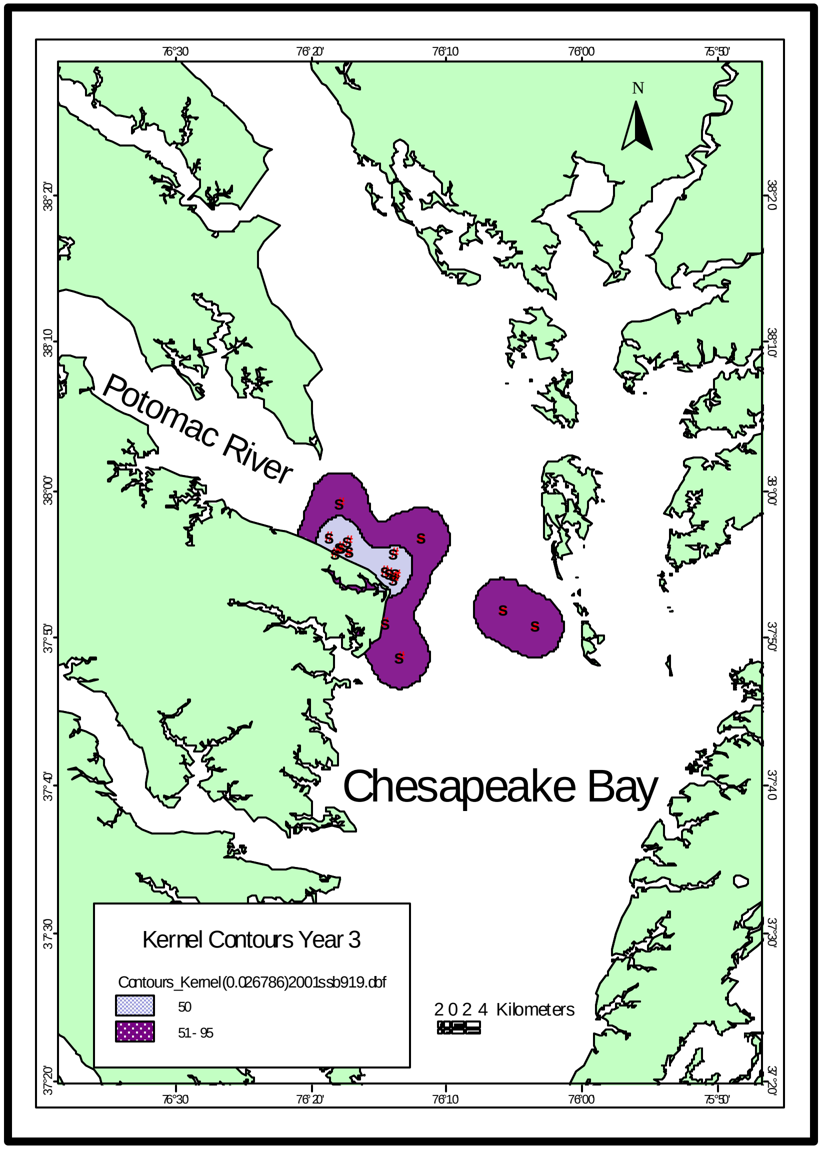


Figure 8.9 Year Three SSB-919 Kernel analysis, September 18-October 10, 2001

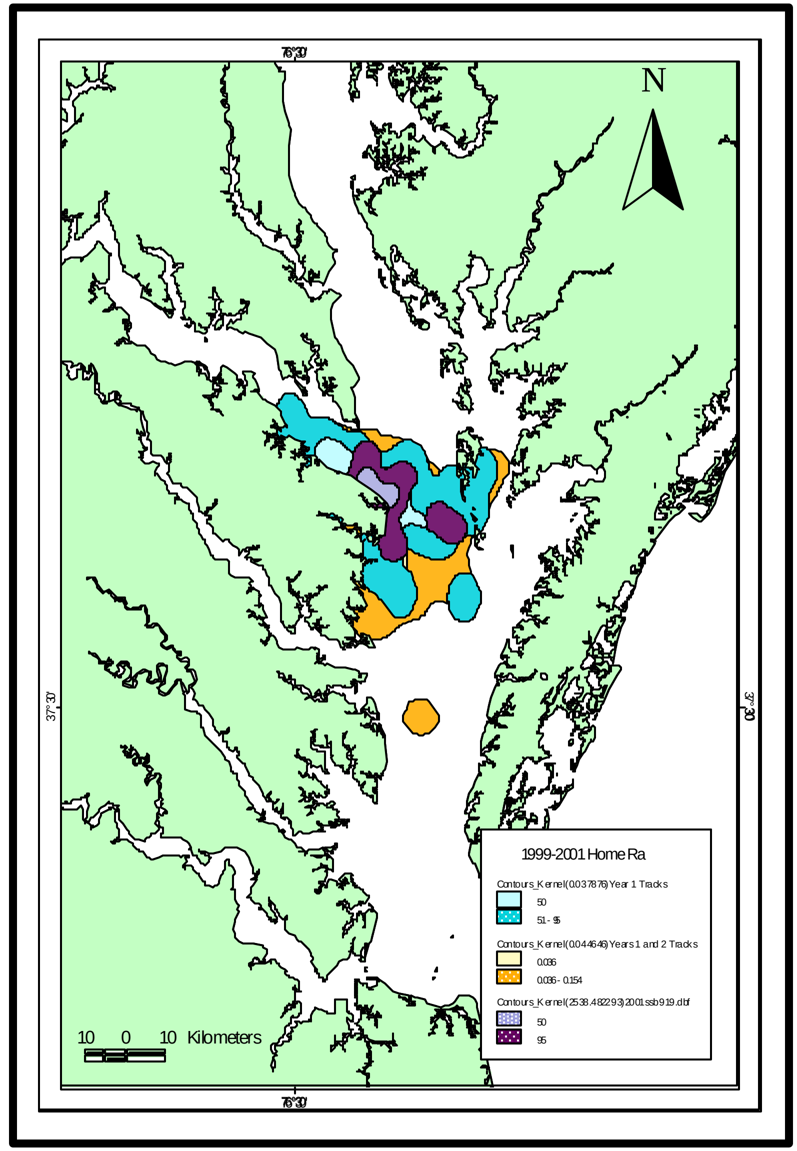


Figure 8.10 Years One, Two and Three (Bay residency) Kernel overlap

Table 8.1 ARGOS location code distribution for SSB-919 tracks 1999 to 2001

	Track Year		
	1999	**2000**	**2001**
Release Date	8/10/1999	6/22/2000	9/18/2001
Release Location	37.900N	37.247N	37.247N
	-76.250W	-76.507W	-76.507W
Duration (days)	72	237	22
LC			
3	0	0	0
2	2	3	1
1	5	12	0
0	2	32	0
A	5	33	6
B	42	62	14
Total Locations	**56**	**142**	**21**

Table 8.2 Summary statistics of SSB919 movement data derived in STAT, 1999 to 2001 (Coyne and Godley 2005).

Track Year	Release Date	Mean Depth (m)	Depth Range (m)	Distance from Shore (m)	Distance Range (m)	Mean Speed (km/hr)	Speed Range (km/hr)	Mean Bearing (º)
1999	8/10/1999	7.9 (+/- 5.8 SD)	1.2 to 25.3	3.2 (+/- 3.3 SD)	0 to 12.0	1.6 (+/- 2.4 SD)	0 to 12.9	167 (+/- 101 SD)
2000	6/22/2000	18.2 (+/- 13.7 SD)	0.13 to 49.0	2.0 (+/- 2.7 SD)	0 to 115	2.0 (+/- 2.7 SD)	0 to 14.8	176 (+/- 99 SD)
2001	9/18/2001	6.7 (+/- 4.1 SD)	2.0 to 15.4	2.3 (+/- 2.4 SD)	0 to 8.0	1.4 (+/- 1.6 SD)	0 to 6.0	165 (+/- 98 SD)

the antennae or exposed tags. Tags were removed and returned to the manufacturer for refurbishment.

In addition to three years of satellite telemetry, SSB-919 was radio-tracked during the 2002 season. She was captured for a fourth year in a row in July 2002, and subsequently released and radio-tracked from the VIMS beach on July 16, 2002. A detailed synopsis of this track including surfacing and dive times may be found in Chapter 2 (Track ID #211; Figure 2.11). SSB-919 was last seen swimming against a flood tide towards the mouth of the York River. She was recaptured in the mouth of the Potomac River ten days later within the same pound net that she was originally captured in earlier that season. She was captured one more time in the same pound net later in the summer.

Two additional turtles captured by pound net were satellite and radio-tracked for the surfacing behavior study in Chapter 2. One turtle was a juvenile loggerhead (Chapter 2; Track ID #137; Figure 2.17), the other, a juvenile Kemp's ridley (Chapter 2; Track ID #192; Figure 2.4). Both turtles were displaced to the mouth of the Chesapeake Bay for release. Each turtle returned to the vicinity of its original capture location, establishing concentrated home ranges near the mouth of the Potomac River (Chapter 2, Figures 2.4 and 2.3). The Kemp's ridley, also established an initial home range within Mobjack Bay before eventually returning to the vicinity of the Potomac River Mouth (Figure 2.4).

DISCUSSION

The Potomac River pound nets in the site fidelity study represent only a handful of pound nets that are present throughout the Chesapeake Bay. The total number of nets set by the Potomac River fisherman ranged between five and seven nets per year, versus upwards of 300 pound nets set throughout the Bay in the 1980's and approximately 70 to 80 nets currently set in the Bay (Mansfield et al. 2001a; 2002a; 2002b; Chapter 7). With the exception of the Potomac River fisherman, most fishermen have not regularly informed VIMS of incidental captures since the mid-1980's. At best, the incidental captures and recapture rates presented in this chapter provide a conservative recapture estimate.

Few data are available on the frequency of incidental captures within other Bay nets over time. More data are needed regarding whether there is a higher concentration of foraging turtles near the mouth of the Potomac River, or whether the frequency of incidental capture is consistent throughout the Bay. Aerial data (Chapter 5; Mansfield et al. 2002a; 2002b) suggest, however, that there is a smaller concentration of sea turtles in this region than in the lower Bay. Considering that the Potomac River nets alone captured 14 to 94 turtles per year, total incidental captures of turtles in Bay pound nets may be very high compared to actual bycatch mortalities from leader entanglements (6 to ~130 turtles per year: Bellmund et al. 1987, versus 4 to 5 per year: NMFS 2004a; Chapter 7).

Regardless, the high number of loggerhead turtles caught per year within the Potomac nets has strong management implications. These mark-recapture data indicate that some turtles show fidelity to particular nets and will return to the same nets year after year. Strong foraging site fidelity among loggerheads, including strong inter-annual site fidelity, indicate that some turtles actively interact with pound nets. However, once inside the pound head, the type of take associated with this behavior is typically non-lethal. This behavior and the different types of sea turtle takes associated with this gear type should be considered when developing management plans. These results also suggest that studies using live captures of loggerheads from pound nets or other fixed gears in order to characterize habitat utilization and turtle distribution within a broad region should identify foraging site fidelity as a potential spatial bias.

Kernel analyses of SSB-919 indicate that her concentrated home range was larger than the area within which the Potomac River pound nets occupied. After satellite attachment in 2000, this turtle was found in another fisherman's pound net just south of the Potomac River mouth near Reedville, Virginia. The high percentage (73.9%) of home range overlap between Year One and Year Two and recaptures in the same nets within one to two weeks of release from the York River further supports a hypothesis of strong foraging site fidelity for this turtle. It is also possible that adult loggerheads may exhibit larger home range than juveniles: Byles (1988) radio-tracked 14 juveniles foraging in Bay; juvenile range (95% probability) was 10-80 km^2, and preferred juvenile home range (50% probability) was 5-15 km^2. There is some difficulty in making these comparisons as the method of track collection and home range analyses differ between studies. Byles home ranges were calculated using minimum convex polygons, resulting in areas that encompassed the entire track. His sampling was also limited to site specific radio and acoustic receivers versus the wider reception area associated with satellite telemetry; however, location accuracy associated with satellite telemetry is not as precise as observed bearings from manual radio and sonic tracking.

SSB-919's four-year tracking dataset provided rare insight to inter-annual behavior of an adult Chesapeake Bay forager. These data help define both her migration route and over-wintering habitat. The close proximity of her over-wintering site to her summer foraging grounds would indicate that her energetic expenditure for seasonal migration was minimal relative to other adult turtles tracked from Virginia's nesting beaches (Chapter 3; Mansfield et al. 2001b). These data also provided insight into the temperature preferences of this individual. SSB919 remained in Bay until temperatures dropped much lower than previously estimated critical migration temperature of 18° C (Coles 1999).

Kemp's ridleys were not recaptured with the same frequency as the loggerheads perhaps as a result of differences in habitat preference and foraging patterns or habitat partitioning between the two species. Radio and acoustic tracking data of both species in the Bay indicate that loggerheads preferentially orient towards the outflows of rivers and along channels, foraging with the tides (Byles, 1988). In contrast, Kemp's ridleys were found to stay within shallower areas less affected by tidal flux (Byles, 1988). Pound nets located in areas of higher tidal flow typically have large mesh (> 8 in or 20 cm bar) leaders or string leaders in order to be able to withstand the force of the currents and to minimize the amount of debris snagged by the nets. Turtles that frequent these nets may be at greater risk early in the season after their spring migration.

Due to recently declines in both fishing effort and in the use of large mesh or string leaders, Virginia's pound net fishery is no longer the sole or primary source of sea turtle mortality in the Chesapeake Bay (Chapters 6 and 7). However, pound heads may remain a significant source of non-lethal take due to both gear type (semi-permanent fixed gear) and turtle behavior (foraging site fidelity). This is demonstrated by high recapture rates observed in just a handful of nets. Turtle behaviors such as fidelity to a particular foraging area and/or 'trap-happiness' of some turtles recaptured multiple times in pound heads, contribute to bycatch rates in Virginia's pound net fishery. Allowable sea turtle take limits for Virginia's pound net fishery should incorporate both non-lethal incidental captures of sea turtles in pound heads and lethal takes in leaders.

APPENDICES

APPENDIX A. ARGOS location accuracy codes (LC) and estimated accuracy (ARGOS Users Manual; Millspaugh and Marzluff, 2001). 68% of locations are expected to fall within the distances listed. Codes pertain to data generated after 1994.

Class Code	Specifications	Accuracy
3	> 4 messages received from satellite	150 m
2	> 4 messages received from satellite	350 m
1	4 messages received from satellite	1 km
0	2 messages received from satellite	> 1 km
A	3 messages	> 4 km*
B	2 messages	> 10 km*

* Based on data from Brothers et al. (1998) and Britten et al. (1999)

APPENDIX B. ARGOS location indicator (LI) codes and associated estimated accuracy (ARGOS Users Manual 1988).

Location Indicator	Specifications	Equivalent LC Code*
0	> or = 4 messages received from satellite; less than 24 seconds between start and end of pass	~0
-1	> or = 4 messages received from satellite; messages are bunched at end of pass or excessive oscillator drift during pass	~0
-2	3 messages received from satellite; last location more than 12 hours old	A
-3	3 messages received; last location more than 12 hours old	B
-4	2 messages received; last location more than 12 hours old	Z
-5	2 messages received; last location less than 12 hours old	Z
-6	Location impossible: either one location received or geometric initialization aborted	Z
-7	Location rejected: unacceptable distance from ground track	Z
-8	Location rejected: unsatisfactory internal consistency	Z
-9	Location rejected: excessive longterm oscillator drift	Z
-10	Location or choice of solution impossible	Z

*LC Code based on number of messages received. Additional filtering of data points may be necessary. Class Code 0 may represent LC Code 0-3; a minimum of 0 was assumed.

Appendix C. Transect line locations, Chesapeake Bay, Virginia 2001-2004

Lines		Latitude		Longitude	
Transect	**Point Origin**	**Degrees**	**Minutes**	**Degrees**	**Minutes**
1	**West**	36	56.5	-76	13.8
	East	36	56.5	-75	56.5
2	**West**	36	57.5	-76	15.4
	East	36	57.5	-75	56.5
3	**West**	36	58.5	-76	16.5
	East	36	58.5	-75	56.5
4	**West**	36	59.5	-76	16.5
	East	36	59.5	-75	56.5
5	**West**	37	0.5	-76	16.5
	East	37	0.5	-75	56.5
6	**West**	37	1.5	-76	16.5
	East	37	1.5	-75	56.5
7	**West**	37	2.5	-76	16.5
	East	37	2.5	-75	56.5
8	**West**	37	3.5	-76	16.5
	East	37	3.5	-75	56.5
9	**West**	37	4.5	-76	16.5
	East	37	4.5	-75	56.5
10	**West**	37	5.5	-76	16.5
	East	37	5.5	-75	56.5
11	**West**	37	6.5	-76	16.5
	East	37	6.5	-75	56.5
12	**West**	37	7.5	-76	17.6
	East	37	7.5	-75	58.3
13	**West**	37	8.5	-76	19.4
	East	37	8.5	-75	58.5
14	**West**	37	9.5	-76	20.4
	East	37	9.5	-75	58.7
15	**West**	37	10.5	-76	23.6
	East	37	10.5	-75	59.5
16	**West**	37	11.5	-76	23.4
	East	37	11.5	-76	0.0
17	**West**	37	12.5	-76	25.1
	East	37	12.5	-76	0.8
18	**West**	37	13.5	-76	23.3
	East	37	13.5	-76	0.7
19	**West**	37	14.5	-76	27.0
	East	37	14.5	-76	1.1
20	**West**	37	15.5	-76	25.6
	East	37	15.5	-76	1.5
21	**West**	37	16.5	-76	23.0
	East	37	16.5	-76	1.0

Lines		Latitude		Longitude	
Transect	**Point Origin**	**Degrees**	**Minutes**	**Degrees**	**Minutes**
22	**West**	37	17.5	-76	23.6
	East	37	17.5	-76	0.7
23	**West**	37	18.5	-76	23.3
	East	37	18.5	-75	59.8
24	**West**	37	19.5	-76	24.7
	East	37	19.5	-76	1.0
25	**West**	37	20.5	-76	25.1
	East	37	20.5	-76	0.2
26	**West**	37	21.5	-76	26.3
	East	37	21.5	-75	59.6
27	**West**	37	22.5	-76	15.0
	East	37	22.5	-75	59.2
28	**West**	37	23.5	-76	14.4
	East	37	23.5	-75	56.5
29	**West**	37	24.5	-76	14.9
	East	37	24.5	-75	58.2
30	**West**	37	25.5	-76	15.0
	East	37	25.5	-75	58.9
31	**West**	37	26.5	-76	15.1
	East	37	26.5	-75	58.8
32	**West**	37	27.5	-76	16.2
	East	37	27.5	-75	58.2
33	**West**	37	28.5	-76	15.8
	East	37	28.5	-75	57.8
34	**West**	37	29.5	-76	16.2
	East	37	29.5	-75	57.6
35	**West**	37	30.5	-76	16.8
	East	37	30.5	-75	57.4
36	**West**	37	31.5	-76	22.6
	East	37	31.5	-75	56.9
37	**West**	37	32.5	-76	19.7
	East	37	32.5	-75	56.3
38	**West**	37	33.5	-76	17.9
	East	37	33.5	-75	56.5
39	**West**	37	34.5	-76	23.3
	East	37	34.5	-75	56.1
40	**West**	37	35.5	-76	25.0
	East	37	35.5	-75	55.4
41	**West**	37	36.5	-76	25.9
	East	37	36.5	-75	55.0
42	**West**	37	37.5	-76	16.9
	East	37	37.5	-75	52.9
43	**West**	37	38.5	-76	18.2
	East	37	38.5	-75	53.6
44	**West**	37	39.5	-76	20.3
	East	37	39.5	-75	52.8

Lines		Latitude		Longitude	
Transect	**Point Origin**	**Degrees**	**Minutes**	**Degrees**	**Minutes**
45	**West**	37	40.5	-76	19.5
	East	37	40.5	-75	50.4
46	**West**	37	41.5	-76	21.3
	East	37	41.5	-75	51.0
47	**West**	37	42.5	-76	18.3
	East	37	42.5	-75	50.3
48	**West**	37	43.5	-76	19.2
	East	37	43.5	-75	48.0
49	**West**	37	44.5	-76	18.7
	East	37	44.5	-75	49.4
50	**West**	37	45.5	-76	18.8
	East	37	45.5	-75	46.5
51	**West**	37	46.5	-76	18.8
	East	37	46.5	-75	46.8
52	**West**	37	47.5	-76	18.7
	East	37	47.5	-75	48.6
53	**West**	37	48.5	-76	18.5
	East	37	48.8	-75	43.4
54	**West**	37	49.5	-76	15.6
	East	37	49.5	-75	43.0
55	**West**	37	50.5	-76	14.9
	East	37	50.5	-75	41.9
56	**West**	37	51.5	-76	14.7
	East	37	51.5	-75	41.4
57	**West**	37	52.5	-76	14.5
	East	37	52.5	-75	40.8
58	**West**	37	53.5	-76	15.0
	East	37	53.5	-75	42.0
59	**West**	37	54.5	-76	15.7
	East	37	54.5	-75	44.4
60	**West**	37	55.5	-76	17.8
	East	37	55.5	-75	43.6

Appendix D. Lower Bay strip transect abundance estimates by survey with seasonal corrections for sightability, 2001-2004

Survey Day	Area	No. Turtles Observed	Mean Densities	5% Correction	10% Correction	25% Correction
6/8/2001	64.80	8	0.123	3568.51	1888.10	755.24
6/12/2001	66.34	10	0.151	4357.09	2305.34	922.13
6/19/2001	59.68	8	0.134	3874.65	2050.08	820.03
6/26/2001	64.96	8	0.123	3559.72	1883.45	753.38
7/3/2001	56.92	2	0.035	1015.63		
7/10/2001	63.23	9	0.142	4114.25		
7/17/2001	72.62	3	0.041	1194.09		
8/7/2001	65.05	4	0.061	1777.40		
8/28/2001	62.30	6	0.096	2783.78		
9/6/2001	61.88	4	0.065	1868.45		
10/2/2001	63.42	1	0.016	455.77		
5/24/2002	65.14	2	0.031	887.47	469.56	187.82
5/29/2002	75.66	5	0.066	1910.18	1010.68	404.27
6/11/2002	62.17	6	0.097	2789.60	1475.98	590.39
6/20/2002	59.80	1	0.017	483.36	255.75	102.30
6/26/2002	64.49	4	0.062	1792.83	948.59	379.43
7/2/2002	63.41	2	0.032	911.68		
7/9/2002	59.93	1	0.017	482.31		
7/17/2002	64.18	8	0.125	3602.98		
7/30/2002	62.51	4	0.064	1849.62		
8/8/2002	60.78	2	0.033	951.13		
8/20/2002	65.19	2	0.031	886.79		
9/3/2002	73.22	5	0.068	1973.84		
9/17/2002	63.84	0	0.000	0.00		
10/1/2002	62.32	2	0.032	927.63		
10/28/2002	66.09	1	0.015	437.36		
5/14/2003	64.79	2	0.031	892.26	472.10	188.84
5/28/2003	59.18	0	0.000	0.00	0.00	0.00
6/5/2003	66.10	6	0.091	2623.74	1388.22	555.29
6/11/2003	67.56	9	0.133	3850.56	2037.34	814.93
6/27/2003	63.25	11	0.174	5026.94	2659.76	1063.90
7/9/2003	61.80	6	0.097	2806.30		
7/16/2003	77.43	0	0.000	0.00		
7/24/2003	61.14	2	0.033	945.53		
8/12/2003	61.85	7	0.113	3271.37		
8/26/2003	60.43	6	0.099	2869.92		

Survey Day	Area	No. Turtles Observed	Mean Densities	%5 Correction	10% Correction	25% Correction
5/13/2004	59.18	6	0.101	2930.54	1550.55	620.22
5/19/2004	62.02	2	0.032	932.12	493.18	197.27
5/25/2004	64.47	4	0.062	1793.39	948.88	379.55
6/1/2004	64.04	7	0.109	3159.50	1671.69	668.68
6/22/2004	61.87	2	0.032	934.38	494.38	197.75
6/29/2004	61.55	1	0.016	469.62	248.47	99.39
7/6/2004	62.04	1	0.016	465.91		
7/13/2004	59.69	3	0.050	1452.75		
7/20/2004	73.15	0	0.000	0.00		
8/10/2004	66.39	7	0.105	3047.66		
8/24/2004	64.96	2	0.031	889.93		
10/13/2004	62.03	1	0.016	465.98		

Appendix E. Upper Bay strip transect abundance estimates per survey with seasonal corrections for sightability, 2001-2004.

Survey Day	Area	No. Turtles Observed	Mean Densities	5% Correction	10% Correction	25% Correction
6/8/2001	18.79	1	0.053	1890.41	1000.22	400.09
6/12/2001	84.73	9	0.106	3773.02	1996.30	798.52
6/19/2001	77.78	2	0.026	913.37	483.26	193.31
6/26/2001	75.61	5	0.066	2348.95	1242.83	497.13
7/3/2001	25.79	0	0.000	0.00		
7/10/2001	79.00	2	0.025	899.26		
7/17/2001	90.87	4	0.044	1563.59		
8/7/2001	79.93	9	0.113	3999.60		
8/28/2001	77.50	1	0.013	458.33		
9/6/2001	81.61	1	0.012	435.25		
10/2/2001	76.01	0	0.000	0.00		
5/24/2002	67.46	8	0.119	4212.37	2228.77	891.51
5/29/2002	81.65	16	0.196	6960.61	3682.86	1473.14
6/11/2002	25.37	0	0.000	0.00	0.00	0.00
6/26/2002	81.16	3	0.037	1312.99	694.71	277.88
7/2/2002	78.46	4	0.051	1810.90		
7/9/2002	79.70	1	0.013	445.68		
7/17/2002	80.46	3	0.037	1324.42		
7/30/2002	84.06	2	0.024	845.13		
8/8/2002	81.93	1	0.012	433.55		
8/20/2002	40.76	0	0.000	0.00		
9/3/2002	78.43	2	0.026	905.80		
9/17/2002	72.08	1	0.014	492.80		
10/1/2002	66.09	2	0.030	1074.92		
5/14/2003	67.80	0	0.000	0.00	0.00	0.00
5/28/2003	12.08	0	0.000	0.00	0.00	0.00
6/5/2003	89.29	15	0.168	5967.22	3157.26	1262.90
6/11/2003	25.79	0	0.000	0.00	0.00	0.00
6/27/2003	73.02	15	0.205	7296.81	3860.74	1544.30
7/9/2003	80.12	5	0.062	2216.73		
7/16/2003	33.78	2	0.059	2103.07		
7/24/2003	73.59	2	0.027	965.37		
8/12/2003	84.28	3	0.036	1264.39		
8/26/2003	81.27	6	0.074	2622.43		
5/13/2004	38.41	6	0.156	5548.69	2935.81	1174.33
5/19/2004	30.53	2	0.066	2326.95	1231.19	492.48
5/25/2004	85.67	4	0.047	1658.50	877.51	351.00
6/1/2004	83.86	7	0.083	2965.01	1568.79	627.52
7/6/2004	74.06	1	0.014	479.62		
7/13/2004	87.97	3	0.034	1211.35		
7/20/2004	79.78	0	0.000	0.00		
8/10/2004	77.84	7	0.090	3194.32		
8/24/2004	40.35	2	0.050	1760.64		

Appendix F. Lower Bay strip transect abundance estimates by survey with seasonal corrections for sightability, 1982, 1983, 1985-1987 and 1994.

Survey Day	Area	No. Turtles Observed	Survey Densities	5% Correction	10% Correction	25% Correction
5/17/1982	75.15	54	0.719	18782.30	9937.72	3975.09
6/3/1982	67.55	14	0.207	5417.35	2866.32	1146.53
6/17/1982	60.80	5	0.082	2149.56	1137.34	454.93
7/2/1982	70.80	29	0.410	10706.53		
7/6/1982	66.90	17	0.254	6642.12		
8/2/1982	72.80	13	0.179	4667.63		
8/15/1982	72.60	3	0.041	1080.11		
9/2/1982	72.80	17	0.234	6103.82		
9/17/1982	68.85	5	0.073	1898.24		
10/1/1982	68.85	2	0.029	759.29		
5/16/1983	68.85	17	0.247	6454.00	3414.81	1365.93
5/25/1983	66.90	42	0.628	16409.95	8682.51	3473.00
6/2/1983	72.80	43	0.591	15439.07	8168.82	3267.53
6/13/1983	68.55	86	1.255	32792.53	17350.55	6940.22
6/30/1983	68.55	18	0.263	6863.55	3631.51	1452.60
7/14/1983	66.90	10	0.149	3907.13		
8/3/1983	72.80	3	0.041	1077.14		
8/22/1983	68.55	16	0.233	6100.94		
9/1/1983	70.45	7	0.099	2597.17		
9/20/1983	72.60	29	0.399	10441.08		
10/6/1983	70.45	5	0.071	1855.12		
10/18/1983	68.55	8	0.117	3050.47		
5/16/1985	72.65	16	0.220	5756.63	3045.84	1218.33
5/28/1985	70.45	3	0.043	1113.07	588.93	235.57
6/?/1985*	68.65	58	0.845	22083.68	11684.49	4673.79
7/5/1985	68.55	7	0.102	2669.16		
7/19/1985	72.65	46	0.633	16550.31		
7/31/1985	72.65	6	0.083	2158.74		
8/15/1985	68.55	15	0.219	5719.63		
8/27/1985	72.70	9	0.124	3235.88		
9/24/1985	70.45	3	0.043	1113.07		
10/1/1985	66.90	8	0.120	3125.70		
10/18/1985	72.80	2	0.027	718.10		

***Detailed survey data missing from archives**

Survey Day	Area	No. Turtles Observed	Survey Densities	5% Correction	10% Correction	25% Correction
5/26/1986	68.20	20	0.293	7665.31	4055.72	1622.29
6/4/1986	65.20	6	0.092	2405.40	1272.70	509.08
6/18/1986	68.20	4	0.059	1533.06	811.14	324.46
6/30/1986	62.30	17	0.273	7132.55	3773.84	1509.53
7/16/1986	72.65	16	0.220	5756.63		
8/3/1986	68.20	25	0.367	9581.63		
9/9/1986	65.20	12	0.184	4810.80		
9/29/1986	65.20	13	0.199	5211.70		
10/17/1986	62.30	5	0.080	2097.81		
10/30/1986	68.90	4	0.058	1517.49		
5/29/1987	70.45	49	0.696	18180.22	9619.16	3847.67
6/5/1987	66.90	7	0.105	2734.99	1447.09	578.83
6/9/1987	68.85	7	0.102	2657.53	1406.10	562.44
6/19/1987	72.60	18	0.248	6480.67	3428.93	1371.57
6/30/1987	74.25	13	0.175	4576.47	2421.41	968.57
7/10/1987	66.90	7	0.105	2734.99		
7/29/1987	66.90	20	0.299	7814.26		
8/20/1987	66.90	8	0.120	3125.70		
9/18/1987	72.80	12	0.165	4308.58		
10/6/1987	72.60	2	0.028	720.07		
10/30/1987	72.60	2	0.028	720.07		
5/6/1994	68.55	3	0.044	1143.93	605.25	242.10
6/1/1994	68.55	6	0.088	2287.85	1210.50	484.20
6/21/1994	70.80	10	0.141	3691.91	1953.39	781.36
7/6/1994	72.80	23	0.316	8258.11		
8/10/1994	66.90	21	0.314	8204.97		
8/24/1994	70.45	2	0.028	742.05		
9/15/1994	70.45	4	0.057	1484.10		
9/27/1994	68.55	1	0.015	381.31		
10/18/1994	66.90	2	0.030	781.43		

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