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Spatial and Temporal Patterns of Habitat Use and Mortality of the Florida Manatee (*Trichechus manatus latirostris*) in the Mid-Atlantic States of North Carolina and Virginia from 1991 to 2012

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Abstract

Florida manatees (*Trichechus manatus latirostris*) are known to range north into the U.S. mid-Atlantic during warmer summer and fall months. However, rapid cooling of water temperatures in the fall can be detrimental to their survival in this region. This study reports upon all known manatee sightings ($n = 211$) and strandings ($n = 9$) from 1991 to 2012 in North Carolina and Virginia. The goals were to describe spatial and temporal patterns of manatee habitat use and mortality and relate those patterns to seasonal water temperatures, and to develop a finer-scale understanding of environmental temperatures across the region by deploying temperature data loggers at multiple sites throughout inland and coastal waterways.

Although sightings were opportunistically gathered and, thus, not corrected for effort, they reveal a consistent picture of manatee presence in the mid-Atlantic. In both states, sightings were most common from June to October when water temperatures were above 20° C. Sightings in North Carolina were most common in the Intracoastal Waterway (27%), and in rivers and creeks (46%) in Virginia. Fine-scale temperature data collected throughout the region demonstrated highly variable, declining water temperatures in late fall, with temperatures dropping by as much as 1.35° C/d. Manatee sightings decreased precipitously with water temperature in November, while strandings increased. The results of this study demonstrate that manatees are predictably found in North Carolina and Virginia throughout the late spring, summer, and fall. These data can be used to plan future education and outreach, monitoring, regulatory actions, and habitat protection measures for this endangered species in this region.

Key Words: mid-Atlantic, habitat, strandings, Florida manatee, *Trichechus manatus latirostris*

Introduction

The Florida manatee (*Trichechus manatus latirostris*), a subspecies of the West Indian manatee (*Trichechus manatus*), is listed as endangered under the U.S. Endangered Species Act (ESA) (Lefebvre et al., 2001; Reep & Bonde, 2006) and protected under the Marine Mammal Protection Act (MMPA), Section 3(6)(A). The current best available population count for the Florida manatee is 4,834, which is derived from a 2011 annual aerial synoptic survey (Florida Fish and Wildlife Conservation Committee [FWC], 2011). According to a recent population projection model (Runge et al., 2007), there will likely be a long-term decline in the Florida manatee population and a change in their regional distribution throughout Florida. These model predictions are based in part upon the projected loss of warm-water refugia within Florida, given scheduled closures of power plants and human use of aquifers that may reduce flows at natural warm-water springs (Laist & Reynolds, 2005).

Manatees are large, slow-moving herbivores with a low metabolic rate and high thermal conductance, which limits their ability to maintain core body temperatures in cold waters (Scholander & Irving, 1941; Gallivan & Best, 1980; Irvine, 1983; Rommel & Caplan, 2003; Reep & Bonde, 2006; Marsh et al., 2011). Likely because of the constraints of their thermal physiology, manatees typically modify their behavior to seek warmer water when temperatures drop below 20° C (Irvine, 1983; O'Shea et al., 1985; Bossart et al., 2002; Reep & Bonde, 2006; Marsh et al., 2011). While manatees can briefly tolerate water temperatures below 16° C, chronic exposure to these temperatures can lead to cold stress (Hartman, 1979; Bossart et al., 2002; Glaser & Reynolds, 2003). Cold stress describes a suite of clinical conditions and disease processes, including emaciation; infectious diseases of the skin and gastrointestinal tract; serous fat atrophy; lymphoid depletion; and compromise to metabolic, nutritional, and immunological functions that can lead to death (Walsh, 1998; Bossart, 2001; Bossart et al., 2002). The Florida manatee's thermal dependency on warm-water environments generally restricts their geographic distribution to tropical and subtropical waters of the eastern United States (Lefebvre et al., 2001; FWC, 2007).

It is generally accepted that the Florida manatee's year-round habitat is restricted to peninsular Florida where water temperatures remain relatively high throughout winter months and where there are numerous warm-water refugia (Reynolds & Wilcox, 1994). Manatees display seasonal home ranges and show strong philopatry to winter refuge sites (Domning & Hayek, 1986; Reid et al., 1991; Reynolds & Odell, 1991; Lefebvre et al., 2001; Deutsch et al., 2003). During spring through fall, Florida manatees are known to range extensively in the southeastern U.S. and Gulf of Mexico (Weigle et al., 2001; Deutsch et al., 2003; Fertl et al., 2005). Manatees tagged in Florida, for example, were tracked to South Carolina, and one individual traveled as far north as Rhode Island (Deutsch et al., 2003). Manatee distributional patterns have been best studied within Florida and Georgia, and also have been documented across the Gulf of Mexico and into the Bahamas (Powell & Rathbun, 1984; Lefebvre et al., 2001; Deutsch et al., 2003; Fertl et al., 2005). However, little is known about the distributional patterns of the Florida manatee north of the Georgia border on the Atlantic coast of the U.S.

Rathbun et al. (1982) collected all known sighting and stranding (carcasses) records available from 1908 through 1981 for manatees in Georgia, North Carolina, South Carolina, and Virginia. These authors reported that manatees could occur as far north as Virginia during summer months but that there were no known winter aggregations north of Florida. In total, five occurrences of manatees in Virginia (four live, one stranded) and 17 occurrences of manatees in North Carolina (13 live, four stranded) were reported. Schwartz (1995) collected all known sighting and stranding records in North Carolina (n = 53 and 2, respectively, which had not already been included in Rathbun et al., 1982) from 1919 through 1994. Many of these observations were of apparently young (1.8 to 2.4 m) manatees, and many were in inland river systems (Schwartz, 1995). To the best of our knowledge, no other information exists regarding manatees within the Mid-Atlantic States of North Carolina and Virginia.

Over the last decade, manatee sighting reports outside of Florida have steadily increased (U.S. Fish and Wildlife Service, pers. comm.). It has been suggested this pattern may be due to several factors, including an increase in the Florida manatee population, changes in regional weather patterns in possible response to global climate change, range expansion of the Florida manatee, and an increase in education and awareness resulting in greater reporting. As a result, in September 2009, the U.S. Fish and Wildlife Service (USFWS) held multiple manatee workshops along the Atlantic and Gulf coasts to increase coordination among agencies and organizations outside of Florida. The workshops were intended to enhance manatee reporting for sightings, rescues, and stranding response; promote standardized data collection; increase general knowledge of manatee biology and of the USFWS's Manatee Rescue, Rehabilitation and Release Program; and promote safe capture and handling techniques. Additionally, the USFWS was considering revising critical habitat designated for the Florida manatee, which currently did not extend beyond the state of Florida. This study was initiated to address existing gaps in our understanding of this thermally dependent, endangered species in the Mid-Atlantic States of North Carolina and Virginia.

The overall goals of this study were two-fold. The first was to describe the spatial and temporal patterns of manatee habitat use and mortality in the waters of North Carolina and Virginia between 1991 and 2012, and to relate those patterns to seasonal water temperatures. This portion of the study relied upon gathering sighting and stranding records for these states. The second goal was to develop a finer spatial scale understanding of the thermal environment experienced by manatees by deploying temperature data loggers at eight sites throughout the inland and coastal waterways of North Carolina and Virginia. These data can be used to inform future conservation efforts for this endangered species in this region.

Methods

Manatee Sighting Reports and Stranding Records

This study relied upon opportunistic sighting reports and stranding records, dating from July 1991 through September 2012. Historic manatee records were collected from private, state, and federal agencies in North Carolina and Virginia, including the North Carolina Division of Marine Fisheries, North Carolina Aquariums, Cape Fear River Watch, North Carolina Maritime Museum, North Carolina

Wildlife Resources Commission, North Carolina State University, Duke University, University of North Carolina Wilmington (UNCW), Virginia Aquarium and Marine Science Center, USFWS, and the U.S. Geological Survey (Sirenia Project). In addition, and building upon USFWS protocols, a request was made by UNCW to receive all future manatee sightings reported in these states.

A database was created for all sighting and stranding reports from North Carolina and Virginia and archived at UNCW. Because sighting reports were collected from numerous agencies over a 21-y period, the quality and type of data available for each record varied. When the general public reported a sighting, and the report could not be verified (confirmed with an image or by someone knowledgeable on manatees), the sighting was included in the dataset only if the description and behavior of the animal supported its identification as a manatee. In addition, for inclusion, the report needed to include a date and sufficient location information to record or determine latitude and longitude. Google Earth was used to obtain geographic coordinates for reports in which only a street address was given. Each sighting was treated as an independent event unless (1) a sighting was reported multiple times at the same location within a 24-h period, or (2) photographic evidence demonstrated that multiple sightings were of the same individual. In these cases, only the first sighting of the individual was included in the database. However, sighting data may include multiple sightings of the same individual when photographs were not obtained.

All sightings and strandings were mapped using *ArcGIS*, Version 10 (ESRI). Maps were used to identify manatee habitat use patterns and specific locations through which manatees often traveled. In this study, five habitats were identified: (1) open ocean, (2) Intracoastal Waterway, (3) sounds and bays, (4) rivers and creeks, and (5) marinas. Manatee sighting and stranding data were also plotted by latitude across years using *SAS*, Version 9.2, and overlaid on a map of coastal North Carolina and Virginia to investigate distributional patterns across the study period.

Water Temperature Data

Historic water temperature data records were required to investigate the relationship between environmental temperature and manatee sighting and stranding patterns. Unfortunately, no publicly available and consistent historic water temperature data records were found for the smaller inland waterways visited by manatees in the mid-Atlantic. Currently, the longest running water temperature database is that maintained by the U.S. Army Corps of Engineers Field Research Facility (USACE) in Duck, North Carolina. This shore-based ocean site provided data records of daily water temperatures from 1991 to 2012. Data were downloaded from the website (www.frf.usace.army.mil) and exported into *Excel* (Microsoft Office 2010). Data from the USACE for all years were combined to generate monthly median water temperatures. The monthly median temperatures were plotted against similarly combined monthly manatee sightings (all manatee sightings within a given month summed for 1991 through 2012) to examine the relationship between manatee presence and water temperature. These data were used to identify when manatees might be expected to enter and exit the coastal waters of North Carolina and Virginia.

To investigate spatial and temporal variation in inland water temperatures within the study area, eight temperature data loggers (Onset Computer Corporation, Hobo Model U22-001) were deployed (Figure 1). Deployment sites were chosen, in part, by examining historical sighting data to determine areas of high manatee sightings. Five data loggers were deployed in North Carolina and three in Virginia; these eight sites represent all five habitat types identified for this study. All data loggers were deployed between 28 July and 15 September 2011 and were retrieved between 17 and 26 September 2012 to yield at least one full year of temperature data at each site.

Before deployment and after retrieval, data loggers were calibrated using a Lauda Brinkmann water bath (Ecoline RE 120) over a temperature range of 3° to 33° C. Each data logger was set to record water temperatures every 4 h and was placed in a PVC housing to minimize fouling. The walls of the PVC housing had been pierced by multiple 0.5 to 1.0 cm diameter holes to permit water flow through the housing. The data loggers were deployed during low tide and placed as deeply as possible to minimize the possibility that they would be exposed during extreme low tides.

After a year's time, the data loggers were retrieved, and recorded temperatures were downloaded and plotted using HOBOware *Pro Software*, Version 3.2.0. Review of the temperature data indicated that the data loggers had been exposed during low tide at seven of the eight sites; however, this occurrence was rare. These exposures were marked by abrupt changes in recorded temperatures of greater than 3° C across a 4-h time period. After checking the timing of a subset of these events against tidal charts and confirming that the aberration occurred during extreme low tides, these data points were manually removed from the record.

Statistical Analyses

To visualize and compare water temperatures collected from the data loggers located throughout

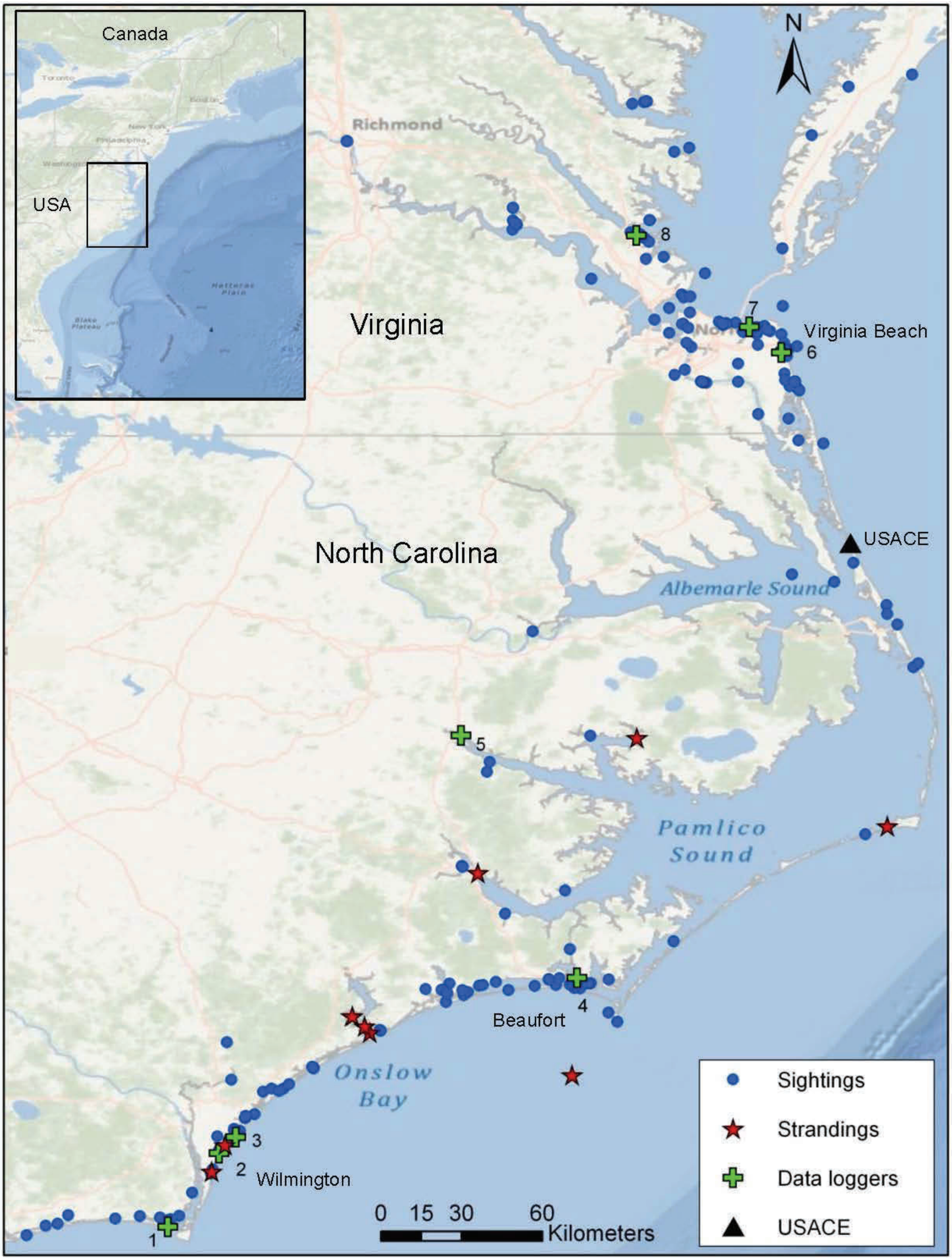

Figure 1. Distribution of Florida manatee sightings ($n = 211$) and strandings ($n = 9$) in North Carolina and Virginia from 1991 through 2012; temperature data logger locations (numbered 1 through 8, from south to north) and the U.S. Army Corps of Engineers (USACE) Field Research Facility are also displayed.

North Carolina and Virginia, discrete Fourier transforms were performed at each site on all temperature data. The temperature signal was then reconstructed, eliminating all components with a period of less than 1 wk, producing a smoothed estimate of the temperature-time relationship at each site. To compare short-term rates of change in temperature for the warm summer months (June, July, and August) and the colder fall months (September, October, and November), local linear regressions of smoothed data were conducted. To avoid variability that would be generated by day-to-day temperature fluctuations, a roughly 1 wk (6 d) window was chosen as the time interval. This window was moved in 3-d increments to generate sufficient data to reasonably interpolate for the plots. These slope estimates describe the relative volatility of short-term temperature change for each of the two seasons. All data were analyzed using *SAS*, Version 9.2.

Results

Manatee Sighting and Stranding Records

From 1991 to 2012, there were 211 Florida manatee sightings reported in North Carolina (n = 99) and Virginia (n = 112) (Figure 1), while strandings were only reported in North Carolina (n = 9). The patterns of manatee sightings differed between the two states (Figure 2). In Virginia, manatees have been reported since 1991, while sightings in North Carolina (with the exception of a single sighting in 1994) have been reported only from 1998 onwards. Sighting records varied across years, but in both states, the number of manatee sightings recorded from 2009 through 2012 was higher than any earlier 4-y period.

Manatee sightings were reported throughout North Carolina and Virginia, although the majority of the sightings were concentrated around the more densely populated coastal areas of Beaufort and Wilmington, North Carolina, and Virginia Beach, Virginia (Figure 1). The overall latitudinal pattern of sightings appeared to be relatively stable over time, although more sightings have been recorded in the Outer Banks region of North Carolina (the barrier beaches that lie to the east of the Albemarle and Pamlico Sounds) since 2011 (Figure 3). Eight of the nine manatee strandings were reported in southeastern North Carolina (Figure 1).

Manatees were sighted across all habitat types along the coastal areas of North Carolina and Virginia (Table 1). In North Carolina, the largest number of sightings occurred within the narrow Intracoastal Waterway, followed closely by sounds and bays, and rivers and creeks, with open ocean and marinas having equal sighting numbers. Few manatee sightings have been recorded in the large inland sounds of northern North Carolina (Figure 3). The largest number of sightings in Virginia occurred in rivers and creeks, followed by open ocean, sounds and bays, the Intracoastal Waterway, and marinas.

Water Temperature and Monthly Manatee Sighting and Stranding Patterns

Total manatee sightings varied with monthly median water temperatures which were collected by USACE (1991-2012) (Figure 4). Manatees arrived in North Carolina in April, and, with one exception, arrived in Virginia in May. Peak sightings occurred from June through October when median water temperatures reached or exceeded 20° C. In both states, sightings dropped precipitously in November, and live manatees appeared to be absent from the region from December through February. All nine recorded manatee strandings occurred in North Carolina, and seven of those were reported from November through January.

Data retrieved from the eight temperature data loggers deployed across the defined habitats in North Carolina and Virginia demonstrated that although water temperatures varied across the region, overall patterns of temperature change were similar (Figure 5). During the year of this study, water temperatures dropped below 20° C around the beginning of November and did not rise above this temperature until May. In this study year, there were differences in temperature across latitude in both states. For example, the southernmost site (Site 1: U.S. Coast Guard Station, Oak Island, NC) was 2° to 4° C warmer than the northernmost site (Site 8: Wormley Creek Marina, VA) throughout the fall, winter, and spring (Figure 5). In contrast, the temperatures at these sites were very similar during the summer months when both approached 30° C. The overall, multi-year, pattern of seasonal temperature change recorded at the USACE Research Facility was similar to the single year pattern recorded by the eight data loggers.

Water temperatures across all sites displayed more volatility in the fall than in the summer months (Figure 6). During summer, temperatures across the study site remained high and stable; temperatures varied by only ± 0.5° C/d across a 6-d window of time (Figures 5 & 6B). In contrast, as water temperatures began to fall in September, they displayed greater daily fluctuations, dropping a maximum of 1.35° C/d across a 6-d window of time (Figures 5 & 6A).

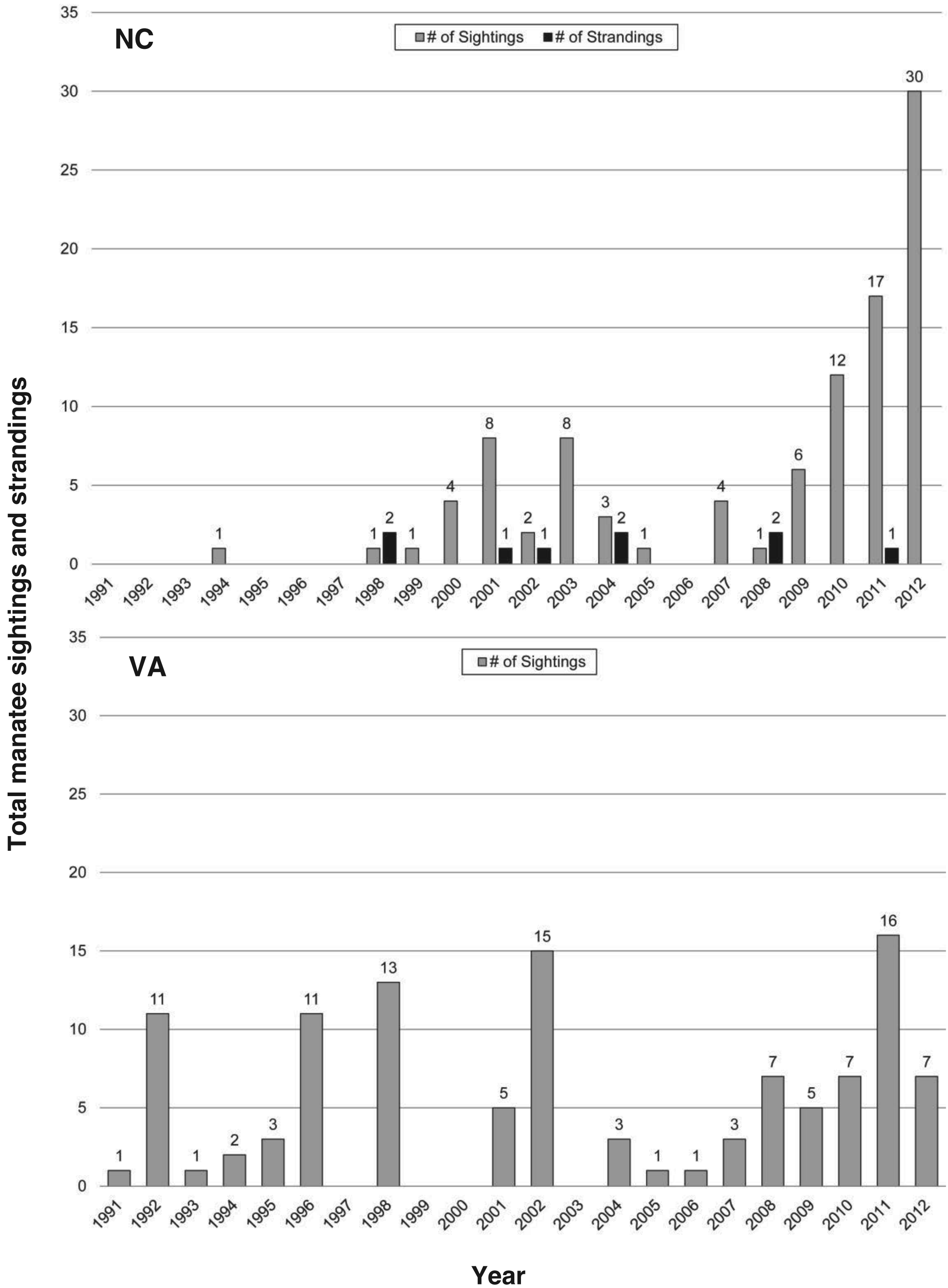

Figure 2. Total manatee sightings and strandings by year for North Carolina and Virginia from 1991 through 2012: North Carolina, n = 99 sightings and 9 strandings; and Virginia, n = 112 sightings.

Table 1. Habitat use by manatees in North Carolina and Virginia from 1991 through 2012

	North Carolina		Virginia	
Habitats	#	%	#	%
Open ocean	14	14	25	22
Intracoastal Waterway	27	27	14	13
Sounds and bays	23	23	20	18
Rivers and creeks	21	21	51	46
Marinas	14	14	2	2
Total	99	100	112	100

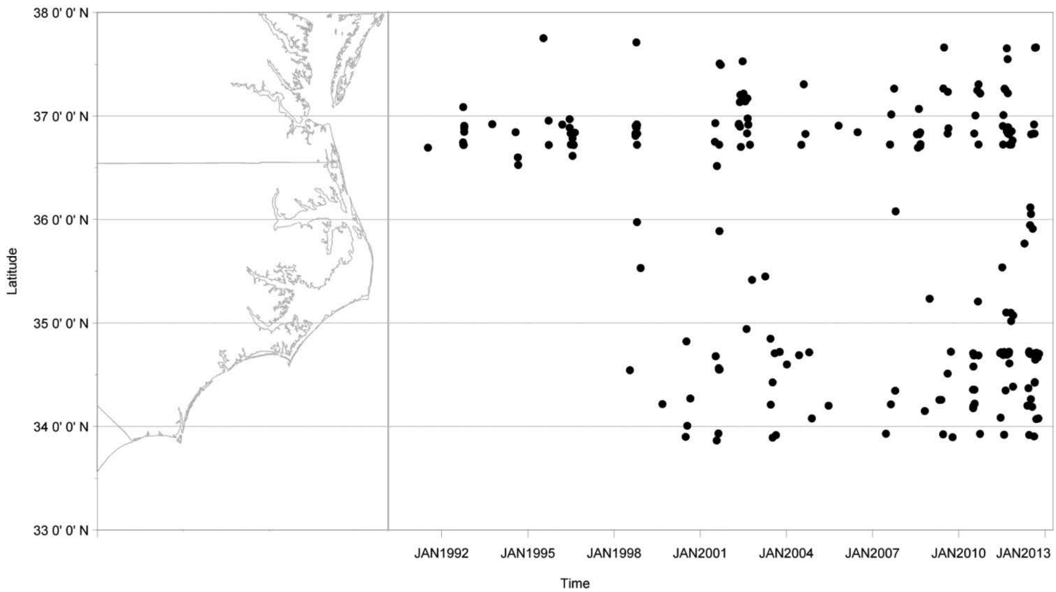

Figure 3. Latitudinal distribution of manatee sightings in North Carolina and Virginia plotted from 1991 through 2012; each circle represents a manatee sighting, and each year begins on January 1.

Discussion

In 1982, the northernmost sighting of the Florida manatee (*Trichechus manatus latirostris*) along the U.S. Atlantic coast was a single individual in the Potomac River, Maryland, and only five manatee sightings had been recorded in Virginia (Rathbun et al., 1982). Since then, manatees have been sighted as far north as Massachusetts, and a well-known manatee named "Chessie" has made multiple seasonal trips to the Chesapeake Bay and points north (Manatee Rescue, Rehabilitation and Release Program Database, pers. comm.). These events suggest that manatees have undertaken more northern movements over the last 30 y, although these extreme northern excursions appear to be rare.

In contrast to these extralimital northern movements, the results of this study suggest that since 1991, the Florida manatee has become a common visitor to the Mid-Atlantic States of North Carolina and Virginia, with 211 sightings recorded (Figures 1 & 2). Because this study relied upon a historic database of opportunistic sighting reports, they are not corrected for effort and cannot be used to quantitatively describe any changes in patterns of appearance of this endangered marine mammal species over the study period; however, they do reveal a consistent pattern of manatee presence in the region. Manatees occur in the inland and coastal waters of North Carolina and Virginia for at least 5 mo of the year (June through October) when water temperatures exceed 20° C.

Within the study region, the majority of manatee sightings were reported around the more densely populated areas of Beaufort and Wilmington, North Carolina, and Virginia Beach, Virginia, which are each surrounded by extensive

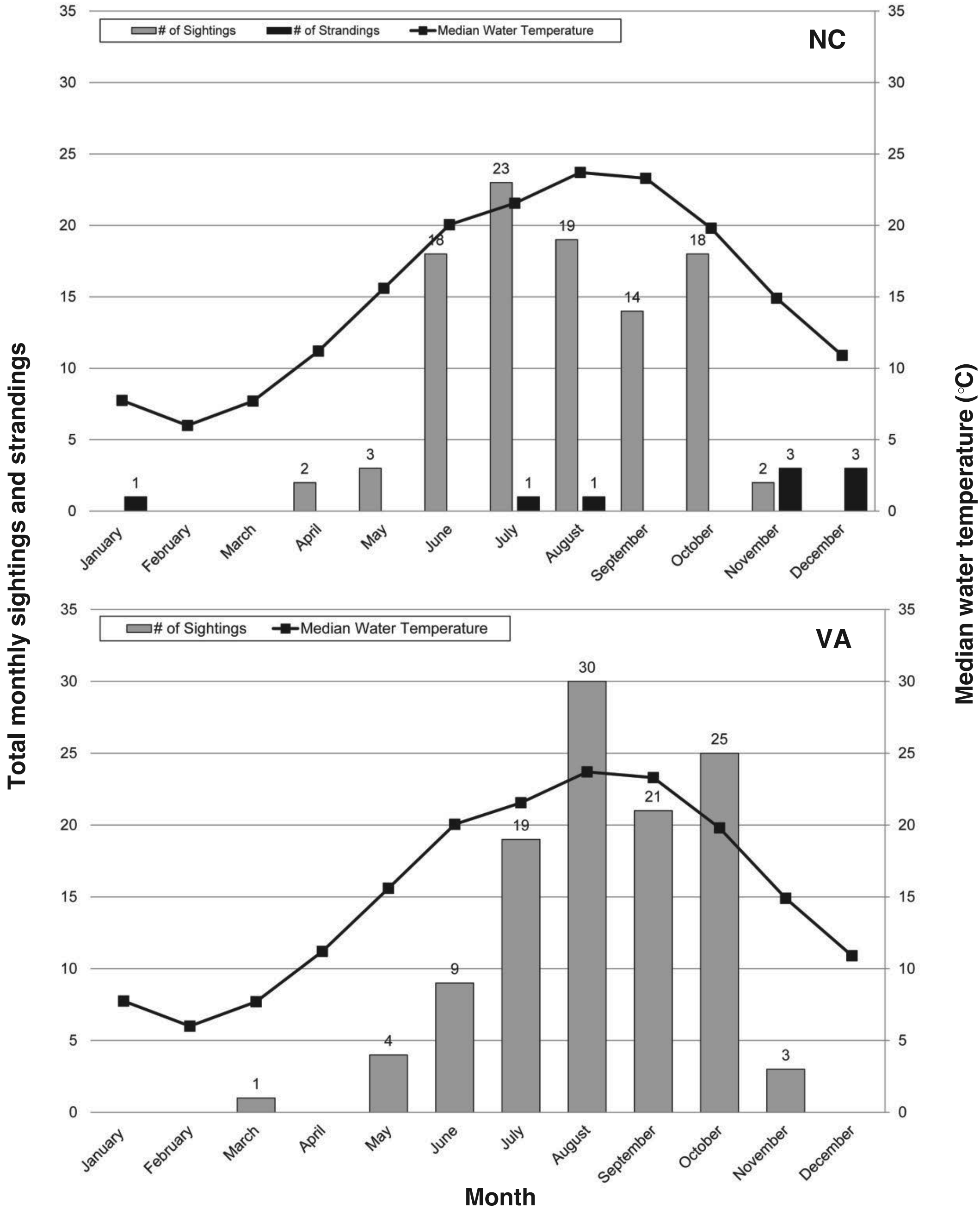

Figure 4. Total monthly manatee sightings and strandings (across all years) in North Carolina and Virginia and total median monthly water temperatures from 1991 through 2012; water temperatures were collected from the U.S. Army Corps of Engineers Field Research Facility in Duck, North Carolina.

waterways (Figure 1). In North Carolina, Beaufort and Wilmington are located near the Intracoastal Waterway, a very narrow channel with high-density boat traffic (Haviland-Howell et al., 2007). These conditions suggest that manatees that travel through the Intracoastal Waterway have a relatively high likelihood of being observed. These areas are also where long term, well-established marine mammal

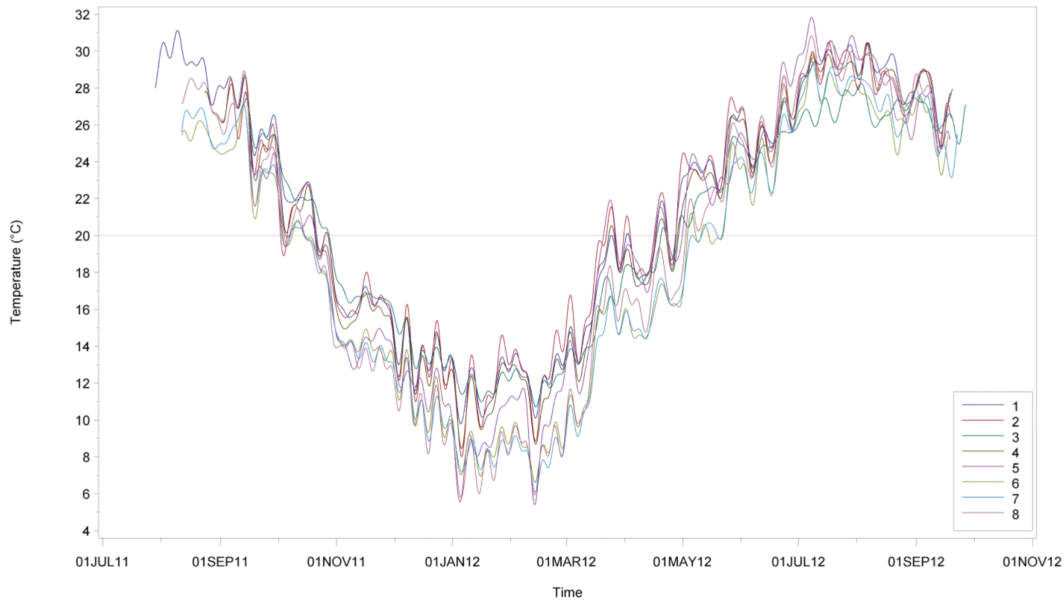

Figure 5. Smoothed daily water temperature data recorded continuously at eight sites throughout the study area; data logger sites were numbered 1 through 8, from south to north (see Figure 1).

stranding response organizations are located, and thus, residents may be more likely to report sightings.

In northeastern North Carolina, the Intracoastal Waterway opens into the vast Albemarle and Pamlico Sounds. These large bodies of water experience a relatively lower density of boat traffic and are surrounded by inland areas of low population, factors that may have contributed to the historically low number of manatee sightings reported from these areas (North Carolina population's data were used from this website on 10 January 2013: www.osbm.state.nc.us/ncosbm/facts_and_figures/socioeconomic_data/population_estimates/demog/countygrowth_bysize_2012.html). Since 2011, manatee sightings from these areas have increased (Figure 3), likely because of enhanced communication between agencies in the state and the U.S. Fish and Wildlife Service (USFWS), the establishment of a more organized reporting network with standardized reporting protocols, and increased education and outreach to residents regarding the importance of reporting sightings in this region.

Manatees were observed in all habitat types defined in this study, but the patterns of habitat use appeared to vary across the states (Table 1). The Intracoastal Waterway is a dominant waterway in southern North Carolina where the majority of manatee sightings were reported for this state. In contrast, the Intracoastal Waterway represents a relatively small percentage of the available habitat in Virginia, where most sightings occurred in rivers, creeks, and the open ocean. Differences in the distribution of sightings between habitats across these two states could not be investigated because there was no means to correct for effort or bias in the sample. Relatively fewer sightings were reported in marinas in both states, which is somewhat surprising given documented human interactions of the public reportedly feeding, watering, and petting manatees at these sites.

Florida manatees regularly appeared in North Carolina and Virginia in months when water temperatures exceeded 20° C (Figure 4). It is likely that the manatee's thermal dependency on warm tropical and subtropical waters, and its inability to survive extended periods of time in waters below 20° C, restrict it to waters further south during the remainder of the year (Irvine, 1983; O'Shea et al., 1985; Bossart et al., 2002; Reep & Bonde, 2006; Marsh et al., 2011).

Manatees appear to arrive in North Carolina in April but are not usually reported in Virginia until May. This pattern is likely due to their northerly movement from their winter habitat in Florida as waters begin to warm. Manatee sightings peak during summer months when water temperatures are historically high (Figure 4) and relatively stable throughout the inland and coastal waters of both states (Figure 6B). Thus, from June through early October, visiting manatees will reliably experience their required thermal conditions (Bossart et al., 2002) in this region. The observed seasonal sighting trends in this study are similar to those observed by Rathbun et al. (1982) and Schwartz (1995).

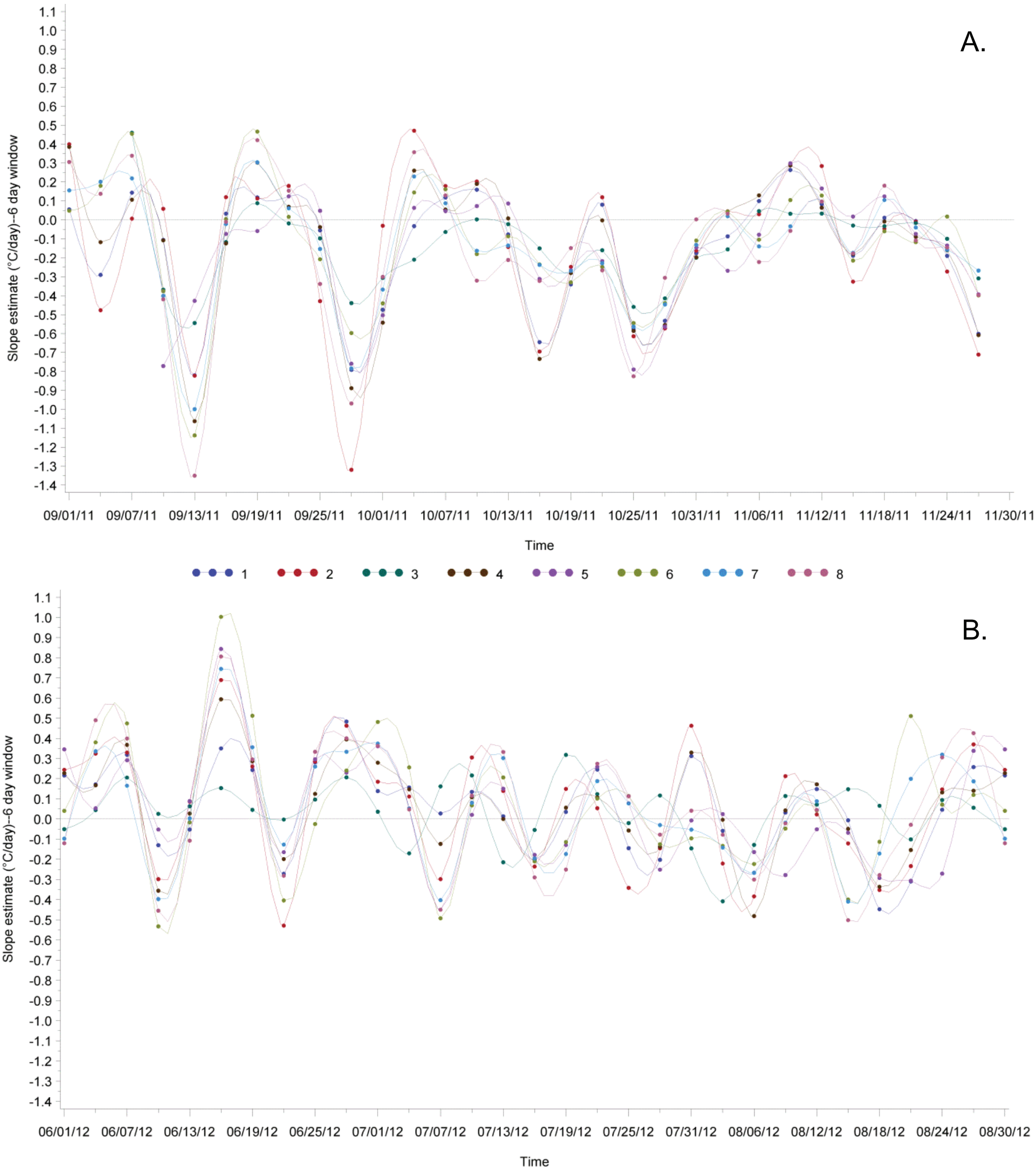

Figure 6. Changes in water temperature (°C/d) calculated across 6-d windows, moved across time in 3-d increments, for all data loggers: A. September through November 2011 and B. June through August 2012.

Temperatures recorded from multiple sites across the region displayed consistent trends over 1 y, including high and stable temperatures in the summer and volatility in daily temperatures in the fall (Figures 5 & 6). Throughout the year, water temperatures remained cooler in the Virginia locations than in North Carolina, and the temperature differences were greater from November to May. Location did influence temperature in a predictable way. For example, the North Carolina Estuarium site (Data Logger Site #5; see Figure 1), located inland on the Pamlico River, experienced the lowest temperatures (5.4° C) in North Carolina during the winter, with a temperature comparable to that of the northernmost site in Virginia—Wormley Creek Marina (Data Logger Site #8) (5.7° C).

Due to the volatility in the water temperatures during the fall, those data were investigated more closely, in 6-d windows from September through

November (Figure 6A). There were several dramatic drops in temperature during a week's time throughout September and October. For example, from 29 September through 5 October 2011, temperatures dropped by 5° C and fell below 20° C. By November, temperatures had become less variable but were consistently below 20° C. This volatility in early fall can be hazardous to manatees if they have not started traveling south toward Florida. If they remain in the mid-Atlantic past this period, they are likely to experience temperatures that could lead to cold stress. Two known manatee sightings observed in North Carolina in October, for example, eventually stranded dead in November with signs of cold stress at necropsy (UNCW stranding records). In total, four strandings during the months of November, December, and January in North Carolina exhibited signs of cold stress (Hartman, 1979; Bossart et al., 2002; Glaser & Reynolds, 2003; UNCW stranding records).

The results of this study, which rely upon historic sighting and stranding records, demonstrate that the Florida manatee is a common visitor to the mid-Atlantic and remains in this region for over 5 mo of the year. Because there are hundreds of bays, coves, and estuarine marshes within these two states where manatees could go unreported, the relatively low numbers of sightings and strandings may not reflect true manatee occurrence. Currently, seasonal abundance of manatees cannot be determined because there are no dedicated surveys in North Carolina or Virginia. Without observer programs, there will be insufficient data to track manatee occurrence and to understand the potential changes in seasonal habitat usage of this endangered marine mammal. These data are critical as it is likely that the mid-Atlantic may become a more important region for manatees in the future.

Global climate change has caused increases in water temperatures throughout the world's oceans, and this increase is expected to continue in the future (Levitus et al., 2000; Barnett et al., 2001; Learmonth et al., 2006; MacLeod, 2009). Species can respond to environmental change by changing their distribution to keep within their ecological niche (Wiens & Graham, 2005). Because manatees are thermally dependent, it is possible that they are currently undergoing seasonal movements into the Mid-Atlantic States earlier, and staying later into the year, than they did even 30 y ago (Rathbun et al., 1982). Sightings throughout the eastern seaboard will likely continue to increase as coastal and inland water temperatures increase.

A species' range is also determined by the distribution of its food, which can be affected by temperature (Learmonth et al., 2006; Simmonds & Isaac, 2007). Manatees are generalist herbivores, feed on over 60 species of marine and freshwater vegetation, and consume 10 to 15% of their body weight per day (Smith, 1993; Marshall et al., 2000). There currently are no data available on the feeding ecology of manatees while they are in the mid-Atlantic. However, the three dominant sub-aquatic vegetation species in coastal North Carolina and the Chesapeake Bay, Virginia—*Zostera marina, Ruppia maritima*, and *Halodule wrightii* (Ferguson & Korfmacher, 1997; Moore et al., 2000)—are known forage species for the Florida manatee (Lefebvre et al., 2000; Reep & Bonde, 2006; Castelblanco-Martínez et al., 2009; Marsh et al., 2011).

Changing environmental temperatures could mean a future shift in the marine and freshwater vegetation that is available for manatee consumption. For example, the rate of relative sea-level rise in the mid- and upper-Atlantic U.S. region is higher than the global average, causing frequent flooding (Wu et al., 2009). Flooding can cause changes in salinity in estuarine areas, which, in turn, can cause a change in species richness of aquatic vegetation (Sharp & Baldwin, 2012). Climate change cannot only cause sea-level rise, but it can also increase streamflow, which can degrade water quality and have negative impacts on sub-aquatic vegetation (Najjar et al., 2000). Future collaboration with agencies that monitor the distribution of sub-aquatic vegetation would be useful to help predict current and future potential habitats for manatees in both North Carolina and Virginia as temperature, coastal habitat modifications, and fresh water availability may produce changes in wild vegetation.

The most recent Manatee Recovery Plan (USFWS, 2001) identifies four actions needed to promote the recovery of this endangered species: (1) minimize causes of disturbance, harassment, injury, and mortality; (2) determine and monitor status of manatee populations; (3) protect, identify, evaluate, and monitor manatee habitats; and (4) facilitate recovery through public awareness and education. Although the USFWS Recovery Plan is primarily focused on the manatees in Florida, these management actions appear well-suited for, and identify current data gaps within, the Mid-Atlantic States. The predictable seasonal appearance of the Florida manatee in North Carolina and Virginia for at least 5 mo of the year suggests that state management plans should be updated to include specific strategies on protecting this endangered marine mammal species.

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