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# Feasibility of using sea surface temperature imagery to mitigate cheloniid sea turtle–fishery interactions off the coast of northeastern USA

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ABSTRACT: As sea turtles migrate along the Atlantic coast of the USA, their incidental capture in fisheries is a significant source of mortality. Because distribution of marine cheloniid turtles appears to be related, in part, to sea surface temperature (SST), the ability to predict water temperature over the continental shelf could be useful in minimizing turtle–fishery interactions. We analyzed 10 yr of advanced very high resolution radiometer (AVHRR) SST imagery to estimate the proportion of 18 spatial zones, nearshore and offshore of Hatteras, North Carolina, USA (35° N), to north of Cape Sable, Nova Scotia (44° N), at temperatures >10 to 15°C, by week. Detailed examples for 11°C, the temperature employed by some management actions in the study area, and for 14°C, the lowest temperature at which turtles were sighted by some studies in the area, demonstrate a predictable pattern of rapid warming in March and April, followed by rapid cooling in October and November, with nearshore waters warming more rapidly than those offshore. Of those loggerhead turtles *Caretta caretta* that stranded, were sighted, or were incidentally captured between Cape Hatteras, North Carolina, and Cape Cod, Massachusetts, those at lower latitudes occurred when 25 % or more of the area reached a water temperature of 11°C, while those in the northern zones did not occur until 50 % or more of the area had reached a water temperature of 14°C. This analysis provides a means of predicting marine cheloniid turtle presence, which can be helpful in regulating fisheries that seasonally interact with turtles.

KEY WORDS: Cheloniid · Management · Sea turtles · Sea surface temperature · Sea turtle–fishery interaction

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## INTRODUCTION

Sea turtles are poikilotherms and, with the exception of the leatherback *Dermochelys coriacea* (James & Mrosovsky 2004), have distributions that are limited geographically and temporally by water temperature. Although leatherback turtles can maintain a body core temperature at an average of 8°C above ambient temperatures (James & Mrosovsky 2004) and have been documented in the Atlantic in waters off eastern Canada (Bleakney 1965, Lazell 1980, Goff & Lien 1988), where the water was as cold as 0°C (Goff & Lien 1988), temperatures need to remain above certain levels in order for marine cheloniid turtles (such as loggerhead *Caretta caretta*, green *Chelonia mydas* and Kemp's ridley *Lepidochelys kempii* sea turtles) to maintain physiological functions. Temperatures that are too high or too low will negatively impact the feeding behavior of these sea turtles, locomotor movements, and stress hormone levels (for a review, see Milton & Lutz 2003).

For example, Birse & Davenport (1987) found that temperature had a great effect on the rate of food passage through the digestive system of small (<2500 g) loggerheads, even though the turtles were allowed to acclimate at the test temperature (from a holding tem-

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perature of 25°C) for 4 to 5 d before testing. Likewise, captive, immature green (8 yr old) and Kemp's ridley (3 yr old) sea turtles displayed semi-dormant behavior and stopped feeding when water temperatures decreased to <15°C (Moon et al. 1997). Schwartz (1978) reported that immature loggerhead, green, and Kemp's ridley sea turtles held in shallow, outdoor ponds in North Carolina quit feeding and began floating when temperatures reached 9 to 10°C, with a lethal temperature for all 3 species between 5 and 6.5°C. Davenport et al. (1997) discovered that swimming coordination in 1 mo old green turtles was compromised at 15°C. In other studies, captive sub-adult loggerhead sea turtles exposed to water temperatures that rapidly decreased at a rate of 2.5°C $d^{-1}$ (from 30 to 10°C) had a failure of important metabolic processes between 10 and 15°C (Lutz & Dunbar-Cooper 1984, Lutz et al. 1989). Even when temperatures were slowly reduced by 5 to 6°C every 2 wk, captive turtles continued showing signs of stress (Moon et al. 1997). Clearly, temperatures below a certain tolerance level hinder the turtles' ability to function.

In addition to affecting their physiology, water temperatures can influence sea turtle migratory behavior and movement patterns. During spring, as water temperatures begin to increase, cheloniid marine turtles migrate north along the United States Atlantic coast and into inshore waters; in autumn, as water temperatures decrease, this migratory pattern is reversed (Shoop & Kenney 1992, Witzell & Azarovitz 1996, Musick & Limpus 1997, Morreale & Standora 1998, Braun-McNeill & Epperly 2002, Morreale & Standora 2005). When conducting aerial surveys off North Carolina and Virginia, Coles & Musick (2000) reported that only one of the 16 turtles sighted was in waters colder than 14°C (13.3°C), while Witzell & Azarovitz (1996) reported no sightings along the entire United States Atlantic coast in waters colder than 14°C. Similarly, water temperatures experienced by satellite-tagged adult loggerhead turtles wintering along the edge of the Gulf Stream of the southeast USA ranged from 14 to 26°C, warmer than nearby inshore waters where temperatures regularly fell below 8 to 10°C (Hawkes et al. 2007). In all these studies, colder waters were available, but no sea turtles were observed in the coldest waters.

Although the previously mentioned studies provide some documentation that marine cheloniid turtles are intolerant of waters <15°C, other observations of wild turtles indicate that, in certain circumstances, some can acclimate to cooler temperatures. Carr et al. (1980) uncovered juvenile and adult loggerheads buried in the mud off Cape Canaveral, Florida, when waters averaged 11°C, but found them swimming off the bottom by mid-March when waters had warmed to almost 20°C. Nine rehabilitated loggerhead turtles tracked in the Mediterranean Sea remained active to some degree and continued to feed throughout the winter despite experiencing temperatures <15°C (minimum of 11.8°C) (Hochscheid et al. 2007).

Sea turtles also may be able to adapt to cooler temperatures if the rate of change is slow enough (Milton & Lutz 2003). Epperly et al. (1995) sighted cheloniid turtles off North Carolina during aerial surveys in waters as cold as 8°C and also reported capturing active turtles with bottom trawls in waters as cold as 10°C. Similarly, turtles were captured in pound nets in North Carolina, even as water temperatures dropped to <10°C (Epperly et al. 2007). Likewise, water temperature data recorded for 12 of the 14 sea turtles observed captured in the monkfish fishery off North Carolina and Virginia ranged from 8.6 to 12.7°C and averaged 12.1°C (NMFS [National Marine Fisheries Service] 2001a). During aerial surveys, Shoop & Kenney (1992) reported 8 sightings of loggerhead turtles in waters ≤10°C off the northeast coast of the USA, and a loggerhead turtle was reported actively swimming on the south coast of Newfoundland when water temperatures were 8°C (Ledwell 2007). Finally, telemetric studies of sea turtles also have documented the presence of turtles in waters <15°C. For example, 3 of 6 wild loggerheads were tracked in waters between 6 and 9°C (Keinath 1993), and Kemp's ridleys that were tracked in the waters surrounding Long Island, New York, displayed active, directed movements when ambient temperatures were <15°C (Standora et al. 1989). Although most cheloniid marine turtles are found in water temperatures >20°C, managers need to be mindful of the fact that certain species (e.g. loggerheads) and/or larger individuals (sub-adults and adults) can tolerate lower water temperatures (Spotila et al. 1997) when evaluating the risk for sea turtles interacting with a particular fishery.

As they embark upon their spring and autumn migrations over the continental shelf off the northeast USA, sea turtles are vulnerable to incidental capture by fisheries, including trawls (Epperly 2003, Murray 2006), gill nets (NMFS 2001a), scallop dredges (Murray 2007), and pots and traps (Allen 2000). Because the northern distribution of cheloniid marine turtles appears to be seasonally related to water temperature, at least northward to Cape Cod (Shoop & Kenney 1992, Witzell & Azarovitz 1996), a means of predicting SST and, thus, sea turtle presence in an area could provide a mechanism for mitigating sea turtle–fishery interactions. The NMFS implemented the use of a minimum temperature to mitigate sea turtle–fishery interactions in ocean waters off North Carolina and Virginia (Epperly et al. 1995, 1996, NMFS 2001a). After determining that the likelihood of sea turtle captures is negligible when surface water temperatures fall below 11°C (Epperly et al. 1995), the NMFS eliminated the requirement for turtle excluder devices (TEDs) between Oregon Inlet, North Carolina, and Cape Charles, Virginia, from January 15 to March 15 in the winter trawl fishery for summer flounder *Paralichtys dentatus* (NMFS 1996). They also established a seasonal closure of the large-mesh gill net fishery for goosefish (monkfish) *Lophius* spp., based on a minimum temperature of 11°C to prevent interactions when sea turtles were present (NMFS 2002). Our objective is to provide a method of predicting potential sea turtle presence along the northeast coast of the USA, which, in turn, can be useful in the management of fisheries that interact with sea turtles by assessing the likelihood of turtle presence in a management area at different times of the year.

We analyzed SST imagery and calculated the areal proportion of surface waters above temperatures ranging from 10 to 15°C in ocean waters from just south of Cape Hatteras, North Carolina, to Cape Sable, Nova Scotia. This range in temperatures was chosen based on the historical precedent of using 11°C as a potential minimal temperature employed in the seasonal regulation of sea turtle–fishery interactions (Epperly et al. 1995, 1996), and research that identified 14°C as another possible minimal temperature for sea turtles (Coles & Musick 2000, Witzell & Azarovitz 1996).

## MATERIALS AND METHODS

SST imagery was provided by the NOAA Satellite and Information Service, Comprehensive Large Array-Data Stewardship System (National Environmental Satellite, Data and Information Service, August 28, 2003, www.class.noaa.gov/) from the CoastWatch Northeast Regional Node. NOAA CoastWatch SST images are acquired by the advanced very high resolution radiometer (AVHRR) sensor on board NOAA polar operational environmental satellites (POES), and are produced 4 times daily for the coastal waters of the United States. All images were initially viewed using Windows Image Manager (WIM), a software package that allows display and analysis of images (Windows Image Manager, June 12, 2008, www.wimsoft. com/). Only images free of cloud cover and other obstructions were selected at approximately 7 to 14 d intervals beginning January 1 and ending December 31 for the years from 1993 to 2002, resulting in 690 images. The pixel size of images from 1993 to 1994 was 4.410 km (rows = 512, columns = 512), while the pixel size of images from 1995 to 2002 was 1.4699 km (rows = 1401, columns = 1302). Images were registered using the CoastWatch GeoCorrector Extension for ArcView GIS 3.3 (ESRI 2000). The original data were in the Mercator projection, and an *xy* shift was applied to line up the image with the vector shoreline.

We defined 18 zones whose northern/southern boundaries were spaced at 30′ intervals from just south of Cape Hatteras, North Carolina (35° N), to north of Cape Sable, Nova Scotia (44° N) (Fig. 1). We also defined 2 strata in each of these zones: nearshore, the coastline (from the COLREGS demarcation line) to 20 m depth; and offshore, shelf waters from 20 to 200 m in depth. We imported the selected images into ArcView GIS 3.3 with Spatial Analyst as ArcView grids, with a cell resolution of 1.46 × 1.46 km (Environmental Systems Research Institute). We then reclassified each raster to 1°C temperature bins and tabulated the area within each zone that fell within a specific temperature bin from 0 to 35°C.

From these temperature distributions, we calculated the proportion of the zone at or above a particular temperature, from 10 to 15°C, for each week of the year. Second-order polynomial curves were then fit to 10 yr of weekly data for each of the 18 zones, 2 strata, and 6

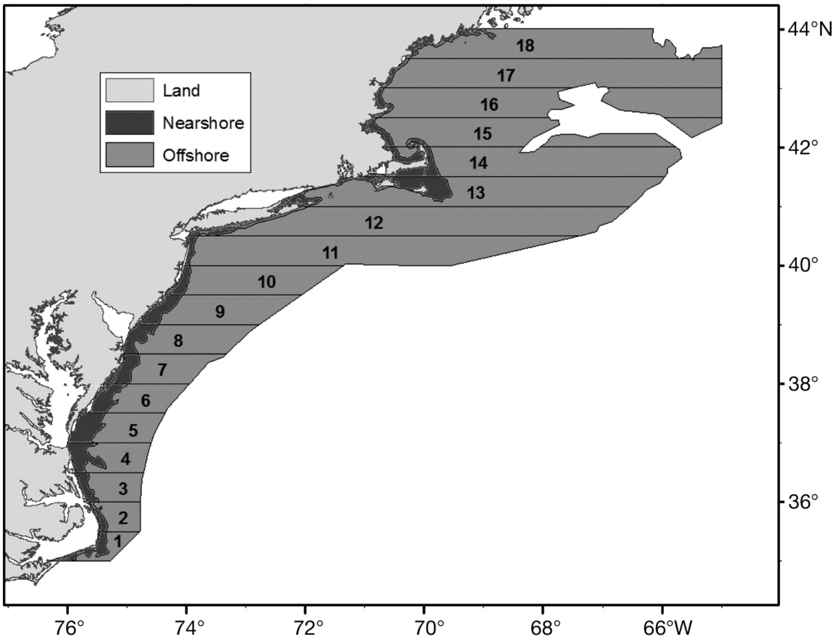


Fig. 1. Zones and depth stratum polygons from which sea surface temperature data were extracted from Cape Hatteras, North Carolina, to Cape Sable, Nova Scotia, from 1993 to 2002. The nearshore strata represent the coastline (from the COLREGS demarcation line) to the 20 m depth contour, and offshore strata represent shelf waters from 20 to 200 m in depth

temperatures (10 to 15°C) using the GLM procedure in SAS Version 9.1.2 to predict by week what proportion of each stratum in each zone was above the given temperature. Because the lowest temperatures were reached in mid-February, our thermal year began February 19 and all analyses were adjusted accordingly. We provide detailed results for both 11 and 14°C, while results for 10, 12, 13, and 15°C are provided in Appendix 1 (available as Supplementary Material at: www.int-res.com/journals/suppl/n005p257_app.pdf). Finally, we demonstrate how water temperatures changed along the Atlantic coast at different times of the year and when different proportions of a zone reached a given temperature.

## RESULTS

The proportion of a zone at or above 11 and 14°C varied through time, but yielded a predictable pattern of rapid warming in March and April, followed by rapid cooling in October and November (Figs. 2 & 3). Generally, shallow nearshore waters warmed more rapidly than deeper offshore waters in the spring and cooled more rapidly than offshore waters in the autumn. Models for both temperatures and all zones were significant ($p < 0.001$; Table 1). The lower R-squared values for Zone 1 are likely due to shifts in the Gulf Stream and northeasterly winds, which can rapidly alter SSTs in this area (Epperly et al. 1995).

To demonstrate how water temperatures changed along the Atlantic coast at different times of the year and when different proportions of a zone reached a given temperature, we provide detailed examples arbitrarily using the dates when 25 and 50% of the zones reached 11 and 14°C (Fig. 4, temperature lines only). Of these examples, the most conservative approach (25% of a zone at or above 11°C) indicates a need for sea turtle conservation regulations in the nearshore and offshore waters of the southernmost zone all year, with the need for regulations in the most northern zone as early as April 16 in nearshore waters and April 23 in offshore waters. Using the least conservative approach (50% at or above 14°C), sea turtle conservation regulations would not be needed in the southernmost zone until March 19 in offshore waters and April 2 in nearshore waters, with the need for regulations in the most northern zone as late as June 11 in nearshore waters and July 23 in offshore waters.

## DISCUSSION

Despite the documented occurrence of the incidental capture of sea turtles in many fishing gears, there are still many fisheries in the USA without regulations to mitigate these effects (dredges [Murray 2007, Haas et al. 2008]; gill nets [Epperly et al. 1995, NCMFC 2006]; hook and line [Epperly et al. 1995, NMFS 2005]; pots and traps [Allen 2000]; pound nets [Morreale & Standora 2005, Epperly et al. 2007]; and trawls [Murray 2006, 2007]; see also NMFS SEFSC 2001, their Appendix 2), and several fisheries mentioned in the 'Introduction' with regulations covering only a part of the geographic area in which they operate. The National Research Council (1990) identified the shrimp fishery as the largest source of anthropogenic mortality to sea turtles. As a result of regulatory efforts by the NMFS (1987, 2003), the shrimp fishery, which operates almost exclusively south of Cape Hatteras, North Carolina, is now required to use TEDs in all places at all times. Two other regulated fisheries operating in the mid-Atlantic with documented incidental capture of sea turtles are the winter trawl fishery for summer flounder *Paralichtys dentatus* and the large-mesh gill net fishery for goosefish (monkfish) *Lophius* spp. (Epperly et al. 1995, 1996, NMFS 2001a). Since 1992, participants in the flounder winter trawl fishery have been required to use TEDs when fishing south of Cape Charles, Virginia (37.083° N) (NMFS 1992). This requirement is in effect for all times of the year for that fishery with the exception of January 15 to March 15, when the northern boundary for use of TEDs shifts south to Oregon Inlet, North Carolina (35.775° N) (NMFS 1996). This and other bottom trawl fisheries also operate northward (Orphanides & Magnusson 2007), and interactions with turtles occur north of the boundary where TEDs are not required (Murray 2006, 2007). Likewise, seasonal closures were enacted in the southern range of the monkfish gillnet fishery to reduce incidental capture of sea turtles (NMFS 2002), but do not include waters north of Virginia where this and other gillnet fisheries also occur (Palka & Rossman 2001, Belden et al. 2006, New England Fishery Management Council 2007).

The NMFS is considering additional regulations to reduce the unintended bycatch of sea turtles in trawl and other fisheries along the Atlantic coast of the USA and in the Gulf of Mexico, including moving the northern boundary for TED regulations farther north and requiring TEDs in other fisheries (NMFS 2007). Our analysis of SST data could help predict marine cheloniid presence that may, in turn, provide guidance for mitigating sea turtle–fishery interactions.

It has been suggested that while autumn/winter movements out of an area appear to be initiated by SST decreases, spring/summer movements may be related to food resources (Bentivegna 2002). This implies that, although some minimal water temperature must be reached for turtles to avoid cold stunning

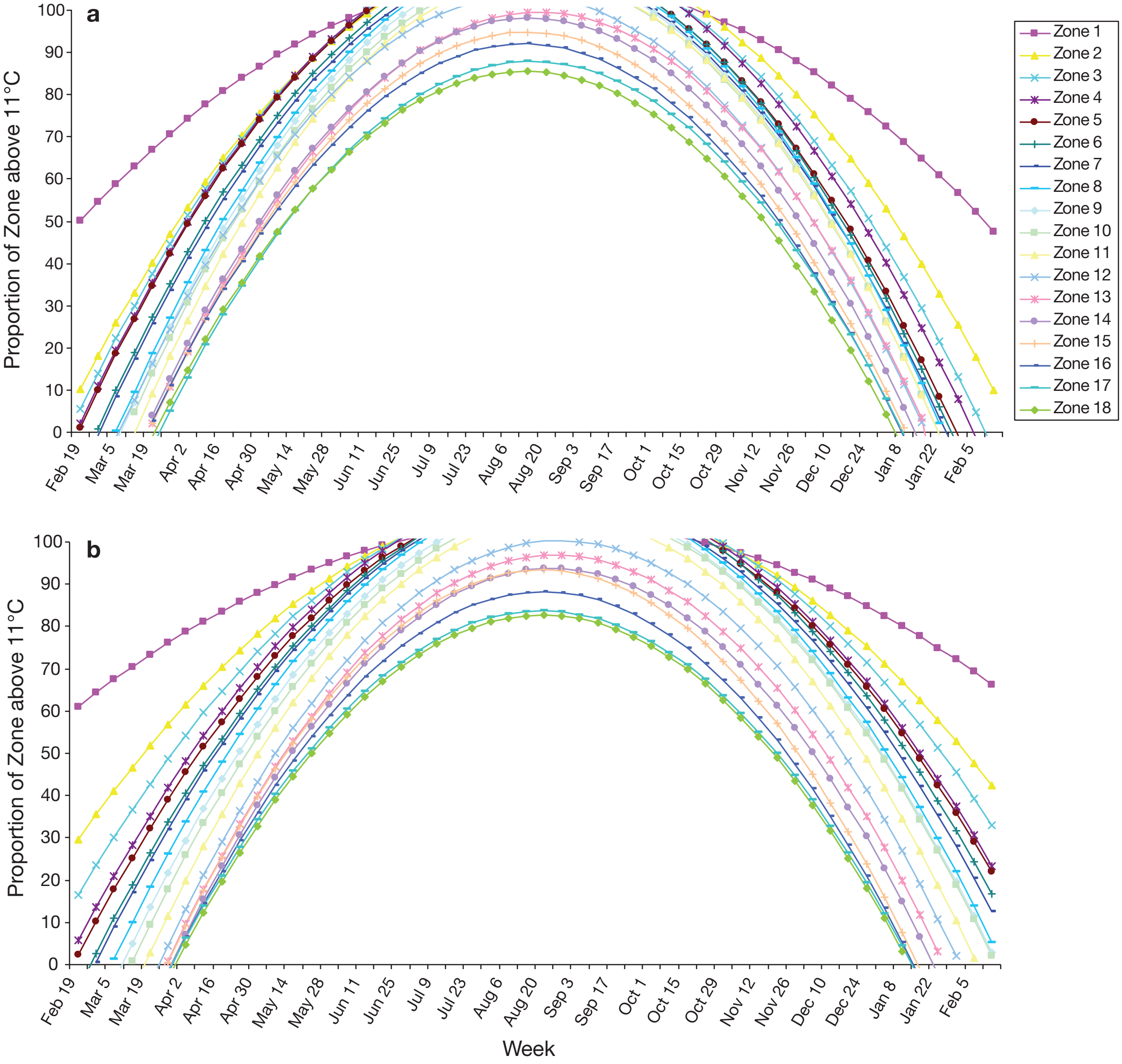


Fig. 2. Predicted proportion of (a) nearshore and (b) offshore zones ≥11°C, by week, from 1993 to 2002. Zones are defined in Fig. 1. Variability around these point estimates is not displayed. Note that the thermal minimum occurs in February and thus our year begins in February

in the autumn and winter, they may be tracking food resources as the water warms in the spring. If true, turtles may be present when a relatively small proportion of the area has reached a minimal temperature and food resources are present and, conversely, may not be present when food is absent and waters are relatively warm.

Thus, in addition to waters that reach or exceed a given minimal temperature, the likelihood of a marine cheloniid turtle being present in a particular zone increases as the proportion of the zone reaching that minimal temperature increases. Therefore, managers not only have to decide upon a given minimal temperature, but also need to determine what proportion of the zone must be at or above that temperature, thereby constituting an unacceptable risk and indicating a need for fishery restrictions. Dates determining the likelihood of a turtle being present can vary, depending upon the water temperature and proportion of a zone meeting or exceeding that water temperature.

Of the examples we provided (Fig. 4), the most conservative approach was 25 % of a zone at or above 11°C, while the least conservative approach was 50 % of a zone at or above 14°C. Epperly et al. (1995)

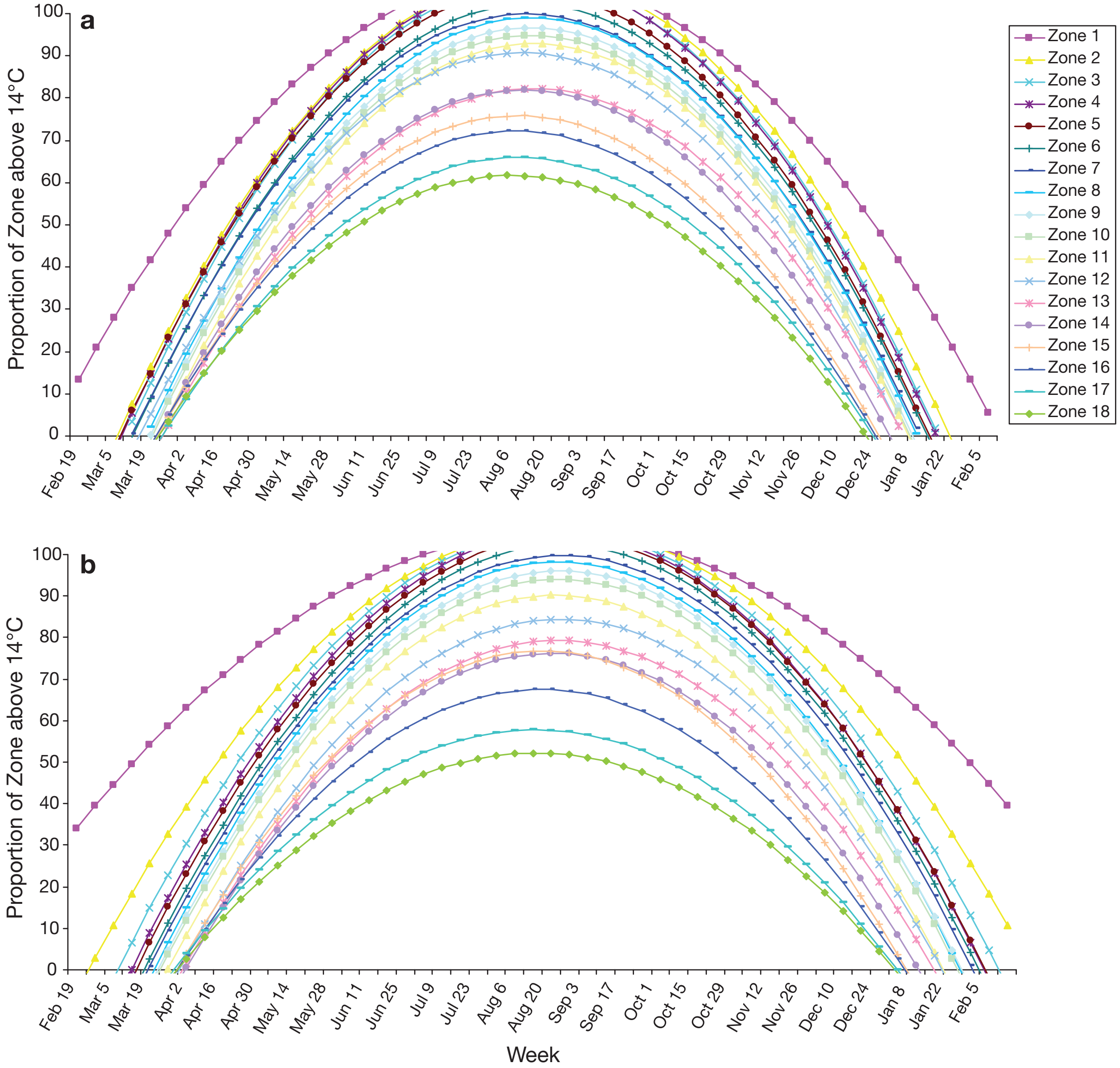


Fig. 3. Predicted proportion of (a) nearshore and (b) offshore zones ≥14°C, by week, from 1993 to 2002. The zones are defined in Fig. 1. Variability around these point estimates is not displayed. Note that the thermal minimum occurs in February and thus our year begins in February

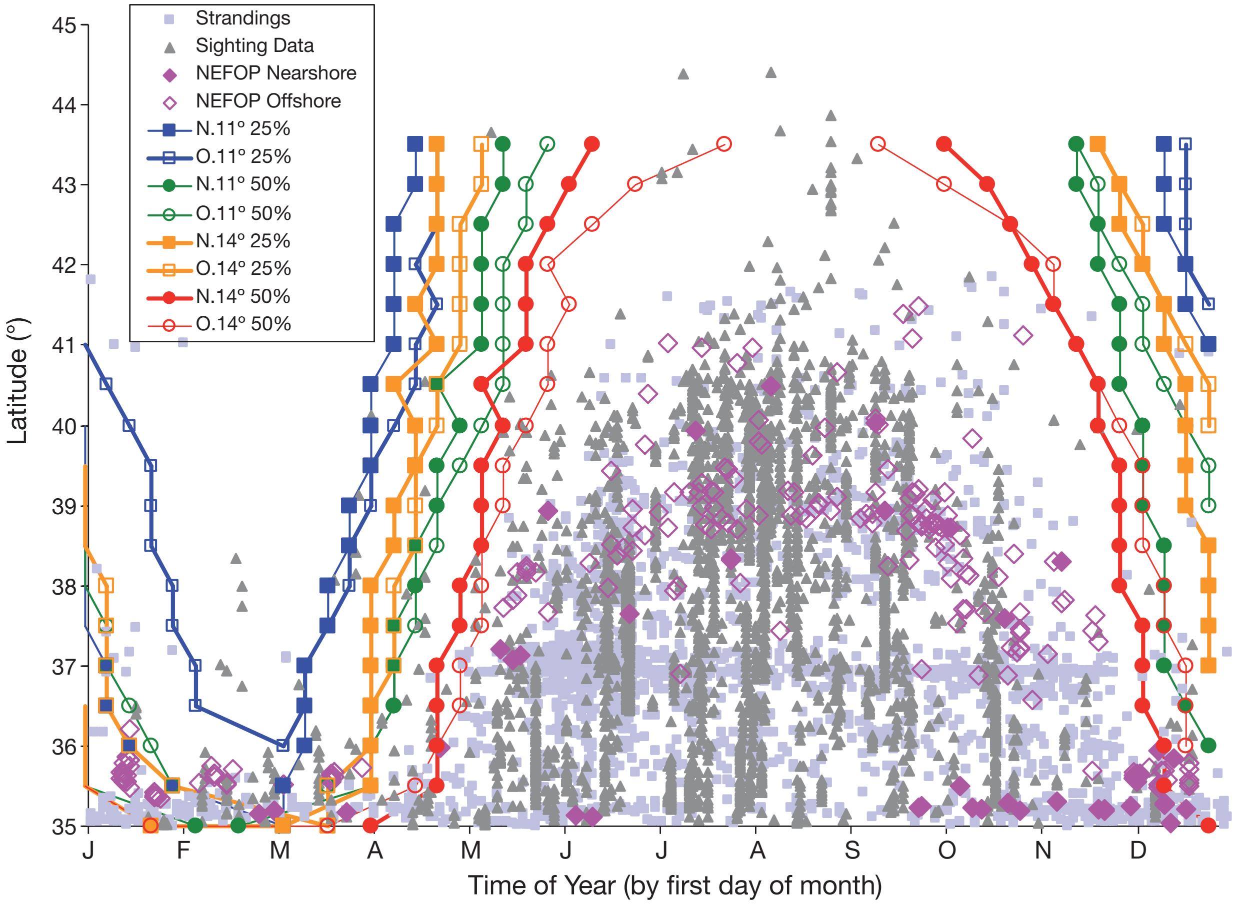
Fig. 4. *Caretta caretta*, *Lepidochelys kempii*, *Chelonia mydas*, and *Eretmochelys imbricata*. Strandings (n = 2487), sightings (n = 4845), and fishery bycatch (n = 276) of loggerhead sea turtles north of 35° N in the United States Atlantic. Strandings are all species except leatherbacks and include only live, fresh dead, or moderately decomposed (not severely decomposed or dried carcasses) turtles found on the beaches; cold stuns and incidental captures are not included. Strandings data are from the period 1998 to 2004 (modified from Richards & Belskis 2007). Sightings are from aerial and shipboard survey data contained in the Sea Turtle Atlantic Strategy GIS database (NMFS 2001b). North East Fishery Observer Program (NEFOP) fishery bycatch data are from the NMFS Northeast Fisheries Science Center and from Epperly et al. (1995) and show nearshore and offshore interactions. The SST analysis results for nearshore and offshore strata are depicted with 4 examples for each stratum: ≥25 % of the area of a zone predicted to be ≥11°C in the nearshore and offshore strata (N.11° 25 %, O.11° 25 %, respectively); ≥50 % of the area of the zone predicted to be ≥11°C in the nearshore and offshore strata (N.11° 50 %, O.11° 50 %, respectively); ≥25 % of the area of a zone predicted to be ≥14°C in the nearshore and offshore strata (N.14° 25 %, O.14° 25 %, respectively); ≥50 % of the area of a zone predicted to be ≥14°C in the nearshore and offshore strata (N.14° 50 %, O.14° 50 %, respectively)

Table 1. R-squared values of sea surface temperature polynomial curves for Zones 1 to 18, nearshore and offshore strata, from 1993 to 2002, for threshold temperatures of 11 and 14°C. Zones and strata are defined in Fig. 1

| Zone | Nearshore 11°C | Offshore 14°C | Nearshore 11°C | Offshore 14°C |
|---|---|---|---|---|
| 1 | 0.42 | 0.26 | 0.61 | 0.41 |
| 2 | 0.57 | 0.45 | 0.70 | 0.60 |
| 3 | 0.64 | 0.54 | 0.73 | 0.69 |
| 4 | 0.70 | 0.62 | 0.75 | 0.73 |
| 5 | 0.75 | 0.61 | 0.76 | 0.72 |
| 6 | 0.75 | 0.67 | 0.73 | 0.72 |
| 7 | 0.76 | 0.67 | 0.74 | 0.73 |
| 8 | 0.74 | 0.71 | 0.71 | 0.72 |
| 9 | 0.76 | 0.73 | 0.71 | 0.71 |
| 10 | 0.76 | 0.74 | 0.71 | 0.69 |
| 11 | 0.73 | 0.79 | 0.66 | 0.70 |
| 12 | 0.80 | 0.79 | 0.71 | 0.67 |
| 13 | 0.79 | 0.76 | 0.67 | 0.64 |
| 14 | 0.75 | 0.70 | 0.64 | 0.58 |
| 15 | 0.71 | 0.70 | 0.56 | 0.57 |
| 16 | 0.68 | 0.67 | 0.52 | 0.53 |
| 17 | 0.65 | 0.64 | 0.46 | 0.47 |
| 18 | 0.65 | 0.63 | 0.45 | 0.43 |

reported turtles in Zone 1 during February, a time when we would predict as little as 10% of the area to be >14°C (Fig. 3). This supports the position that only a relatively small proportion of a zone must exceed 14°C for turtles to be present in the southern part of our study area. In view of these findings, it is not unreasonable to assume that turtles begin migrating to zones farther north when relatively small proportions of the zone warm to this specific threshold temperature.

We compared these minimum temperature examples (Fig. 4) with what is known about sea turtle distributions in nearshore and offshore waters north of 35° N, using strandings data (Richards & Belskis 2007), observed captures (NMFS Northeast Fisheries Science Center unpubl. data and data from Epperly et al. 1995), and sightings data (NMFS Sea Turtle Atlantic Strategy GIS unpubl. database, NMFS 2001b). Strandings represent the spatio-temporal distribution of turtles in the nearshore waters off the northeast coast. Strandings are expected to lag behind the turtles' arrival at a nearshore area by several days to a couple weeks (Hart et al. 2006), and are expected to continue with a similar lag after turtles emigrate from a nearshore area, as



weakened individuals left behind die and as old carcasses are discovered. Observed captures mostly represent captures in offshore waters, as that was where the effort of the sampled fisheries was directed. Sightings from shipboard and aerial platforms were distributed in both nearshore and offshore waters. The spatio-temporal distribution of stranded turtles between Cape Hatteras, North Carolina, and Cape Cod, Massachusetts (n = 2487), correlates well with the above-mentioned minimum temperature examples for nearshore waters (Fig. 4; Richards & Belskis 2007). The observer data (n = 276) are comparable to the strandings data in their spatial distribution, but are slightly more restricted temporally, which could be a function of smaller sample size. The more numerous sightings (n = 4845) show a greater distribution temporally and geographically than either the strandings or observed captures. In the southern zones, the data indicate that relatively few turtles occur in nearshore or offshore waters when <25% of the area is <11°C, and in the northern zones relatively few occur in nearshore or offshore waters when <50% of the area is <14° C.

This finding, along with few documented cheloniids north of 42° N (Shoop & Kenney 1992) despite the fact that temperatures are warm enough during the summer to harbor cheloniid turtles (Fig. 4), led us to conclude that SST alone does not control the distribution of cheloniid sea turtles. Gardner et al. (2008, this Theme Section) determined that the relationship between the number of loggerheads captured in the North Atlantic pelagic longline fishery and temperature was not linear, but varied by region. In fact, the number of loggerheads captured off the northeast USA declined when water temperatures exceeded 21°C (Gardner et al. 2008). Thus, even though SST data can indicate the possible presence of cheloniid turtles in zones south of Cape Cod, their absence at northern latitudes at similar SSTs suggests the possible temporal unavailability of food resources or strong thermoclines restricting their bottom foraging abilities. These results indicate that: (1) use of minimum SST to manage interactions would be a conservative approach and (2) the choice of a minimum temperature or percent at or above that minimum temperature may be area specific and, if so, can be determined only with additional information on sea turtle distributions in the area of concern.

Although research has shown that temperature affects metabolic function and behavior and it is not unreasonable to expect a minimum water temperature for marine cheloniid turtles, their presence is also influenced by thermal fronts and ocean currents (Luschi et al. 2003), as well as food resources (Bentivegna 2002). In addition, because certain species of sea turtles (e.g. loggerheads) can regulate their body temperature to a certain extent via their large size, metabolism, or behavior (such as basking) (Spotila et al. 1997), they may be able to tolerate cooler water temperatures than other species of sea turtles, such as greens or Kemp’s ridleys, which are much smaller off the northeast USA than loggerheads. Therefore, research is needed to identify the prevalence of migrating sea turtles in different water temperatures and to relate their presence not only to SSTs, but to other environmental parameters as well as the physiological, anatomical, and behavioral characteristics of the turtles.

Regardless, this analysis does provide a framework for conservatively predicting marine cheloniid turtle presence and, thus, could provide a means of regulating fisheries that seasonally interact with sea turtles. With the exception of Zone 1 (35 to 35.5° N), where the frequent intrusion of Gulf Stream eddies in winter creates temperatures that are hospitable to turtles at all times (Epperly et al. 1995), surface water temperatures increase in a predictable movement up the Atlantic coast of the USA. Where turtles and fisheries are known to interact, managers also may consider the use of real-time monitoring of SST, onboard observers, and/or aerial surveys for turtles as temperatures begin to increase in the spring and decline in the autumn to reduce the likelihood of interactions.

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