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# Canadian waters provide critical foraging habitat for leatherback sea turtles

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ABSTRACT

From 1998–2005, we collected 851 geo-referenced records of leatherback turtles, *Dermochelys coriacea*, from a volunteer network of commercial fishers and tour boat operators in Atlantic Canada. These data provide new insight into the spatial and temporal distribution of leatherbacks in temperate northwest Atlantic waters. Patterns in sightings data were consistent with the results of concurrent satellite telemetry studies, revealing a broad distribution of leatherbacks on the Scotian Shelf throughout the foraging season, and regular occurrence in the southern Gulf of St. Lawrence in late summer and fall. Our results suggest inter-annual variation in leatherback abundance in Canadian waters, with reported sightings across all years peaking on August 5 (95% CI: July 25–August 15). Weekly mean area sea surface temperature (SST) had a significant effect on the number of leatherback sightings reported, independent of day of year, with each 1 °C rise in temperature increasing reported sightings by 12.5% (95% CI: 2.1–23.8%). Most turtles were reported inshore from the continental shelf break and mean SST associated with sightings was 16.6 °C (sd = 2.3 °C). Our findings suggest that Canadian waters support one of the highest summer and fall densities of leatherbacks in the North Atlantic, and should be considered critical foraging habitat for this endangered species. Conservation efforts must be broadened to address threats to leatherbacks in this area.



## 1. Introduction

An incomplete understanding of the distribution patterns of endangered species creates serious challenges for identifying where implementation of conservation efforts would be most effective. This is the case for the leatherback turtle, *Dermochelys coriacea*, a marine reptile that occurs in tropical through to arctic waters (Carriol and Vader, 2002). Leatherback nesting populations have declined in many regions (Spotila et al., 1996) with the most marked decreases reported in the Pacific (Chan and Liew, 1996; Sarti et al., 1996; Spotila et al., 2000). Incidental capture in fisheries are posited as a leading cause of population decline (Spotila et al., 2000; Lewison et al., 2004); however, conservation efforts largely remain focused on protecting leatherback nesting habitat and enhancing survivorship of eggs. Areas of leatherback aggregation beyond nesting beaches, where fisheries impacts on this species may be significant, remain poorly defined. To promote leatherback recovery, there is an urgent need to identify critical leatherback foraging habitat and address anthropogenic hazards to turtles in those areas.

Leatherbacks specialize on a diet of gelatinous zooplankton (Den Hartog and Van Nierop, 1984; Bleakney, 1965), which are typically exploited in multiple, disparate foraging areas

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(James et al., 2005b). Information on the occurrence of leatherbacks in most foraging areas is largely derived from records of turtles incidentally captured in fisheries or found stranded on the shore (Witzell, 1984, 1999; Godley et al., 1998; Carranza et al., 2006). Both sources of data introduce considerable biases when evaluating spatial and temporal patterns of leatherback occurrence. Satellite telemetry provides a more independent means of addressing this issue, and has advanced understanding of the behaviour of leatherbacks in areas distant from nesting colonies (Ferraroli et al., 2004; Hays et al., 2004; James et al., 2005a,b). However, telemetry data alone does not permit evaluation of seasonal distributions or relative abundance of leatherbacks in specific areas.

In the temperate northwest Atlantic, leatherbacks occur in shelf waters off the northeastern United States (Lazell, 1980; Shoop and Kenney, 1992) and are also regularly incidentally captured in mobile longline fisheries operating in pelagic areas (Witzell, 1984; Witzell, 1999; Lewison et al., 2004). Three years of aerial and shipboard surveys off the northeastern United States revealed seasonal distributions of leatherbacks, with peak abundance occurring between late June and late September (Shoop and Kenney, 1992). Although more than 372,000 km of survey track was sampled during these surveys, only 128 leatherbacks were sighted (Shoop and Kenney, 1992). These findings suggest a relatively low density of leatherbacks in coastal temperate waters of the eastern United States.

Further north, in Canadian waters, information on the distribution of this species is even more limited. Aerial and shipboard surveys for sea turtles have not been conducted, and published accounts of leatherbacks in Canadian waters summarize observations of small numbers of turtles, typically found entangled in nearshore fishing gear (Bleakney, 1965; Goff and Lien, 1988). Bleakney (1965) presented the largest number of such records ($n = 29$), spanning 140 years (1824–1964), and Goff and Lien (1988) collected 20 observations of leatherbacks from Newfoundland over a ten-year period (1976–1985). Small sample sizes from these studies preclude identification of spatial and temporal patterns of leatherback distribution in Canadian waters.

To evaluate the importance of Canadian Atlantic habitat to leatherbacks, a formal program was launched in 1998 to promote the reporting of sightings of sea turtles by commercial fishers and other mariners in Nova Scotia (Martin and James, 2005). Similar programs have been used to collect data on a variety of large pelagic species (Epperly et al., 1995a; Morey et al., 2003; Southall et al., 2005). Volunteered sightings data, combined with sea turtle observations made during two seasons of aerial surveys for right whales (*Eubalaena glacialis*) and records from pelagic fisheries observers, has yielded rare data on the occurrence of leatherbacks in Canadian waters. Here we describe seasonal and inter-annual patterns of reported leatherback distributions in Atlantic Canada, and compare reported seasonal distributions with movement patterns revealed by satellite telemetry. Our results highlight the importance of Canadian waters to Atlantic leatherbacks and indicate the times of year when strategies to reduce their incidental capture in regional fisheries would be most effectively implemented.

## 2. Methods

### 2.1. Volunteered sightings

To enhance awareness and promote reporting of leatherbacks among commercial fishers and other mariners, public education and outreach initiatives targeting coastal communities in Nova Scotia began in 1998 under the direction of the Nova Scotia Leatherback Turtle Working Group, NSLTWG (for more details see Martin and James, 2005). A toll-free phone number was established for reporting leatherback sightings. Active recruitment of fishers as volunteer data collectors took place at wharves and fishing organization meetings. Passive recruitment of volunteers included advertising the toll-free project hotline and study objectives on posters in areas frequented by fishing community members. Fishers were asked to record the date, time, GPS location and condition (e.g., alive or dead, free-swimming or entangled) of each leatherback observed during the years 1998–2005. They were also encouraged to document their sightings using video and/or photographs; approximately 200 single-use waterproof cameras were distributed for this purpose. Reporting of leatherback sightings was primarily promoted in Nova Scotia; however, limited distribution of project posters and other educational materials also occurred in the surrounding provinces (Fig. 1).

To evaluate the extent to which temporal patterns in reported sightings of leatherbacks mirrored true seasonal

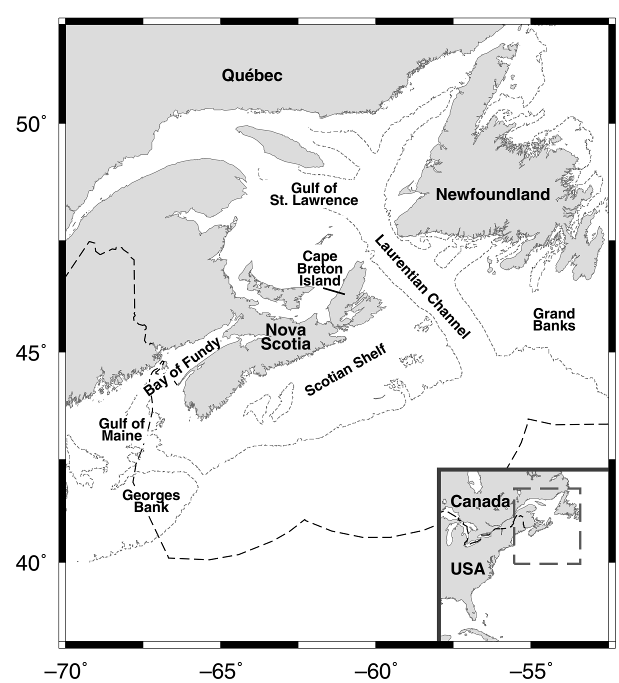


**Fig. 1 – Map of Nova Scotia and surrounding area indicating place names referred to in the text. Thin dashed line indicates 200 m depth contour. Canadian territorial waters are bounded by the Canadian Exclusive Economic Zone (thick dashed line). Inset shows region in context of the broader northwest Atlantic Ocean.**

patterns in leatherback departure from Canadian waters, we determined the dates at which nine turtles equipped with satellite tags off Nova Scotia assumed southward migrations from shelf and/or slope waters in Canada's Exclusive Economic Zone. These nine animals were selected for this analysis from a broader sample (James et al., 2005b) because they were tagged in early summer and remained exclusively within Canadian waters during their northern foraging period.

### 2.2. Other sources of leatherback records

#### 2.2.1. Aerial surveys

While dedicated aerial surveys for sea turtles have never been conducted in Canadian waters, we obtained sightings of leatherbacks recorded in 1998 and 1999 during summer aerial surveys for right whales (Brown and Tobin, 1999, 2000). Aerial survey tracklines were limited to areas of known right whale habitat on the southwest portion of the Scotian Shelf and in the Bay of Fundy, bordered by 67.25°W and 62°W longitude (for further details on survey design, see Brown and Tobin, 1999, 2000).

#### 2.2.2. Canadian pelagic fisheries observer data

Locations of leatherback interactions with Canadian pelagic longline fisheries (1998–2005) were obtained from the DFO Maritimes At-Sea Observers Database (Fisheries and Oceans Canada, 2006).

### 2.3. Environmental correlates of sightings

Sea surface temperature (SST) was obtained for sightings using Advanced Very High Resolution Radiometer (AVHRR) Oceans Pathfinder (version 5) data from the Physical Oceanography Distributed Active Archive Center at the NASA Jet Propulsion Laboratory (http://podaac.jpl.nasa.gov). The best quality temperatures within one day and 0.1° of the sighting were averaged to produce an SST estimate for the sighting. To obtain an overall index of SST in the study area, we averaged temperatures for each week from all AVHRR pixels (~4 km resolution) not obscured by cloud cover and corresponding to locations shallower than 200 m in the study area.

Bathymetry associated with sightings was obtained from the 15 second Atlantic Bathymetry Compilation (ABC) Dataset, Canadian Hydrographic Service (http://www.charts.gc.ca/).

### 2.4. Statistical analyses

To elucidate potential temporal patterns in the latitudinal distribution of sightings, we evaluated the relationship between latitude and day of year using Spearman's rank correlation.

To assess seasonal, annual and SST-based variation in reported sightings, sightings per day were modeled against year, day of year, day of year squared and weekly average area SST using a generalized linear model with a negative binomial distribution (Venables and Ripley, 2002). We compared differences in number of sightings reported between years using likelihood ratio tests and post hoc comparisons using Wald tests.

## 3. Results

### 3.1. Volunteered sightings

From 1998–2005, fishers and other mariners reported 851 geo-referenced sightings of free-swimming or entangled leatherback turtles in Atlantic Canada. Sightings principally corresponded to the Scotian Shelf, mainly reflecting reporting by fishers in Nova Scotia (Fig. 2). However, smaller numbers of sightings were also reported outside of the principal study area, including coastal Newfoundland and slope waters south of Nova Scotia (Fig. 3). The most northerly records corresponded to the coast of mainland Quebec and the north coast of Newfoundland (Fig. 3). Relatively few turtles were reported in the Bay of Fundy and northern Gulf of St. Lawrence.

The first reported sightings of the year typically occurred in June and often corresponded to waters in the vicinity of Georges Bank. Turtles were not regularly sighted until July. In July and August, turtles were reported along most of the Scotian Shelf. Sightings off Cape Breton Island, further to the north, increased in August, and remained frequent in this area later into the season as reporting decreased in more southern areas (Fig. 4). There was a marked decrease in sightings during late September and October (Fig. 4), and of the few sightings reported in October and November, many corresponded to waters in the southern Gulf of St. Lawrence. Sightings there include an apparent area of seasonal concentration on the Gulf of St. Lawrence side of the Canso Causeway, a stone embankment built to connect mainland Nova Scotia to Cape Breton Island. No live turtles were reported during the months of January to April.

All nine satellite tagged turtles that limited their northern foraging movements exclusively to Canadian waters remained on the continental shelf and/or slope into the second week of September. Eight were still present in the first week of October, and two remained until November (Fig. 6).

### 3.2. Other sources of leatherback records

#### 3.2.1. Aerial surveys

During aerial surveys for right whales on the Scotian Shelf, 31 leatherbacks were sighted in 1998, and 11 leatherbacks were sighted in 1999 (Brown and Tobin, 1999, 2000). Sightings corresponded to waters off the southwest coast of Nova Scotia, between 65.5°W and 63.5°W. Although the Bay of Fundy was intensively surveyed, no leatherbacks were observed there (Fig. 3).

#### 3.2.2. Canadian pelagic fisheries observer data

120 Leatherback interactions with Canadian pelagic longline gear were recorded by fisheries observers during 1998–2005.

### 3.3. Environmental correlates of sightings

Bathymetry extracted for all sightings (Fig. 7) revealed leatherback occurrence in both offshore and coastal waters (range 2–5033 m). The majority of turtles (80.2%) were reported on the continental shelf (waters inside the 200 m isobath). Median

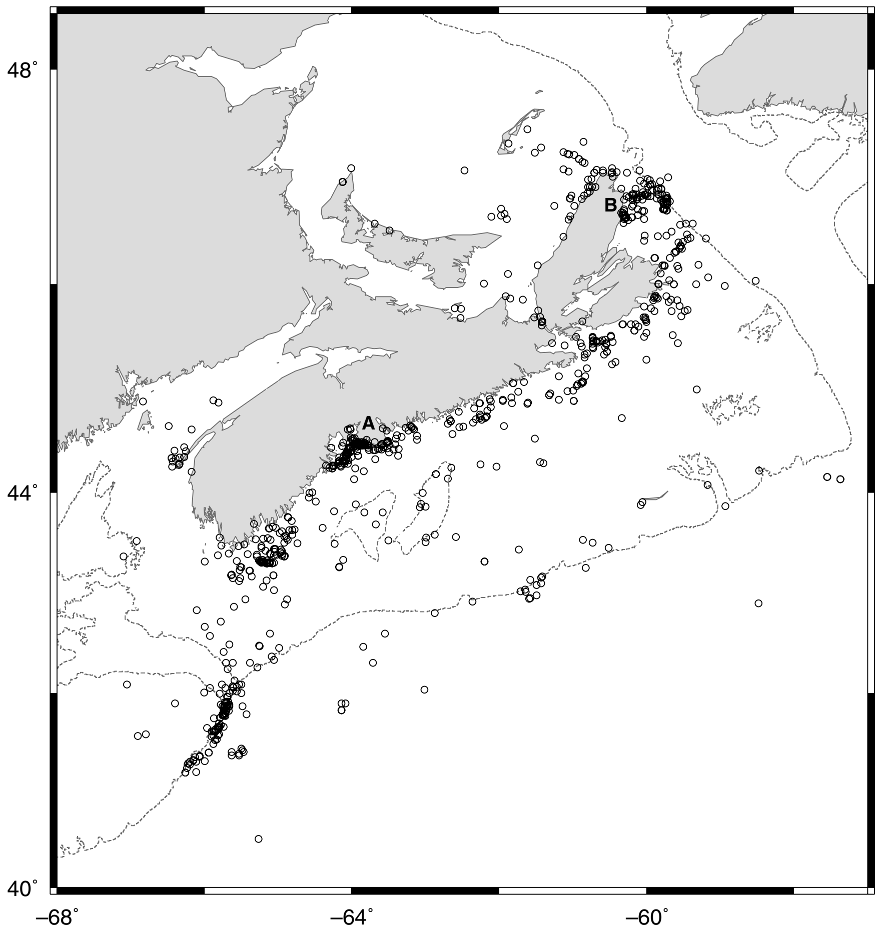


**Fig. 2 – Sightings of leatherback turtles off Nova Scotia (circles) voluntarily reported by fishers and other mariners, 1998–2005. High levels of reporting correspond to areas proximate to (A) the city of Halifax and surrounding areas (Nova Scotia's largest population centre; also where regional leatherback science and outreach efforts are based) and (B) the northeast tip of Cape Breton Island (where associated field research has occurred since 1999). Dashed line indicates 200 m depth contour.**

depth of sightings was 113 m. AVHRR-derived SSTs were available for 66.8% of all reported sightings in Canadian waters. Across all years, mean SST was 16.6 °C (sd = 2.3 °C, range = 6.8–23.2 °C). 19.7% of sightings were reported in waters <15 °C (Fig. 8).

### 3.4. *Statistical analyses*

Spatio-temporal patterns in the distribution of sightings include a significant trend in sighting density from south to north over the season ($p < .0001$, Spearman's $\rho = .40$) (Fig. 4).

There was inter-annual variation in the number of sightings reported each year ($p < .0001$), with 1998 and 2003 significantly higher than all other years (all $p < .05$). Independent of SST, reported sightings across all years peaked on August 5 (95% CI: July 25–August 15) (Fig. 5).

Average weekly SST had a significant effect on the number of reported sightings ($p < .02$) (Fig. 5). For a given day and year, each 1 °C increase in temperature increased turtle sighting reports by 12.5% (95% CI: 2.1–23.8%).

## 4. Discussion

### 4.1. *Spatial distribution of sightings*

Combining reports of leatherbacks volunteered by fishers and other mariners with the results of aerial surveys, pelagic fishery observer programs, and satellite telemetry studies enables us to identify spatial and temporal patterns in this species' distribution in Canadian waters.

The majority of voluntarily reported sightings of leatherbacks corresponded to waters of the continental shelf (Fig. 2); however, Canadian pelagic fisheries observer data also indicates regular occurrence of this species on and beyond the shelf slope (Fig. 3). Therefore, leatherbacks appear to be widely distributed in both inshore and offshore waters.

The Gulf of St. Lawrence has not previously been recognized as an area regularly used by leatherbacks. However, our sightings data, coupled with results of recent satellite telemetry studies (James et al., 2005b, 2006), suggest that this species regularly forages in the southern Gulf of St. Lawrence,

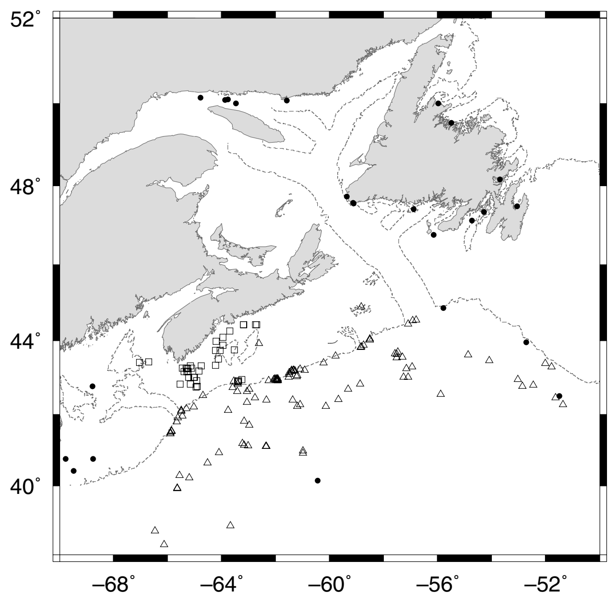


**Fig. 3 – Additional records of leatherbacks in Canadian waters, 1998–2005. Solid circles denote locations of turtles outside the primary study area reported to the Nova Scotia Leatherback Turtle Working Group. Triangles denote locations of leatherbacks from Canadian pelagic fisheries observer programs. Squares represent turtles sighted during aerial surveys for right whales (1998–1999). Dashed line indicates 200 m depth contour.**

with smaller numbers of animals entering more northerly waters near mainland Quebec.

In contrast, turtle sightings were conspicuously rare in the Bay of Fundy, and multiple lines of evidence suggest that this accurately reflects a relative scarcity of leatherbacks in this area. First, the Bay of Fundy hosts a large fleet of whale watch vessels, so there is a high level of observer effort focused on detecting marine life in this region. In addition, tour boat operators were directly approached to report leatherback sightings (Martin and James, 2005). Second, while large numbers of leatherbacks were reported in Canadian waters in 1998 and 1999, none were sighted during aerial surveys of important right whale habitat in the Bay of Fundy (Fig. 3). Finally, not one of 38 satellite-tracked leatherbacks journeyed into the Bay of Fundy during the first or second high-latitude foraging period following tagging off Nova Scotia (James et al., 2005b). These data suggest that the Bay of Fundy may provide less suitable habitat for leatherbacks relative to other areas in Canadian waters.

### 4.2. *Temporal distribution of sightings*

The temporal distribution of leatherback sightings off eastern Canada suggests that a simultaneous seasonal influx of turtles does not occur across the entire region. Following arrival in southern portions of the Scotian Shelf, up to several weeks may elapse before leatherbacks are regularly sighted in areas further to the north, including waters off northern Cape Breton, Newfoundland and the Gulf of St. Lawrence. While the lower thermal tolerance limits of leatherbacks are not well understood, it is possible that intra-regional differences in SST throughout the spring and summer influence spatio-temporal distributions of this species, with turtles entering more northern waters later in the season when temperatures approach seasonal highs. This interpretation is consistent with ocean temperatures associated with records of leatherbacks off Newfoundland (Goff and Lien, 1988). Similarly, the departure of most leatherbacks from high-latitude shelf waters in the fall may be precipitated by decreasing ambient ocean temperature.

Variation in temporal patterns in reported sightings may also reflect response of leatherbacks to seasonal changes in gelatinous zooplankton prey distributions. While in Canadian waters, leatherbacks forage on large scyphomedusae, including *Cyanea capillata* and *Aurelia aurita* (James and Herman, 2001), species which mainly occur in northern coastal areas (Bamstedt et al., 1992). Seasonal increases in water temperature have been shown to be important to both sexual development and the onset of reproduction in *Cyanea* and related species (Hernroth and Gröndahl, 1983; Brewer and Feingold, 1991; Purcell et al., 1999). Rapid spring increases in coastal water temperatures linked to strobilation and exponential growth in *C. capillata* and *A. aurita* (Gröndahl and Hernroth, 1987; Brewer and Feingold, 1991) first occur in southern parts of eastern Canada, with more northerly areas reaching peak seasonal temperatures later in the season (Mason et al., 1999). After reaching maximum size following several months of growth, many *C. capillata* show a sequence of progressive senescence, beginning with the loss of their tentacles, oral folds, then gonads (Brewer and Feingold, 1991). The spatio-temporal seasonal patterns in leatherback distributions inferred from sightings data likely parallel the seasonal cycles of *C. capillata* and other gelatinous leatherback prey, with turtles exploiting emerging food resources and then departing northern waters when prey densities decline. Similarly, variation in the temporal distribution of leatherback sightings between years may reflect inter-annual differences in the timing of various stages of development of *Cyanea* and other scyphomedusae (for details, see Brewer and Feingold, 1991).

In temperate waters, the relative abundance of *C. capillata* and other scyphomedusae can vary greatly between years (Gröndahl, 1988; Brewer and Feingold, 1991). We expect that variation in prey availability is paramount to influencing patterns of leatherback density in Canadian waters and that these patterns are ultimately mirrored in the inter-annual variation in number of sightings reported to us. Further research is required to clarify the potential effects of ocean temperatures on population dynamics of leatherback prey off eastern Canada.

### 4.3. *Environmental correlates of sightings*

The mean SST corresponding to reports of leatherbacks in this study was 16.6 °C. 20% of sightings were associated with SSTs below 15 °C, attesting to this species' capacity to exploit cold, temperate waters. Frequency of reported sightings increased with warmer water temperatures, suggesting that water temperature may affect seasonal distribution and abundance of leatherbacks. Colder average

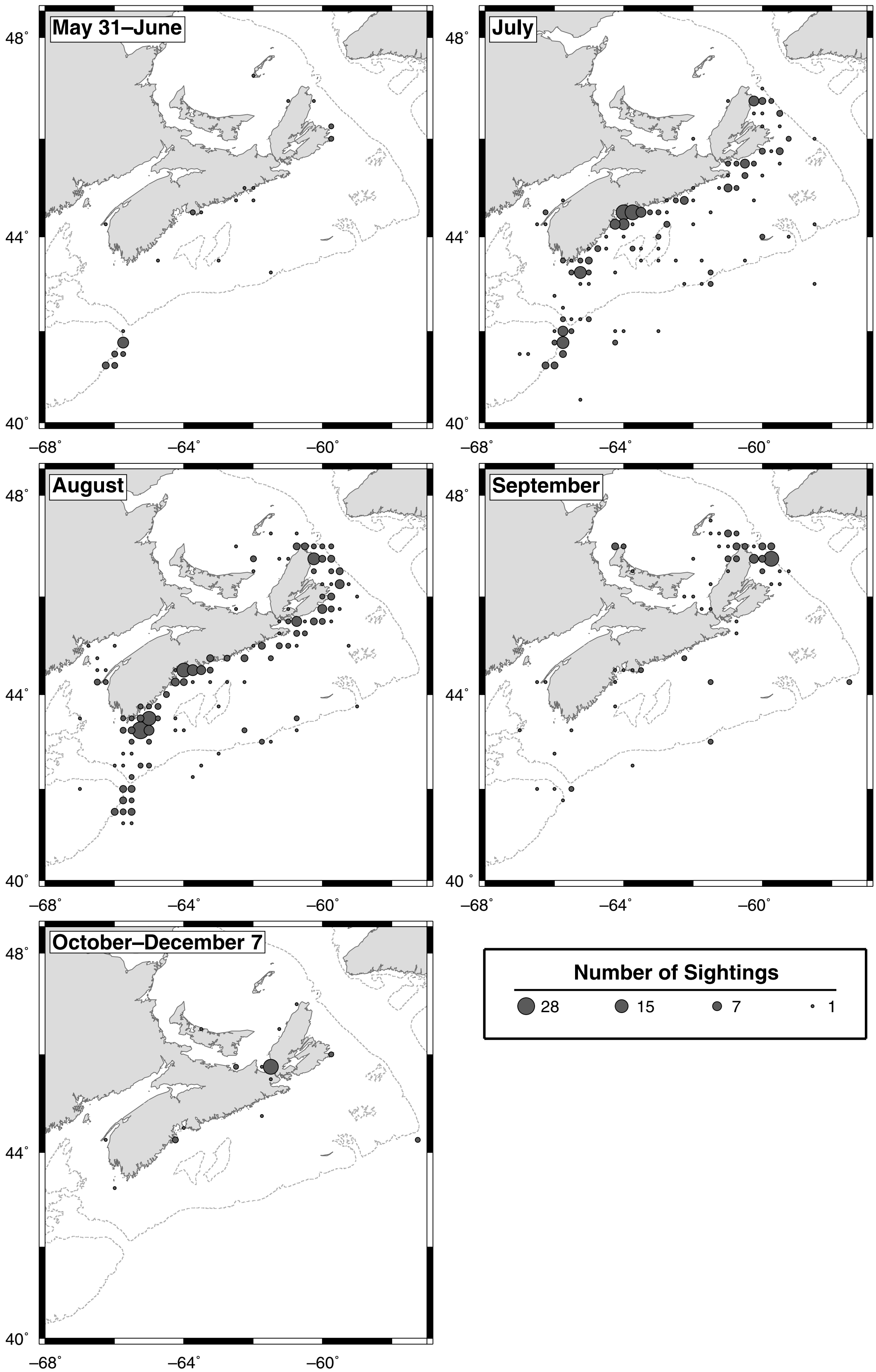


**Fig. 4 – Sightings of leatherback turtles voluntarily reported off Nova Scotia by month, 1998–2005. Sightings are binned in .25 degree increments. Note that there is no standardization for effort, as effort is not reported by volunteer fishers and other mariners. Dashed line indicates 200 m depth contour.**

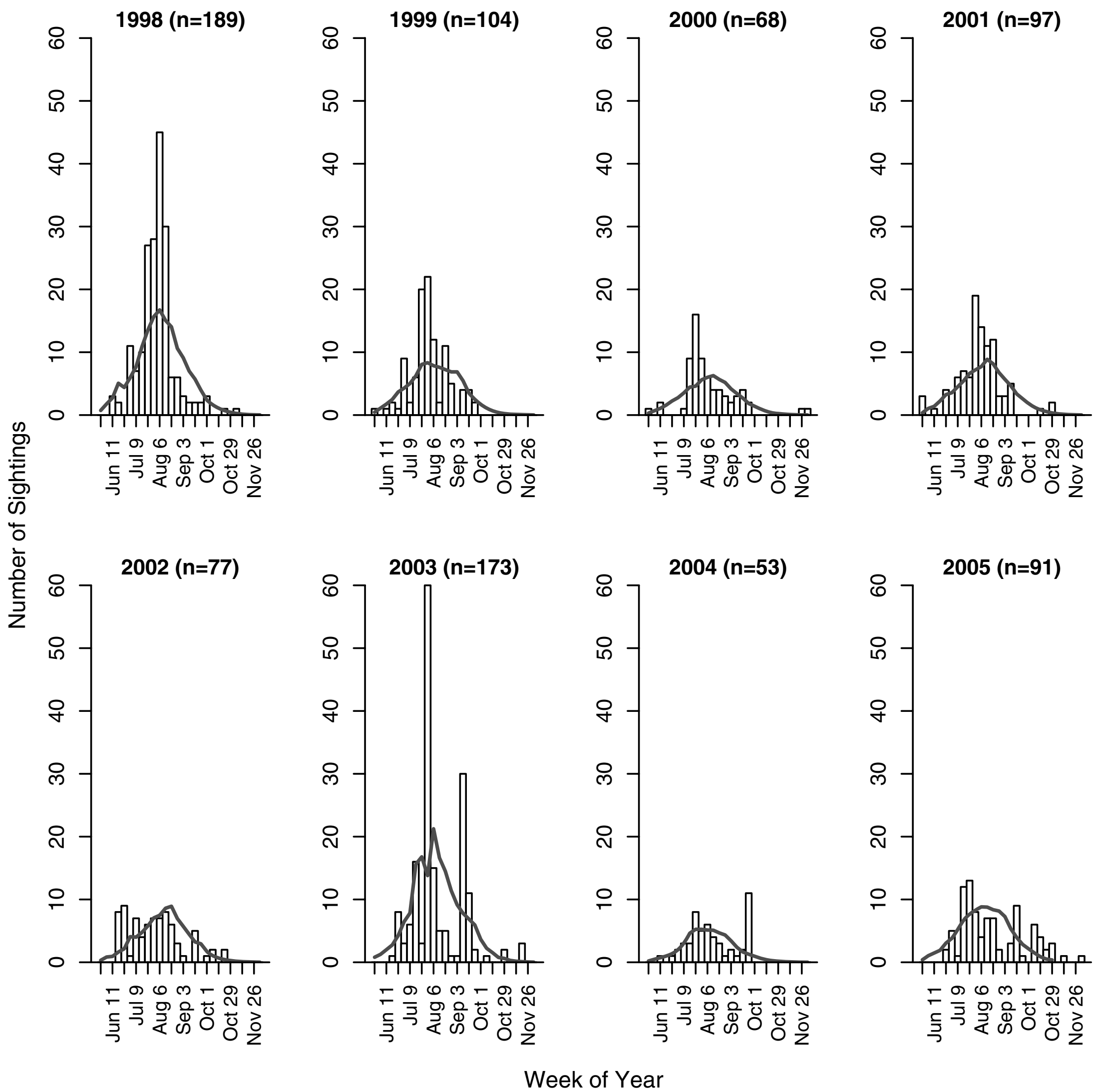


**Fig. 5 – Weekly sums of reported sightings of leatherbacks for 1998–2005 (bars) compared to values predicted from a generalized linear model using year, day of year, day of year squared, and AVHRR sea surface temperature data.**

annual SST could partially account for what appears to be a much lower density of leatherbacks in coastal Newfoundland (Goff and Lien, 1988) versus Nova Scotia. It is possible that the relatively warm SSTs associated with most leatherback sightings may simply reflect seasonal ocean conditions typical of the leatherback's foraging period off eastern Canada, rather than the turtles' true thermal preferences. Ocean temperature may also affect leatherback occurrence more indirectly, for example, by influencing the abundance and distribution of their jellyfish prey as previously discussed.

We have shown that the majority of reported leatherback sightings corresponded to shelf waters. This is consistent with the detection of higher relative densities of leatherbacks in shallow continental shelf waters versus further offshore during aerial surveys off the continental eastern United States and northern Gulf of Mexico (Hoffman and Fritts, 1982; Fritts et al., 1983; Shoop and Kenney, 1992).

### 4.4. *Biases in observer effort*

There are limitations associated with volunteered sightings data. Principal among these is a lack of standardization in observer effort, both within and across seasons. The data are collected opportunistically, and there is no reporting of when turtles are not sighted. Sea state and fog also affect the likelihood of observing turtles, and there are differing, yet unquantified probabilities of observing or interacting with leatherbacks in different fisheries.

Leatherback density across the study area is likely not uniform, consistent with identification of high-use areas via satellite telemetry (James et al., 2005b). The higher concentration of sightings on, as opposed to off, the continental shelf may, as we suggest, reflect a true pattern in this species' distribution, but also partly reflects biases in volunteer effort; inshore fishers are not only more numerous, but also more likely to report their observations of sea turtles than pelagic

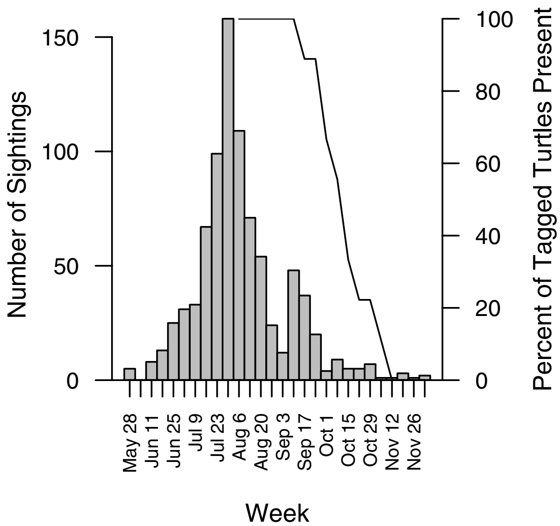


**Fig. 6 – Temporal distribution of leatherback sightings compared to the end of the residency period for leatherbacks in Canadian waters as indicated by satellite telemetry. Bars show frequency of voluntarily reported sightings of leatherbacks by week for all years (1998–2005). Solid line represents percent of nine leatherbacks satellite tagged off Nova Scotia remaining in Canadian waters.**

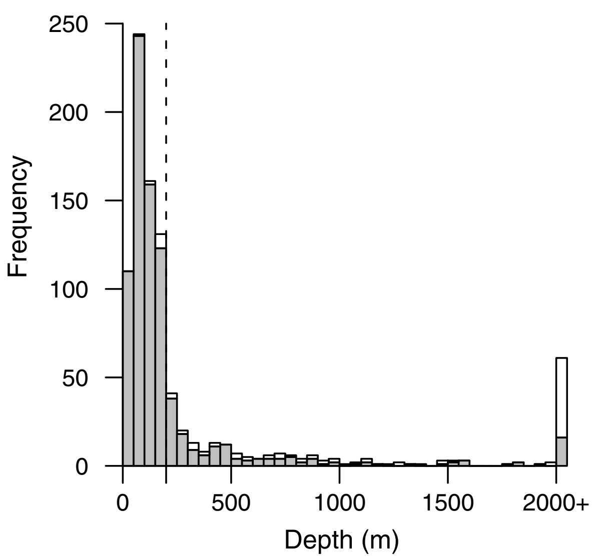


**Fig. 7 – Bathymetry associated with sightings of leatherbacks in Atlantic Canada, 1998–2005. Depth is binned in 50 m increments. Shaded portions of bars indicate volunteered sightings (*n* = 851); open portions of bars indicate reports from pelagic fisheries observers (*n* = 120). Dashed line indicates 200 m depth.**

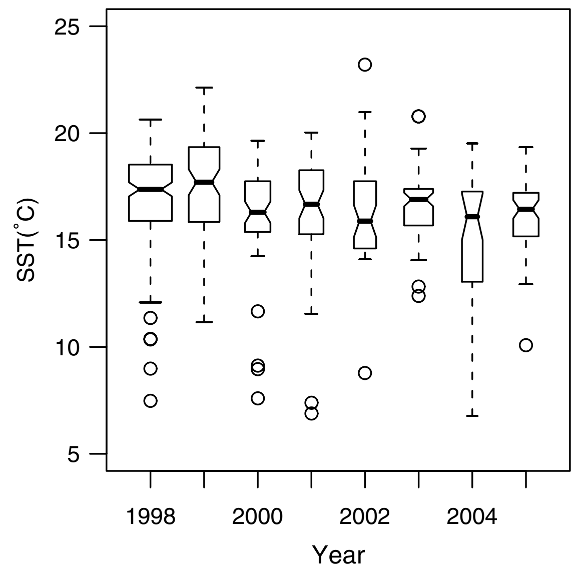


**Fig. 8 – Boxplots of AVHRR-derived sea surface temperatures (SST) for reported sightings of leatherbacks, 1998–2005. Boxes are drawn with widths proportional to the square-roots of the number of observations. Each box contains the middle 50% of the data. The line in each box is the median, the notches are 95% confidence intervals for the median. Whiskers extend to a maximum of 1.5 times the inter-quartile range, and circles represent values that fall outside this range.**

fishers (Martin and James, 2005). Biases in observer effort are also likely reflected in concentrations of sightings on the Scotian Shelf occurring in some areas of high fishing activity (the northeast tip of Georges Bank), along common travel routes for fishing vessels (from southwest Nova Scotia to Georges Bank), near urban centres (Halifax), and where the profile of our sightings program has been heightened through our field research stations (Halifax County and the northeast tip of Cape Breton Island) (Fig. 2).

Concurrent satellite telemetry studies generally corroborate the temporal patterns in seasonal leatherback distributions in Canadian shelf waters (James et al., 2005b); however, an important exception concerns when leatherback density on the shelf declines. Our sightings data suggest leatherback density drops markedly after August (Fig. 4), yet most satellite-tagged turtles remain foraging on the shelf through to October (James et al., 2005a,b), and we have encountered some of the largest concentrations of leatherbacks in coastal areas during fieldwork in late September. In this case, it is a decline in fishing activity, hence, observer effort, across the Scotian Shelf in September that obscures the true temporal pattern of leatherback departure from shelf foraging areas. For those vessels that do continue fishing into the fall, a general deterioration of sea state makes turtles harder to see.

### 4.5. *Leatherback aggregation in Canadian waters*

In most cases, fishers have limited opportunities to observe, let alone record, turtles and other free-swimming marine life during fishing operations. In addition, as participation in our sightings program is voluntary, we expect that only a small proportion of mariners who observe leatherbacks report them to us. Therefore, sightings data must grossly underestimate the number of turtles observed by mariners in the region.

During a period spanning more than three years, aerial and shipboard surveys for marine mammals and sea turtles in a study area encompassing waters off Cape Hatteras, North Carolina (USA), through to the Gulf of Maine yielded 128 leatherback sightings (Shoop and Kenney, 1992). In the much smaller study area off Nova Scotia, mariners reported 851 sightings of leatherbacks over eight seasons. Fundamental differences in both how and when sightings data were collected preclude direct comparison of our data to that presented by Shoop and Kenney (1992); however, we believe it is reasonable to assume a greater overall level of observer effort during the extensive U.S. surveys. Therefore, the relative density of leatherbacks in Canadian waters is likely much higher than Shoop and Kenney's (1992) estimate of a summer population of 100–900 turtles in the large area they surveyed. As the data sets we compare are separated by over 15 years, it is also possible that leatherbacks may be more abundant off both Canada and the northeastern United States now than they were when the Shoop and Kenney (1992) data was collected (1978–1982). Analysis of more recent aerial and shipboard survey data is required to assess potential trends in seasonal densities of leatherbacks off the northeastern United States.

The large regional leatherback foraging population in Canadian waters is likely the result of several factors. First, Canadian waters are closer to major leatherback nesting centres in the western Atlantic than high-latitude foraging areas in the eastern Atlantic, enabling many turtles to complete annual round-trip migrations from southern breeding and foraging areas (James et al., 2005b). Second, shelf waters off eastern Canada support high zooplankton and gelatinous zooplankton productivity, including large species targeted by leatherbacks (James and Herman, 2001). Finally, and perhaps most importantly, the geographic orientation of the provinces of Nova Scotia and adjacent Newfoundland (Fig. 1) physically promote leatherback aggregation. Turtles proceeding northwards along both the coast of the United States (Eckert et al., in press) and across a broad longitudinal area of the western Atlantic (James et al., 2005a,b) are channeled onto the Scotian Shelf. Movement patterns demonstrated by satellite telemetry indicate that leatherbacks venturing to the Scotian Shelf, Gulf of St. Lawrence, or waters off the south coast of Newfoundland often remain in the broader general foraging zone (corresponding to our study area) throughout the summer and early fall before migrating south (James et al., 2005a,b). Few of these animals likely proceed further north after arriving in this area as such movements would initially necessitate entry into the much colder waters of the Labrador Current, which flows south along the northeast coast of Newfoundland. Although the Labrador Current clearly does not act as an absolute thermal barrier to leatherbacks (Threlfall, 1978; Goff and Lien, 1988), their association with this current may principally be limited to areas where it meets warmer water masses, such as on the Grand Banks (Witzell, 1999) or the east coast of Newfoundland (Goff and Lien, 1988). Such frontal zones are known to concentrate gelatinous zooplankton (Graham et al., 2001), and, therefore, may create favorable foraging conditions for leatherbacks.

It is possible that many leatherbacks found in shelf areas of the southern United States in the spring continue northwards to forage in waters off New England and eastern Canada during summer and fall. The marked decrease in leatherback sightings from spring to summer reported by fishers off North Carolina (Epperly et al., 1995) is consistent with this suggestion. Although some leatherbacks may restrict their movements to shallow shelf waters of the United States throughout their entire northward migration, most remain in pelagic waters when returning to Canadian coastal foraging areas the year after they are tagged (James et al., 2005a).

## 5. Conclusions

The present findings, satellite telemetry studies (Hays et al., 2004; James et al., 2005b; Eckert et al., in press), and data from pelagic fisheries observer programs (Witzell, 1999; Lewison et al., 2004) all point to coastal and slope waters of the western Atlantic north of 38°N as preferred summer and fall foraging habitat for leatherbacks. Separated from the largest leatherback nesting centres in the Caribbean and South America (Spotila et al., 1996) by several thousand kilometres, and corresponding to the northernmost extent of the leatherback's regular range in the western Atlantic, these foraging areas appear to be especially important to this species.

Our analysis provides new insight into the spatial and temporal distribution of leatherbacks in temperate northwest Atlantic waters and identifies Canadian waters as critical high-latitude habitat for this species. The significance of Canadian foraging habitat for leatherbacks is further supported by tag recoveries, which indicate that turtles from nesting beaches throughout the western Atlantic occur off Nova Scotia (James et al., in press).

Unfortunately, volunteered sightings do not allow for in-water population estimates. To quantify turtle abundance, more rigorous, standardized surveys are needed. In Canada, aerial surveys are required to assess regional patterns and long-term trends in leatherback abundance, to help identify areas of turtle concentration at smaller scales, and to evaluate the spatial and temporal overlap between leatherbacks and the human activities that impact them. Finally, to enhance our ability to predict occurrence of this endangered species, systematic surveys for leatherbacks in their northern foraging areas should include simultaneous study of turtle behaviour and physical and biological oceanographic conditions, including prey distributions.

Most leatherback turtle conservation efforts in the Atlantic have traditionally focused on protecting the nesting habitat of this species and addressing threats to breeding females and their eggs. Increases in some nesting populations attest to the success of such work (Hughes, 1996; Dutton et al., 2005). However, despite similar efforts in other nesting areas, population trends there are less certain (Troëng et al., 2004). Satellite telemetry has revealed that large sub-adults, and mature male and female leatherbacks in their inter-nesting years return annually to high-latitude foraging areas (James et al., 2005a), where they are vulnerable to incidental capture in many fisheries (James et al., 2005b). Although recent measures have been taken to reduce injury and mortality associated with incidental capture of leatherbacks on pelagic longlines (Watson et al., 2005), little effort has been made to address fisheries interactions and other anthropogenic impacts on leatherbacks in temperate shelf waters of the western Atlantic. The present results indicate the need to expand conservation efforts to these areas.

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