The Use of Satellite Oceanography to Understand Leatherback turtle (***Dermochelys coriacea***) Foraging Behaviour

A Preliminary Paper

Michael C. James
and
Ransom A. Myers
Department of Biology
Dalhousie University
Halifax, Nova Scotia
Canada B3H 4J1
email: mjames@mscs.dal.ca

1 Abstract

Here we describe the feeding sites of 19 leatherback turtles (*Dermochelys coriacea*) tagged with ARGOS Platform Transmitting Terminals (PTTs) in coastal waters of Nova Scotia. To investigate potential oceanographic correlates of foraging, we overlaid turtle location data on three-day Advanced Very High Resolution Radiometer (AVHRR) composites of remotely-sensed sea surface temperature (SST) and chlorophyll-a concentration. This written report includes a subset of these images (n=86), and an initial interpretation of the results[1]. We found evidence of leatherback foraging along several types of oceanographic fronts, areas where their principal prey, jellyfish, are likely to concentrate. We also observed multiple turtles feeding in other areas, including the South Atlantic Bight, the Mid Atlantic Bight south of Cape Cod, and the Gulf of St. Lawrence. Interestingly, no foraging was detected in the mouth of the Bay of Fundy.

[1] The images are also available in electronic format on the enclosed compact disk.

2 Introduction

Leatherback turtles (*Dermochelys coriacea*) are endangered in Canada (James, 2001), and critically endangered globally (Sarti, 2000). Entanglement in fishing gear constitutes a principal threat to this species (Spotila et al., 2000), and is believed to account for the majority of anthropogenic mortality in high-latitude feeding areas. Even small amounts of bycatch mortality are detrimental to long lived marine turtles (Crouse et al., 1987), and a stable population cannot be sustained if adult anthropogenic mortality is more than 1% above background levels (Spotila et al., 1996). Therefore, to develop effective management strategies to recover leatherbacks, we must first understand where and when they may be most vulnerable to entanglement.

Although leatherbacks, like all marine turtles, nest at low latitudes, much of their feeding occurs further north, presumably to take advantage of productive temperate waters which support a large biomass of jellyplankton, their principal prey. Leatherbacks require a large amount of food in order to survive and grow (Lutcavage and Lutz, 1986), and they are likely attracted to concentrated sources of prey. While jellyfish such as *Cyanea* sp. do swim vertically (Costello et al., 1997), these organisms are also actively transported horizontally and vertically by currents, and are, therefore, concentrated in specific areas where ocean currents converge. It has long been hypothesized that turtles feed preferentially in these areas, however, little solid data has been presented to support this idea. Here we specifically consider six types of oceanic fronts as features that may concentrate jellyfish and subsequently attract leatherback turtles. An understanding of how oceanographic features and processes influence foraging behaviour in leatherbacks will help us predict where and when interactions between turtles and commercial fisheries are likely to occur.

3 Methods

We used Advanced Very High Resolution Radiometer (AVHRR) data from NOAA polar orbiting satellites to generate three-day composites of sea surface temperature (SST) and chlorophyll-a concentration and to identify the positions of oceanic fronts. We also generated weekly and bi-weekly SST and chlorophyll-a composites, however, we found that they were of limited value because both the turtles and the oceanographic features generally moved too much over those time frames to permit a reasonable interpretation of the data.

We specifically considered six types of oceanic fronts: planetary fronts, shelf break fronts, western boundary current edges (including warm and cold core rings), upwelling fronts, plume fronts, and shallow-sea fronts (Bowman and Esaias, 1978). We compared our interpretation of the location of fronts with *Jenifer Clark's Gulf Stream Analysis*, a commercial product.

To determine where turtles foraged, we overlaid corresponding filtered locations from 19 Platform Transmitting Terminals (PTTs) deployed on leatherbacks off Cape Breton Island and off southwest Nova Scotia on the SST and chlorophyll-a composites. Leatherback foraging behaviour at high latitudes is characterized by residency in specific areas, with non-linear movements and regular surfacing behaviour yielding clusters of turtle locations from ARGOS. Therefore, we interpreted clusters of turtle locations as indicative of foraging activity, and, when possible, corroborated this interpretation with corresponding diving data.

4 Results

The SST and chlorophyll-a composites revealed numerous instances of leatherback foraging associated with three readily identifiable types of oceanographic fronts: the shelf-slope front (Fig. 14-16), upwelling fronts (Fig. 19, 20), and western current boundary edges (Fig. 1, 2, 12, 13, 22).

Foraging was also associated with specific areas of the northwest Atlantic, including coastal waters off Florida (north to South Carolina) in the South Atlantic Bight (Fig. 3, 4), the Mid-Atlantic Bight south of Cape Cod, MA. (Fig. 5-11), the southwest portion of the Gulf of St. Lawrence (Fig. 17, 18), and shelf waters off the northeast coast of Cape Breton Island, Nova Scotia (the foraging area where nine of the turtles were originally tagged).

5 Discussion

5.1 Foraging associated with Oceanic Fronts

Shelf Slope Fronts

The area where leatherback foraging appeared to occur most frequently with an identifiable oceanographic feature was along shelf slope front. Shelf slope fronts are formed at the edge of the continental shelf, where the relatively fresh and cold shelf water mass meets the saltier and warmer slope water mass. Fish and other marine animals also concentrate along the shelf slope front, therefore, it is an important area for pelagic longline fisheries targeting swordfish and tuna. Because a common strategy in fishing for swordfish is to set the longline parallel to the front (Podesta et al., 1993), this may be the area where the greatest number of interactions between fisheries and leatherback turtles occur in all of eastern Canada.

Upwelling Fronts

During August 2001, a large number of foraging leatherback turtles were observed and tagged off coastal Nova Scotia, in an area 30 km south of Halifax. Leatherbacks also appear to seasonally forage in waters off the south coast of Newfoundland. One possible mechanism that may be responsible for concentrating food, e.g. jellyfish, in both of these areas is the strong coastal upwelling associated with longshore winds from the southwest that usually occur during the summer. During periods of this upwelling, ``streamers'' occur off the coast (Petrie et al., 1987). After the temperature front moves offshore, wavelike features develop rapidly. Estimates by Petrie et al. (1987) suggest that this upwelling, and subsequent eddy development, play an important role in the supply of nutrients to surface waters. We suggest that the same factors may concentrate jellyfish and, therefore, attract foraging leatherbacks.

Western Current Boundary Edges

The intersection of warm, salty, tropical waters, with cold, dilute, higher-latitude water produces very strong fronts. This type of mixing occurs along the edge of the Gulf Stream and may cause meanders to develop in the current. Warm and cold core rings are meanders that are shed to the north and south of the Gulf Stream, respectively.

Warm core rings (Fig.1, 2, 12, 13), are meanders that break off and form circular -or approximately circular- rings to the north of the Gulf Stream. Leatherback turtles appear to feed at approximately two-thirds of the distance from the center of the ring to the outside edge (Fig. 2). It is here that the current shear below the surface is typically strongest. There may be regular interactions between turtles and pelagic longline fisheries in these areas.

Cold core rings (Fig. 22), are similar to warm core rings, however, they break off to the south of the Gulf Stream and are, therefore, surrounded by warmer water. Like the rings contained within the Gulf Stream, these structures concentrate marine organisms. In 2002, one leatherback tagged off Cape Breton foraged extensively in a cold core ring. We do not know of any fishing activity that is commonly directed in cold core rings.

Fronts off Cape Breton

One of most reliable places to locate leatherbacks in Atlantic Canada is the northern east coast of Cape Breton, where nine of the 19 turtles considered here were tagged. Before swordfish populations were reduced by overfishing, this was a productive swordfish harpooning area in the North Atlantic (Fitzgerald, 2000). This area is characterized by oceanic fronts that do not directly correspond to the six categories of fronts proposed by Bowman and Esaias (1978). In some ways, they resemble plume fronts, which form at the boundary between the ocean and the fresh-water discharge produced by large rivers, because the water from the St. Lawrence River enters the Atlantic here. However, in other ways, they resemble shelf slope fronts because the steep slope into the adjacent Laurentian Channel results in oceanographic conditions similar to those found at the shelf slope.

5.2 Foraging associated with specific areas of the northwest Atlantic

South Atlantic Bight

At least some leatherbacks forage on the continental shelf in the mid-Atlantic Bight, within the 200 meter isobath (Fig. 3 and 4). This area is characterized by the close proximity of the Gulf Stream to the shelf break (Olson et al., 1983), and does not appear to be highly productive (Fig. 3). Tagged turtles appeared to be concentrated on transitional zones between relatively high and low primary productivity. This same pattern was observed in loggerhead turtles (*Caretta caretta*) in the North Pacific (Polovina et al., 2000; 2001).

Mid Atlantic Bight south of Cape Cod

Several tagged turtles foraged extensively within the 200 meter isobath in the area south of Cape Cod (Figs 5-11). There is strong tidal mixing in this region, and feeding turtles may be attracted to prey concentrated at a shallow-sea tidal front (as described in Bowman and Esaias, 1978).

The Gulf of St. Lawrence

Leatherback turtles entered the Gulf of St. Lawrence in the late summer and early fall (Fig. 17, 18), with the majority of foraging activity occurring in the southeastern part of the Gulf. The area where we observed foraging behaviour was characterized by very high levels of chlorophyll-a.

Coastal Newfoundland

Several turtles that were tagged off the northern coast of Cape Breton fed along the south coast of Newfoundland (Fig 19, 20). There was no evidence of any distinctive chlorophyll signatures in the region where feeding was observed, however, foraging in this area may be related to coastal upwelling.

Areas where no foraging was observed

There are several areas where no leatherback foraging behaviour was documented. For example, rather than stopping to forage, tagged turtles migrated directly through the Gulf Stream. Tagged turtles also didn't forage in the mouth of the Bay of Fundy. Very few sightings of leatherbacks have ever been made in the Bay of Fundy, and, given the extensive aerial survey effort for right whales (*Eubalaena glacialis*), and the large number of whale watching boats in this area, more reports would certainly be expected if leatherbacks regularly occurred there.

This preliminary analysis does suggest that turtles aggregate at oceanic fronts and in specific areas with unique ocean circulation characteristics. Such behaviour is likely related to the concentration of jellyplankton prey at these sites, including *Cyanea sp.* and *Aurelia sp.*, however, data regarding the distribution and relative abundance of cnidarians at fronts would be required to confirm this hypothesis. To minimize leatherback interactions with commercial fisheries, more information must be collected on the high-latitude foraging behaviour of this species, including a consideration of how oceanographic features and processes concentrate jellyplankton prey.

6 Acknowledgments

Scott Eckert kindly taught M. James the techniques for attaching PTTs to leatherback turtles. We thank J. Breen, P. Fiege, J. Ford, A. Porter, and D. Swan for programming assistance. Special thanks to the ocean colour remote-sensing group at the Bedford Institute of Oceanography, who spent an enormous amount of time assisting with the processing of SST and chlorophyll-a composites, and to Ken Drinkwater for discussions about oceanography. This research was supported by the Department of Fisheries and Oceans, National Marine Fisheries Service (U.S.A.), Pew Charitable Trust, World Wildlife Fund, Environment Canada, George Cedric Metcalf Foundation, Canadian Wildlife Federation, Mountain Equipment Co-op, and NSERC.

References

Bowman, M. J., and Esaias, W. E. 1978. Oceanic Fronts in Coastal Processes. Proceedings of a Workshop Held at the Marine Sciences Research Center, May 25-27, 1977. Springer-Verlag, New York. 114 pp.

Costello, J.H., Klos, E., and Ford, M.D. 1998. In *situ* time budgets of the scyphomedusae *Aurelia aurita, Cyanea* sp., and *Chrysaora quinquecirrha.* J. Plankton Res. **20**(2):383-391.

Crouse, D.T., Crowder, L.B., and Caswell, H. 1987. A stage-based population model for loggerhead sea turtles and implications for conservation. Ecology **68**(5):1412-1423.

Fitzgerald, G. 2000. The Decline of the Cape Breton Swordfish Fishery: An Exploration of the Past and Recommendations for the future of the Nova Scotia Fishery. Ecology Action Centre, Halifax, Nova Scotia. 57 pp.

James, M.C. 2001. Status Report on the leatherback turtle, *Dermochelys coriacea*, in Canada. Committee on the Status of Endangered Wildlife in Canada, Ottawa, 24pp.

Lutcavage, M., and Lutz, P. L. 1986. Metabolic rate and food energy requirements of the leatherback sea turtle, *Dermochelys coriacea*. Copeia **1986**: 796–798.

Olson, D., Brown, O., and Emmerson, S. 1983. Gulf stream frontal statistics from Florida straits to Cape Hatteras derived from satellite and historical data. Journal of Geophysical Research **88**(C*): 4569–4577.

Petrie, B., Topliss, B. J., and Wright, D. G. 1987. Coastal upwelling and eddy development off Nova Scotia. J. Geophys. Res. C. Oceans **92**: 12979–991.

Podesta, G., Browder, J., and Hoey, J. 1993. Exploring the association between swordfish catch rates and thermal fronts on U.S. longline grounds in the western north Atlantic. Cont. Shelf Res. **13**(2/3): 253–277.

Polovina, J. J., Kobayashi, D. R., Parker, D. M., Seki, M. P., and Balazs, G. H. 2000. Turtles on the edge: movement of loggerhead turtles (*Caretta caretta*) along oceanic fronts, spanning longline fishing grounds in the central north Pacific, 1997-1998. Fisheries Oceanography **9**(1):71–82.

Polovina, J. J., Howell, E., Kobayashi, D. R., and Seki, M. P. 2001. The transition zone chlorophyll front, a dynamic global feature defining migration and forage habitat for marine resources. Progress in Oceanography **49**(1): 469–483.

IUCN. 2000. 2000 IUCN Red List of Threatened Species, C. Hilton-Taylor, compiler. International Union for the Conservation of Nature, Gland, 64 pp.

Spotila, J. R., Dunham, A.R., Leslie, A.J., Steyermark, A.C., Plotkin, P.T., and Paladino, F.V. 1996. Worldwide population decline of *Dermochelys coriacea*: Are leatherback turtles going extinct? Chelonian Conservation and Biology **2**(2):209-222.

Spotila, J. R., Reina, R.D., Steyermark, A.C., Plotkin, P.T., and Paladino, F.V. 2000. Pacific leatherback turtles face extinction. Nature **405**:529-530.

Figure Legend

The figures show typical examples of oceanographic features associated with turtle movements. The ARGOS-estimated locations of leatherback turtles are given by black circles. The dates and the turtle PTT number are provided for each image, as are file names that allow the image to be located on the included compact disk.