LEATHERBACK TURTLES (DERMOCHELYS CORIACEA) IN NEWFOUNDLAND AND LABRADOR: DISTRIBUTION, DIET, THREATS AND THE USE OF EDUCATION IN RECOVERY EFFORTS

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LEATHERBACK TURTLES (*DERMOCHELYS CORIACEA*)

IN NEWFOUNDLAND AND LABRADOR:

DISTRIBUTION, DIET, THREATS

AND THE USE OF EDUCATION IN RECOVERY EFFORTS

by

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Abstract

Leatherback turtles (*Dermochelys coriacea*) are critically endangered (IUCN) throughout their range which extends into waters off Newfoundland and Labrador (NL). Geo-referenced sightings, strandings and entrapments were used to map distribution in relation to bathymetry, and remotely-sensed sea surface temperature and chlorophyll density data. Coastal waters (< 50 m in depth) characterized by the warm seasonal layer and increased medusan abundance provide critical leatherback habitat. Caloric content of two jellyfish species (*Aurelia aurita* and *Cyanea capillata*) were determined using bomb calorimetry and used to extrapolate energy requirements of leatherbacks while foraging in northern waters. Daily food energy requirements (43-155% of body mass) confirm the need for high density jellyfish aggregations during their foraging season. While foraging off NL leatherbacks are at risk for entrapment in all types of fishing gear, with the number of entrapments greatest in August and September, and along the south coast. Necropsy results indicate ingestion of plastic debris is a definite threat, while injuries associated with stranding events suggest vessel collisions should also be considered a potential threat. Species at risk education initiatives were also considered. An objective of this study was to examine the current curricula in NL with regards to species at risk, and to evaluate an educational programme aimed at teaching school-aged children about the biology of, and threats to, leatherback turtles.

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Chapter 1: An introduction to leatherback turtles off Newfoundland and Labrador

Leatherback turtles (*Dermochelys coriacea*) are the largest of the marine turtles growing to lengths of two metres and weights of 900 kg (Eckert and Luginbuhl 1988). Leatherbacks also have the most extensive geographical range of any reptile (27° S to 70°15′ N) (Boulon *et al.* 1988; Gulliksen 1990), and occur in the Atlantic, Pacific, and Indian oceans. Seasonal migrations bring leatherbacks into northwest Atlantic waters (Bleakney 1965), including those off Newfoundland and Labrador (NL) (Squires 1954; Miller 1968; Steele 1972; Threlfall 1978; Goff and Lien 1988, Goff *et al.* 1994). Historically, northern leatherback sightings were rare, and in many cases leatherback occurrences in northern waters were deemed accidental (Bleakney 1965). We now know that leatherbacks are regular visitors to northern waters off eastern Canada (James *et al.* 2005a, b, c), and that the appearance of leatherbacks off NL is a predictable annual occurrence.

Aside from a few sporadic reports (Squires 1954; Miller 1968; Steele 1972; Threlfall 1978), a large contribution to the understanding of leatherback distribution off NL came from twenty occurrences (i.e., sightings, entrapments, and strandings) collected between 1976 and 1985 (Goff and Lien 1988). This study confirmed seasonal leatherback presence off NL and touched briefly on their distribution in relation to sea surface temperature. Since then however, very little attention has been paid to these turtles in NL waters. Further studies on the distribution of these turtles are required for the effective implementation of recovery plans by Canadian regulators. Globally, leatherbacks are critically endangered[1] (IUCN 2006), and face threats on their northern foraging grounds as well as their southern nesting beaches. It was therefore a goal of this study (Chapter 2) to gain a better understanding of the distribution of leatherbacks in NL, and the factors that contribute to this distribution through correlations of leatherback occurrences with oceanographic features such as bathymetry, sea surface temperature, and chlorophyll densities.

In addition to oceanographic features, leatherback distribution is undoubtedly influenced by the distribution and abundance of their preferred prey. As dietary specialists, leatherbacks feed primarily on jellyfish and other gelatinous organisms (Bleakney 1965; Brongersma 1969; Davenport and Balazs 1991; Bjorndal 1997), of which they must consume copious amounts. On average, the required daily intake has been estimated at 50% of the body weight of the turtle (Duron 1978, reported in Davenport and Balazs 1991; Davenport 1998), which given the relatively small size of these prey requires that leatherbacks reliably locate large concentrations of these organisms. That they are able to fulfil this requirement on northern foraging grounds may explain why leatherbacks undertake such long migrations to reach NL waters. This assumption is supported by a recent study undertaken in UK and Irish waters, which concluded that temperate jellyfish aggregations are a factor in the distribution and foraging behaviour of leatherback turtles (Houghton *et al.* 2006). Satellite telemetry has shown that leatherback roundtrip migrations can be up to 11,000 km (James *et al.* 2005c;

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[1] A taxon is Critically Endangered when the best available evidence indicates that it meets any of the criteria A to E for Critically Endangered (see Section V), and it is therefore considered to be facing an extremely high risk of extinction in the wild.

Eckert 2006; P. Richardson, pers. comm.). The energetic costs of such a trip and subsequent reproductive costs must therefore be outweighed by the benefits gained by foraging in these distant northern waters.

It seems remarkable that a turtle this large would gain sufficient benefit from prey consisting of 95% water (Lutcavage 1996). Caloric content of leatherback prey has been determined for a tropical jellyfish species (Lutcavage and Lutz 1986) and pyrosomas (Davenport and Balazs 1991), but not yet for medusae known to be leatherback prey species on northern foraging grounds (i.e., *Aurelia aurita* and *Cyanea capillata*) (Bleakney 1965; Eisenberg and Frazier 1983; James and Herman 2001). Examining the energy content of prey in the leatherback diet (Chapter 3) not only provides insight into the quality of these prey items, but also enables determination of food energy requirements. Calculations such as these have potential for use in bioenergetic studies (e.g., Wallace *et al. in review*), which are especially interesting when considering the long distance migrations leatherbacks undertake. Such data also provides a better understanding of the role of leatherbacks in the north Atlantic food web.

Although foraging in northern waters provides leatherbacks with their daily energy requirements and helps fuel their southward migrations, it also puts them at risk through interaction with anthropogenic activities. These include not only interactions with fishing gear, but also ingestion of plastic debris, vessel strikes, and acoustic pollution (which is poorly understood). In order to reduce these impacts and aid conservation efforts, it is necessary to determine where and when leatherbacks interact with these risks (Chapter 4). In terms of fishing gear interactions, much has been done in order to quantify the impact of pelagic longline fisheries on leatherbacks (Witzell 1999; Hays *et al.* 2003; Lewison *et al.* 2004). However, less is known about the impact of fisheries on leatherbacks foraging in coastal and shelf waters (James *et al.* 2005c). To learn more about fishing gear entrapments and other sources of leatherback mortality, it is necessary to work closely with fish harvesters who come in contact with these turtles. Mitigation of fishery-related bycatch would be a significant contribution to the conservation of the Atlantic population and for the survival of this species globally.

Public education and awareness is becoming an essential component of recovery efforts. Education is important not only for fish harvesters in terms of leatherback removal and rescue techniques, but also for the general public. Fostering an appreciation for leatherbacks and other species at risk should begin early, with children gaining exposure from both curricula and educational programmes. Education has already proved an effective conservation measure for sea turtles in tropical nesting countries (e.g., Bird *et al.* 2003; Sammy and Tambiah 2003), and should therefore be implemented, where it does not already exist, in northern areas where threats also exist. An objective of this study (Chapter 5) was to examine the current curricula in NL with regards to species at risk, and to evaluate an educational programme aimed at teaching school-aged children about the biology of, and threats to, leatherback turtles.

The successful conservation of leatherback turtles will require a multi-faceted approach. By improving our understanding of their distribution, feeding ecology, and threats, we can better address the problems that currently threaten the survival of the leatherback by tailoring solutions to match their ecology and behaviour. Using education as a tool can assist in the recovery process through stakeholder involvement. This combination of knowledge and awareness will be helpful in making informed management decisions that will ultimately work to conserve this species.

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Chapter 2: Distribution of leatherback turtles off Newfoundland and Labrador: Links to bathymetry and mesoscale oceanographic features

Introduction

Leatherback turtles are known to make seasonal migrations north to the temperate waters off Atlantic Canada (Bleakney 1965). Reports have been collected from all of the Maritime provinces (James 2000), as well as from Newfoundland and Labrador (NL) (Squires 1954; Miller 1968; Steele 1972; Threlfall 1978; Goff and Lien 1988; Goff *et al.* 1994), with the northernmost turtle recorded off of Nain, Labrador (56°45′N, 61°00′W) (Threlfall 1978). In NL this annual occurrence of leatherbacks runs roughly from June through to October (Bleakney 1965), and although most sightings occur during this period, leatherbacks have been found entangled in gear and free swimming during January, March and December when water temperatures are around 0°C (Goff and Lien 1988; Lien 2001). Satellite telemetry studies of turtles tagged on the Scotian Shelf have shown that leatherbacks continue swimming northwards to frequent areas off the southeastern portion of the island (James *et al.* 2005a, b, c). Historic records and aerial surveys show that leatherbacks occur around the entire island portion of the province, as well as off Labrador.

Even though leatherbacks are recognized as annual migrants to NL waters, very little is known about the distribution of these endangered turtles when they are here. This is largely due to the logistical constraints involved with studying such highly pelagic animals. Furthermore, up until now, no directed study has been undertaken to examine leatherback distribution off NL. Goff and Lien (1988) presented data from twenty leatherback occurrences in NL from 1976-1985. This data consisted of reported turtles incidentally caught in fishing gear and data gathered opportunistically while conducting marine mammal studies. More recently, James (2000) undertook a study of leatherback distribution in Atlantic Canada. However, it largely focused on leatherbacks tagged in Nova Scotia, providing minimal data on turtles off NL. In addition to contributing to the overall understanding of leatherback turtles in NL, establishing distribution and habitat preferences are essential to the identification and subsequent protection of areas deemed to be "critical habitat" for this species. Distribution data also helps in identifying areas where leatherbacks may be at risk for fishing gear interaction. Such information is crucial to the successful fulfilment of the objectives set forth by the National Recovery Strategy for leatherback turtles in Atlantic waters (Atlantic Leatherback Turtle Recovery Team 2006).

To gain an understanding of distribution patterns, the occurrences of marine species are often correlated with oceanographic features such as bathymetry, sea surface temperature, and surface chlorophyll densities. Upon close examination these physical features can reveal areas of biological significance, such as high productivity (Olson *et al.* 1994). This type of data can be useful in describing and predicting preferred habitat for cetaceans and pinnipeds (Smith *et al.* 1986; Tynan *et al.* 2005; Keiper *et al.* 2005), but it is only recently that this type of analysis has been used to explain distribution and migration patterns for sea turtles (Coles and Musick 2000; Polovina *et al.* 2000; Hays *et al.* 2001; Luschi *et al.* 2003a, b). Despite the progress in remote sensing technology, no attempt has been made in the northwest Atlantic, specifically the northern foraging grounds off NL, to relate leatherback distribution to oceanographic mesoscale features.

A primary goal of this study was to gain a better understanding of leatherback distribution around NL by considering the influence of bathymetry and oceanographic mesoscale features. Geo-referenced data of leatherbacks sighted, stranded, or entrapped in fishing gear were analyzed within the context of remote-sensed data to assess the influence of factors such as sea surface temperature, surface chlorophyll density, and bathymetry on leatherback distribution.

Materials and methods

Data collection

Leatherback turtle records were collected throughout Newfoundland and Labrador (NL), Canada from 1946-2005 (see data sources below). Records were classified as 'sightings' (live or dead leatherback observed at sea), 'strandings' (live or dead leatherback observed on shore) or 'entrapments' (live or dead leatherback entangled in fishing gear). All leatherback turtle records collected for use in this study occurred in waters off NL, with the exception of five from the Quebec Region and one from St. Pierre-Miquelon, a French island off the south coast of Newfoundland. Records included the date and location (or approximation) of the occurrence, as well as other pertinent details (e.g., approximate size of turtle, turtle activity, jellyfish presence in area, and type of gear for entrapments).

Data sources

Published accounts

Leatherback turtle records prior to 1976 were collected from published descriptions (i.e., Squires 1954; Bleakney 1965; Miller 1968; Steele 1972; Threlfall 1978).

Whale Research Group (Memorial University of Newfoundland); Whale Release & Strandings Group

Beginning in 1976 reports of leatherback turtles were collected by the Whale Research Group of Memorial University, and by 1979, the Whale Release and Strandings Group. These reports came from discussions with fish harvesters and local fishing committees, disentanglements, and Memorial University research cruises (J. Lien and W. Ledwell, pers. comm.). Trips throughout the province and telephone surveys were also used to collect leatherback occurrence data, as well as a toll free reporting number, which had been widely advertised throughout the province (W. Ledwell, pers. comm.). Twenty leatherback occurrences collected between 1976-1985 were published previously by Goff and Lien (1988).

Aerial survey/DFO reports

In the fall of 2002 and 2003 aerial surveys were conducted around the province by the Department of Fisheries and Oceans, Newfoundland and Labrador Region (DFO) (J.

Lawson DFO, unpubl. data). Surveys were flown in the east-west and north-south directions in a Cessna Skymaster 337 at an altitude of 152 meters and a groundspeed of 105 knots. Tracklines were spaced at 10 nautical miles and were flown up to 200 miles offshore. One observer was located on each side of the plane with a separate recorder to note date, time, and position of turtles. Surveys were flown to sea states of 4, but only data from 3 or less were used. Correction factors for animals missed at the surface or when diving were not applied to these turtle data.

Leatherback reports from the DFO Quebec Region were shared with the DFO Newfoundland Region (J. Lawson DFO, pers. comm.).

Sightings network

In the spring and summer of 2004, three trips throughout the province were made to interview fish harvesters and fisheries officers, and speak to them about leatherbacks (conducted by H. Brock). Leatherback sightings, strandings, and entrapments were collected during these trips and fish harvesters were given booklets to record any further leatherback occurrences during the remainder of their fishing season. They were encouraged to send these completed booklets back to DFO at the end of the season. Fish harvesters that did not get a personal visit received a mailout package containing information regarding leatherbacks and this project, in addition to the sightings booklet. In the fall of 2004 a follow-up telephone survey was conducted to solicit leatherback occurrences from those that were interviewed (conducted by H. Brock).

In the summer of 2005, 120 postcards (Appendix A) were sent to fish harvesters and fisheries officers throughout the province to solicit leatherback sightings. Only postcards or other reports returned before November 1st 2005 were used in the analysis for this thesis.

Analyses

Distribution

All leatherback locations collected between 1946-2005 were digitally overlaid on a NAD 83 projection of Newfoundland and Labrador using MapInfo Professional (7.0) software. Latitudinal and longitudinal means (± SD) were calculated using MapInfo.

Fishing effort

Fishing effort was calculated per Northwest Atlantic Fisheries Organization (NAFO) subzone (Areas 2, 3, and 4) for the year 2004 (vessels up to 64 feet; all types of gear) using data obtained by DFO (A.M. Russell DFO, pers. comm.). To determine the influence of fishing effort on the sighting frequency of leatherbacks, the number of fishing days for each subzone containing a turtle occurrence was plotted against the number of turtles occurring in that subzone for the year of 2004. Correlation between fishing effort and frequency of leatherback sighting was calculated.

Bathymetry

Bathymetry values were derived from a bathymetric layer (NAD 83 projection) in MapInfo Professional (7.0). Leatherback occurrences were digitally overlaid on this layer and a depth value was extracted for each leatherback location. Depth values were not exact depths at the location, but rather corresponded to bin depths. Bins were designated as follows 50 metres (0-50 m), 100 metres (51-100 m), 200 metres (101-200 m), 400 metres (201-400 m), 1000 metres (401-1000 m), and 5000 metres (1001-5000 m). Modal depth was calculated for all leatherback sightings and entrapments.

Remote-sensed data

All remotely-sensed data were obtained from the Bedford Institute of Oceanography (BIO), Nova Scotia, Canada (C. Caverhill BIO, pers. comm.). Sea surface temperature (SST) data were derived from the Advanced Very High Resolution Radiometer (AVHRR) on board the satellites NOAA 14, 15, 16, 17, or 18 (dependent upon the year the data was collected).

Surface chlorophyll *a* (Chl) density data (up until the end of 2004) were derived from the SeaWiFS sensor on the SeaStar satellite owned by Orbimage. Beginning in 2005, Chl data were derived from the Moderate Resolution Imaging Spectroradiometer (MODIS) on board NASA's Aqua satellite (C. Caverhill BIO, pers.comm.).

SST and Chl values were extracted from weekly composite images (1.5 km/pixel resolution) corresponding to the date of the leatherback occurrence. Mean values were calculated from all valid pixels within a 3 pixel × 3 pixel box around the location point. In cases where no specific day was given for a specific turtle sighting location the mean SST or Chl value was calculated from the two bi-weekly composites from that month. The mean SST or Chl value was then averaged from these two values. If no specific day was given, but it was known approximately when the event took place (e.g., late August) the SST or Chl value was extracted from the bi-weekly composite for that part of the month (i.e., day 1-15 or 16-31). The mean (± SD) SST and Chl was calculated for all leatherback occurrences with available remote-sensed SST and Chl values.

Results

A total of 258 leatherback turtle occurrences (i.e., sightings, entrapments, and strandings) were compiled for the period of 1946-2005 (Figure 2.1). Of these occurrences, 166 were sightings; 73 were entrapments; 11 were strandings; 8 were classified as unknown events because of a lack of information regarding the event.

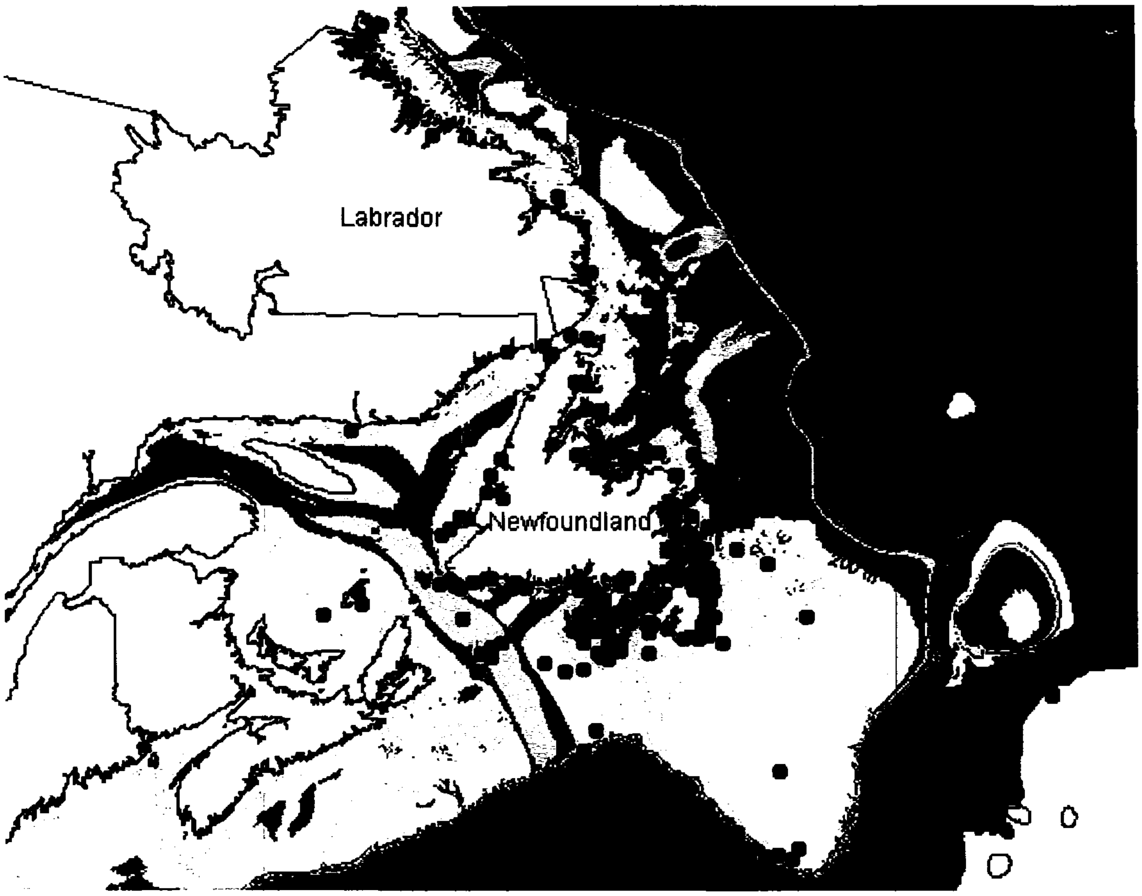

Figure 2.1: Distribution of leatherback turtle (*Dermochelys coriacea*) locations off Newfoundland and Labrador for 1946-2005 (n=258). Circles represent a leatherback sighting, stranding, or entrapment. Some circles may represent more than one occurrence at that particular location.

Spatial distribution

All leatherback occurrences were pooled for spatial analysis. Leatherbacks were distributed widely off all coasts of the island of Newfoundland, as well as off Labrador. The northernmost record occurred off Nain, Labrador, while the southernmost record occurred along the tail of the Grand Banks. Latitude and longitude remained relatively constant throughout the sampling period of two and a half decades (Table 2.1). Nearshore records dominated the occurrences, with the highest concentrations of leatherbacks occurring off the southeast portion of the island. Nearshore predominance is most likely a function of fishing effort which was confined to shelf areas, and made comparison to areas beyond the shelf not possible. It was also recognized that since most leatherback occurrences were reported voluntarily, variable participation may also be a factor in shaping the distribution.

Table 2.1: Mean latitudinal and longitudinal locations of leatherback turtles (*Dermochelys coriacea*) off Newfoundland and Labrador. Overall column includes 10 occurrences prior to 1980. Mean decimal degrees (± SD).

		1980s (n=68)	1990s (n=48)	2000-2005 (n=132)	Overall (n=258)
Latitude	**Maximum**	54.9406	50.8865	53.9297	56.7500
	Minimum	46.2744	43.5258	43.0540	43.0540
	Mean	48.2390	47.8701	47.1767	47.6583
		(1.5846)	(1.2589)	(1.4192)	(1.6095)
Longitude	**Maximum**	-52.6157	-52.7495	-43.7667	-43.7667
	Minimum	-59.7184	-58.2333	-62.4715	-62.4715
	Mean	-54.6943	-54.5155	-54.9587	-54.8170
		(1.8967)	(1.3967)	(2.8811)	(2.4257)

Fishing effort

The year of 2004 was chosen as a snapshot representation of fishing effort for the last few years (i.e., 2000-2005) since this year had the highest number of recorded leatherback sightings and a complete fishing effort data set. Two NAFO subzones with the highest fishing effort were 3PSc and 3PSb, which also corresponded to the highest number of leatherback occurrences in those NAFO subzones for the year 2004 (16 locations) (Figure 2.2). Although this trend was not consistent across all subzones, overall fishing effort (i.e., number of fishing days) in 2004 was related to the frequency of leatherback occurrences ($r^2 = 0.66$, $F = 27.2$, df = 1, 14, $p<0.001$, $n = 16$).

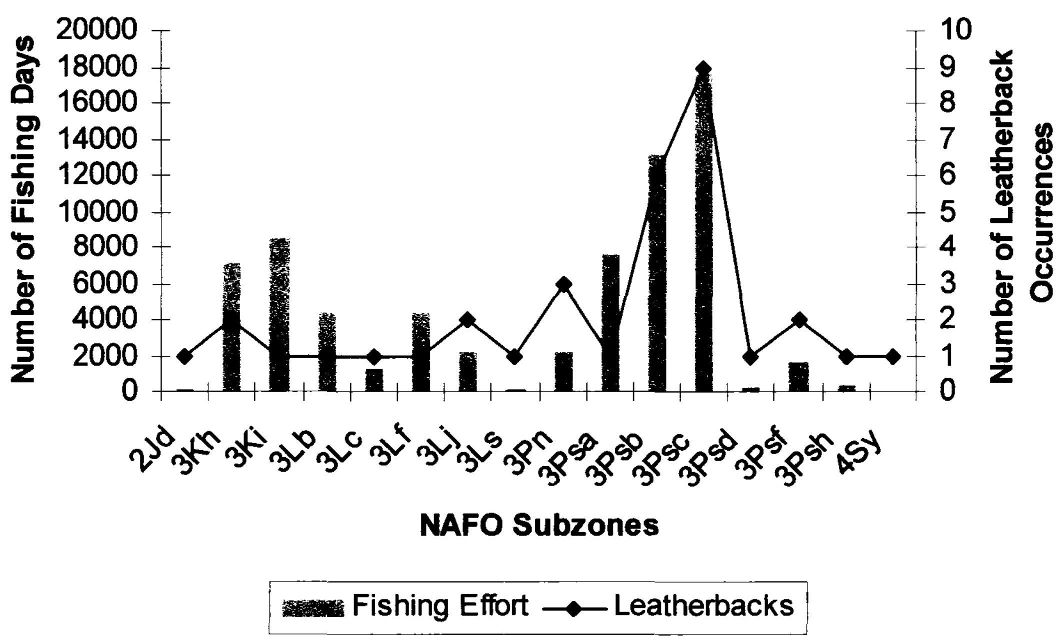

Figure 2.2: Fishing effort in relation to the frequency of leatherback turtle (*Dermochelys coriacea*) occurrence in NAFO subzones off Newfoundland and Labrador in 2004.

Temporal distribution

Although leatherbacks were sighted from January through to December, leatherback occurrences showed a strong seasonal pattern with a peak during the months of August and September (Figure 2.3). Combined, the data from these two months represent approximately 80% of the total number of leatherback occurrences throughout the sampling period.

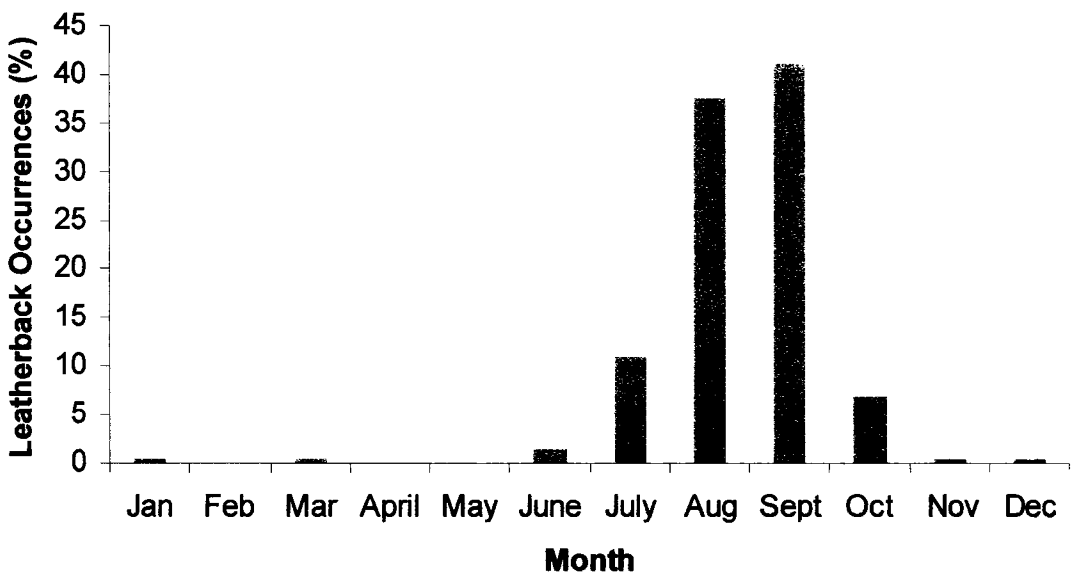

Figure 2.3: Seasonal frequency distribution of leatherback turtle (*Dermochelys coriacea*) records off Newfoundland and Labrador for 1946-2005 (n=202; includes sightings, strandings, and entrapments for which the month of occurrence was known).

Bathymetry

While leatherbacks were sighted in water with depths up to 5000 m, occurrences were more prevalent in shallower waters. The modal depth of all occurrences (n=247;

not including strandings) was 50 m (i.e., 0-50 m). Nearly 40% of leatherback occurrences took place in waters of 50 m or less, while the majority (86%) of occurrences took place within the 200 m depth contour, delimitating the continental shelf (Figure 2.4). Frequency of occurrence gradually decreased with increasing depth, with approximately 5% occurring in depths greater than 400 m.

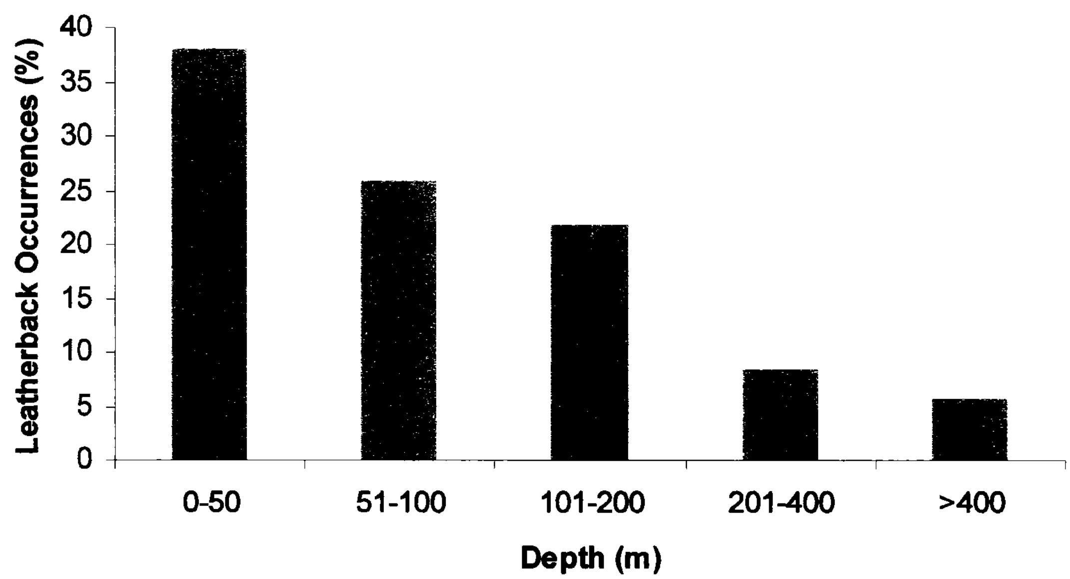

Figure 2.4: Frequency distribution of leatherback turtle (*Dermochelys coriacea*) records off Newfoundland and Labrador in relation to bathymetry for 1946-2005 (n=247; does not include strandings).

Sea surface temperature

Only remote-sensed sea surface temperature (SST) data were used for the analysis, however there were three reports of leatherbacks in waters of 0°C, one previously reported by Goff and Lien (1998) and the other two as unpublished records, which were the coldest recorded temperatures. The mean SST for all leatherback occurrences for which SST data was available (1997-2005) (n=80) was 14.3 ± 2.6°C. Overall, leatherbacks occurred in water ranging from a minimum value of 7.1 to 21.3°C (Figure 2.5). Seventy-five percent of all occurrences took place in waters between 12.0 - 16.9°C, with an associated modal interval of 16.0 – 16.9°C. Just over 16% of leatherback occurrences were associated with temperatures below 12°C, while less than 10% were associated with temperatures above 17°C. It should be noted that SST in NL rarely exceed this value. For example, for August 2005 the mean SST along the eastern coast of Newfoundland (Avalon Channel) was 15.6°C, with a maximum recorded SST of 19°C (H. Maass BIO, pers. comm.).

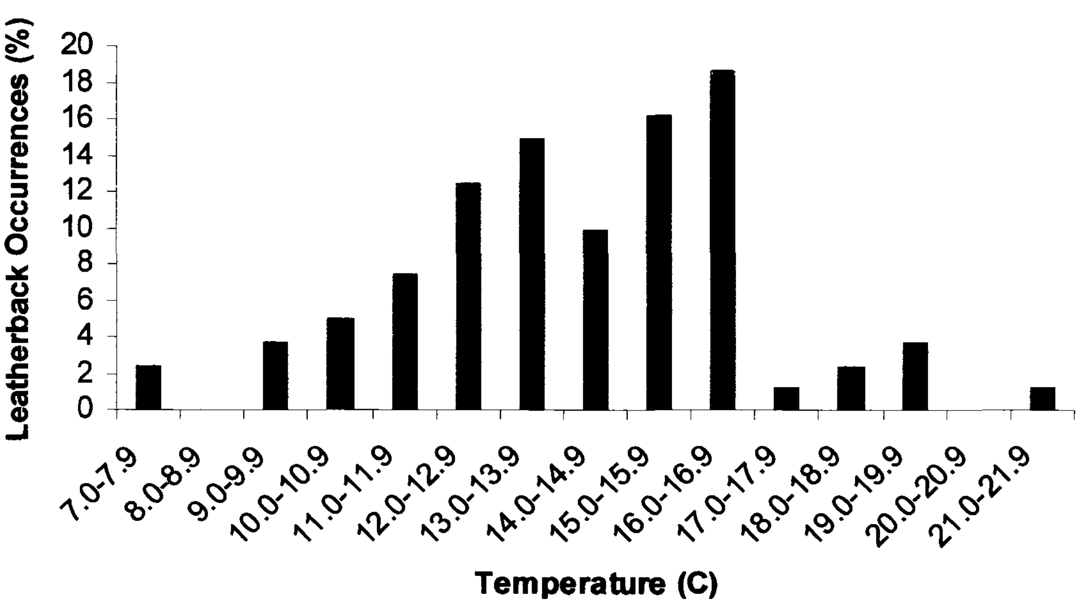

Figure 2.5: Frequency distribution of leatherback turtle (*Dermochelys coriacea*) records off Newfoundland and Labrador for 1997-2005, in relation to sea surface temperature (n=80).

Surface chlorophyll *a* density

Surface chlorophyll *a* (Chl) densities were available for 50 leatherback records from 1997-2004. Chl densities for leatherback occurrences ranged from 0.30 to 6.80 mg/m^3 (Figure 2.6). Mean Chl was 1.36 ± 1.52 mg/m^3 with a median of 0.75 mg/m^3. Eighty percent of leatherback occurrences took place in water with surface Chl densities less than 1.70 mg/m^3 with 50% of those occurring within the range of 0.3 - 0.5 mg/m^3.

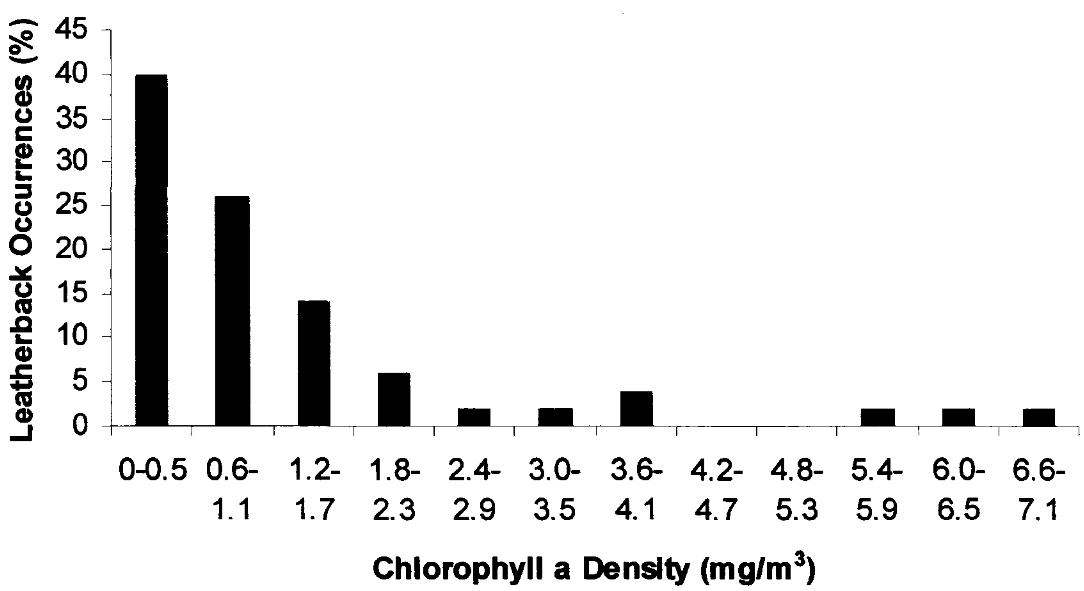

Figure 2.6: Frequency distribution of leatherback turtle (*Dermochelys coriacea*) records off Newfoundland and Labrador (1997-2004) in relation to surface chlorophyll a density (n=50).

Discussion

Several published reports have documented the presence of leatherbacks in waters off Newfoundland and Labrador (i.e., Squires 1954; Miller 1968; Steele 1972; Threlfall

1978; Goff *et al.* 1994). Most contained reports of single sightings or entrapments and it was not until the compilation of twenty leatherback encounters from 1976-1985 (Goff and Lien 1988) that there was any comprehensive examination of leatherback turtle presence off NL. Goff and Stenson (1988) undertook an investigation of the thermal properties of leatherback tissue shortly after this, but since then a report by Goff *et al.* (1994) on the migration of a tagged leatherback remains the only published report concerning this endangered species off NL. Recent satellite telemetry studies (e.g., James *et al.* 2005c) have documented the importance of coastal waters off northeastern Canada as seasonal foraging habitat for leatherbacks by demonstrating that leatherbacks travel great distances to these areas and remain for the summer. The results presented in this thesis corroborate this importance by contributing further information about leatherbacks off NL, as well as highlight the characteristics that might define their habitat here.

Spatial and temporal distribution

Leatherbacks have been thought to occur off the southern margin of Newfoundland. However, data collected in this study reveal a wider distribution that encompasses the entire island, and Labrador as well (Figure 2.1). A leatherback found entrapped in gear off Nain, Labrador in 1973 remains the northernmost record for a leatherback off eastern Canada. It is interesting to note that an Inuit song-story and soapstone carving originating from Cape Dorset, Baffin Island support the contention that leatherbacks might venture even further north, although no confirmed turtle sightings have been documented for this northern area (Shoop 1980).

Areas of concentrated occurrences off the southeast portion of the island described in this thesis are similar to those documented previously by Goff and Lien (1988). Goff and Lien (1988) suggested that this concentration was a function of the high fishing activity taking place off the south coast, but no analysis of fishing effort was undertaken. In this study, fishing effort data and leatherback occurrences (i.e., sightings and entrapments) from 2004 were compared, and it was determined that there was a positive relationship between fishing effort and the probability of sighting a leatherback (Figure 2.2). That is, the more fishing effort (and hence people spending significant time on the water) the more likely they were to sight a leatherback turtle. Accordingly, numbers of turtle sightings presented in this study should be treated as underestimates of the true numbers of leatherback turtles that are likely to occupy these waters. The less than perfect association between fishing effort and frequency of leatherback sightings suggests that fishing effort may not be the only factor affecting the frequency of leatherback reports in NL. Other factors may have included education, public outreach, and increased awareness of leatherback occurrences; this effect is discussed further in Chapter 4. Alternatively, leatherbacks may simply not frequent the areas in which there was increased effort and a low number of leatherback occurrences.

The dominance of nearshore occurrences (i.e., sightings and entrapments) was likely due to the higher number of reports by inshore fish harvesters and increased fishing effort in coastal areas (Figure 2.2). This observed pattern is possibly enhanced by the inshore movement of leatherbacks throughout the summer months in search of medusae (Bleakney 1965). *Aurelia aurita*, a known prey species of leatherback turtles, is found predominantly in coastal areas, especially during spawning in summer and fall (Lucas 2001). Leatherbacks have also been documented feeding on *Cyanea capillata*, another known prey species, in nearshore waters of Newfoundland (D. Ivany, pers. comm.).

In Atlantic Canada the typical "leatherback season" runs from June through to October (Bleakney 1965; Goff and Lien 1988), with rare occurrences of leatherbacks recorded outside of this time period (Goff and Lien 1988; Lien 2001). This appearance of leatherbacks also coincides with the presence of the seasonal warm layer, which develops in June and disappears in October (Schneider and Methven 1988). Recent leatherback records off NL match this pattern, with the majority of events occurring in August and September, and coinciding with the high seasonal abundance of jellyfish. This peak abundance of jellyfish occurs when jellyfish have grown and matured throughout the spring and summer and later aggregate in order to reproduce before dying (Lucas 2001). Since the probability of sighting a leatherback is positively correlated to fishing effort, this peak of leatherback occurrences is also likely related to increased fishing efforts during these months.

It is difficult to understand why leatherbacks have been seen in Newfoundland waters outside of this period (i.e., rare sightings in December, January and March) without knowing additional details. However, it is known that leatherbacks have the unique ability among living reptiles to thermoregulate in a seemingly endothermic manner, which will be discussed further in relation to SST below. Although these physiological adaptations allow leatherbacks to survive in relatively cold water, it is unknown whether these winter occurrences are part of a larger life history strategy or whether they are simply navigational failures.

Bathymetry

Satellite telemetry studies and time-depth recorders have shown that leatherbacks utilize a wide range of depths within the water column (Eckert *et al.* 1986; 1989), and that there are distinct phases of diving behaviour within the course of the migratory cycle (Hays *et al.* 2004b; James *et al.* 2005a; Eckert 2006). When leatherbacks arrive in northern waters they spend a higher proportion of time diving to shallower depths in comparison to the depths frequented at more southern latitudes (James *et al.* 2005a; Eckert 2006). This suggests that leatherbacks may be a) maintaining depths above the seasonal thermocline which develops in the summer and lasts through the fall (Schneider and Methven 1988), and/or b) following the vertical distribution of their prey (Eckert 2006). Although time-depth recorders were not deployed in this study, the leatherbacks that occurred off NL most frequently occurred in shallow waters (< 50 m) of the continental shelf, which closely resemble the depths at which leatherbacks have been found in the northeastern United States (Shoop and Kenny 1992). This depth preference is further corroborated by a female leatherback satellite tagged on the island of Anguilla in May 2005. After arriving in waters off southern Newfoundland at the beginning of August, it spent approximately the next month and a half travelling in shallow coastal waters along the southeastern coast until it began migrating south again (P. Richardson, pers. comm.). It has been suggested that since leatherbacks are able to dive to great depths (Hays *et al.* 2004a), shallow waters may provide resources in greater abundance (Shoop and Kenny 1992), thus causing leatherbacks to preferentially move inshore. As mentioned previously, *A. aurita* abundance is generally greater in shallower coastal waters (i.e., less than several hundred metres) as opposed to deeper pelagic waters (Lucas 2001). This jellyfish species' preference for shallow waters likely results from the availability of suitable substrate required for the reproductive phases of the jellyfish lifecycle (Ishii and Bamstedt 1998), as polyps have not been found any deeper than 20 m (Russell 1970, reported in Lucas 2001). Nutrient availability may also contribute to this increase in jellyfish abundance, in addition to concentrating mechanisms such as currents and frontal circulation (Graham 2001). Coastal embayments also offer shelter from the wind. When all of these factors are combined, coastal areas may favourably support aggregations of gelatinous medusae, which may in turn result in the increased abundance of leatherbacks in search of prey near shore. It should be noted that since the majority of leatherback occurrence data came from fish harvesters confined to shelf waters, a comparison cannot be made between leatherback distribution on the shelf and in areas beyond the shelf.

Sea surface temperature

Leatherbacks are able to withstand a wide range of sea surface temperatures (SST) which is substantiated by the temperatures recorded at the locations of leatherback sightings off NL (7.1 to 21.3°C), as well as comparable ranges for leatherback sightings off Nova Scotia (5.2-20.8°C) (James 2000), and off the northeastern United States (7.0-27.2°C) (Shoop and Kenny 1992). This pattern suggests that leatherbacks may not be randomly distributed, but preferentially remain within these temperature ranges as a result of thermal tolerance limits. The low end of this range, which was recorded at a leatherback sighting off St. Pierre Bank in June of 2004, is just slightly higher than the 6°C reported by Threlfall (1978) for the northernmost leatherback sighting record. The SST associated with this northern occurrence is not however the coldest SST at which a leatherback has been recorded in Canadian waters. Although collected outside the regular "leatherback season", three leatherbacks were recorded at locations with water temperatures of only 0°C (Goff and Lien 1988; Lien 2001). Leatherbacks possess both anatomical and physiological adaptations in order to thermoregulate in cold waters, and as a result they are able to maintain their body temperatures at up to 18°C above ambient (Friar *et al.* 1972). Their large size imparts a large thermal inertia, which is part of a phenomenon termed gigantothermy (Paladino *et al.* 1990). In addition, leatherbacks have an insulating adipose layer structurally similar to that found in marine mammals and some endothermic fishes (Goff and Stenson 1988; Davenport *et al.* 1990). Leatherbacks also have countercurrent heat exchangers in their flippers (Greer *et al.* 1973), which allow heat to be conserved when blood flows out to the extremities. Combined, these adaptations may allow leatherbacks to stay warm enough to survive while foraging in colder northern waters.

These 0°C sighting events are rare however, and it is likely not often that a leatherback turtle encounters 0°C water temperatures, at least at the surface. Although leatherbacks have been observed in areas with abundant jellyfish at the surface (Eisenberg and Frazier 1983; Collard 1990; Penhallurick 1991; Grant and Ferrell 1993; Grant *et al.* 1996; Frick *et al.* 1999), there are also cases in which leatherbacks have been observed consuming prey at the surface without any free-swimming prey present (James and Herman 2001). It is therefore likely that, in these cases, leatherbacks are capturing prey at depth where they experience cooler water temperatures. In fact, it has been suggested that leatherbacks may spend up to 40% of their time diving to cooler waters (James and Mrosovsky 2004). In addition to the cooler temperatures they experience when foraging at depth, leatherbacks subsequently warm their prey upon consuming it which also represents a thermal cost (Davenport 1998). With these thermal constraints present in northern foraging waters such as those off NL, leatherbacks may be restricted to SST of at least 5°C or higher, which allows them to maintain their body temperature. In general leatherbacks off NL are usually sighted in warmer waters of approximately 12-17°C. A leatherback equipped with a satellite-linked time-depth recorder spent over 80% of its time in waters of a comparable temperature range (James and Mrosovsky 2004). This may explain why leatherbacks seem to be more commonly distributed along the southeastern coast of the island since this area is not influenced by the cooler, southward-travelling Labrador Current.

Are leatherbacks associated with this range of SST rather as a by-product of their pursuit of prey? Jellyfish distribution may in fact overlap with seasonally warmer waters, but this may be a function of suitable reproductive habitat, rather than temperature constraints since jellyfish appear to have a wide tolerance. *Aurelia aurita* with its worldwide distribution is able to exploit a wide range of temperatures (Lucas and Lawes 1998), while *Cyanea capillata* is a temperate to arctic species that ranges from the epi- to mesopelagic zones (Bailey *et al.* 1995), and must consequently tolerate the associated temperatures. It is therefore likely that leatherbacks, although they are able to withstand a wide range of temperatures, would be more highly influenced by temperature compared to jellyfish, which lack complex circulatory and nervous systems.

Surface chlorophyll *a* density

Leatherback sighting frequency may be related to chlorophyll *a* (Chl) as a result of their dependence on gelatinous zooplankton, which in turn feed on other zooplankton. If Chl is considered an indirect measure (proxy) of prey availability, then Chl densities might serve as an indicator of leatherback distribution because of the turtles' need to consistently consume large numbers of jellyfish. This assumption stems from the theory that certain jellyfish (e.g., *Aurelia aurita*) exert top-down control over other zooplankton, and consequently reduce the grazing pressure upon phytoplankton (Schneider and Behrends 1998). While jellyfish have been found associated with increased Chl concentrations (Schneider and Behrends 1998), this relationship could also have resulted from physical processes that concentrate both jellyfish and phytoplankton in the same area (Graham *et al.* 2003). In either case, increased Chl levels may be indicative of increased medusan abundance, which in turn may indicate productive feeding habitat for leatherbacks. It should be noted that chlorophyll values in the ocean can range from approximately 0.01 to 30 mg/m^3 (C. Caverhill BIO, pers. comm.).

While no previous work has been undertaken to directly link leatherback distribution to Chl densities, an attempt has been made to relate the distribution of satellite-tracked loggerheads, which also feed on jellyfish, to Chl densities (Polovina *et al.* 2000). The front along which these loggerheads were travelling, characterized by a sharp surface chlorophyll gradient (0.2 mg/m^3), was thought to be a highly productive area for surface-feeding organisms (Polovina *et al.* 2000). Leatherbacks off NL most commonly associated with slightly higher surface Chl densities (0.3-1.7 mg/m^3). These higher Chl densities may be a product of the nutrient-rich coastal areas off NL, which remain, in addition to the continental shelf break, one of the more highly productive areas because of continued coastal upwelling after the spring chlorophyll bloom (Schneider and Methven 1988). Alternatively, leatherbacks may be associated with areas of increased Chl density in order to support their specialist diet, if in fact areas of increased Chl density are synonymous with increased jellyfish abundance. Loggerheads are omnivorous and do not have to rely solely on gelatinous prey which may render high Chl density waters (and possibly lower jellyfish densities) less critical to loggerheads.

Few leatherback occurrences (6%) took place at Chl levels of ~6 mg/m^3, which is considered quite high in terms of chlorophyll density. One explanation for this may be that because satellite derived chlorophyll values are most reliable in open ocean settings, these values may have included land-based material that was mis-read as Chl (C. Caverhill BIO, pers. comm.), therefore not accurately representing the true value of surface Chl. A second possibility may be that these areas are simply highly productive with significant levels of Chl. Interestingly, two out of the three leatherback sightings occurring at Chl densities greater than 5.4 mg/m^3 involved two turtles at that particular location, which may indicate abundant resources.

It should be noted that the occurrence of leatherbacks at these Chl concentrations denote presence as opposed to feeding. Further work is therefore necessary to determine if specific Chl concentrations are in fact responsible for the presence of leatherbacks at certain locations. Until then no definite conclusions can be made regarding a leatherback relationship to surface Chl concentrations.

Before leatherback habitat can be protected, it must be defined. In order to do this it is necessary to examine leatherback distribution and the factors that affect it, which may in turn provide some indication of their habitat preferences. It appears that the shallow coastal waters (< 50 m) off NL, particularly the southeastern coast are important leatherback habitat. Leatherbacks also seem to associate with the 12 - 17°C isotherm, although they should not be dismissed from waters with SST as low as 5°C. Critical habitat, as defined under Canada's Species at Risk Act (SARA), is the "habitat that is necessary for the survival or recovery of a listed wildlife species", and may include a breeding site, nursery area or foraging ground. Given the data presented here, critical leatherback habitat consists of the seasonal warm layer in conjunction with increased medusae abundance in coastal waters. Further studies are needed to address the habitat beyond the shelf, as well as the links between leatherbacks and physical oceanographic processes such as SST and Chl densities.

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Chapter 3: Examining the diet and food energy requirements of leatherback turtles foraging in northern waters

Introduction

Leatherback turtles are dietary specialists that feed exclusively on medusae and other gelatinous organisms such as siphonophores and salps (Bleakney 1965; Brongersma 1969; Davenport and Balazs 1991; Bjorndal 1997). Stomach content analysis and fatty acid signatures in leatherback tissues have both confirmed this type of feeding strategy (Bleakney 1965; Den Hartog and Van Nierop 1984; Frazier *et al.* 1985; Holland *et al.* 1990). Although other invertebrates have been found in the stomachs of some leatherbacks, this is largely attributed to the commensal nature of these organisms with certain jellyfish species (Frazier *et al.* 1985). Hyperiid amphipods commonly associate with medusae (Condon and Norman 1999; Gasca and Haddock 2004), and consequently become ingested incidentally. The mouth and oesophagus of the leatherback are lined with numerous backwards pointing papillae, which further supports their specialized diet of jellyfish (Figure 3.1). This anatomical modification is likely an adaptation to prevent gelatinous prey from slipping back out of the mouth (Bleakney 1965). In terms of locating prey, leatherbacks use both chemical and visual cues (Constantino and Salmon 2003), and forage both at the surface (Eisenberg and Frazier 1983) and at depth (Eckert *et al.* 1989).

Figure 3.1: Rearward-pointed papillae in the oesophagus of a leatherback turtle (*Dermochelys coriacea*) recovered in Newfoundland.

In the Atlantic, reports of leatherbacks feeding on jellyfish have been documented in waters off Great Britain, as well as along the coast of the United States and north to waters off Nova Scotia and Newfoundland (Penhallurick 1991; Grant and Ferrell 1993; Frick *et al.* 1999; James and Herman 2001). Two common species in waters off Atlantic Canada are *Cyanea capillata* (Lion's Mane jellyfish) and *Aurelia aurita* (Moon Jelly) (Shih 1977), both of which leatherbacks are known to consume (Bleakney 1965; Eisenberg and Frazier 1983). In Newfoundland and Labrador both species can be especially plentiful in the summer and early fall with surface swarms occurring in coastal bays and inlets (Department of Fisheries and Aquaculture 2002). *C. capillata* can attain an umbrella diameter of 1 m, while *A. aurita* are smaller, reaching a maximum diameter of 40 cm (Shih, 1977). *C. capillata* have been found within the stomach of leatherbacks (Bleakney 1965), while fatty acid signatures of both species have been found in leatherback tissues (Holland *et al.* 1990). Additionally, leatherbacks have been photo-documented feeding on both species in waters off Nova Scotia and Newfoundland (James and Herman 2001).

Despite the fact that jellyfish are approximately 95% water (Lutcavage 1996) leatherbacks are able to subsist on this low-energy diet. It has been estimated that adults must eat on the order of tens of kilograms a day to sustain their metabolic requirements (Lutcavage 1996). This consumption value has been estimated to be approximately 50% of the turtle's body weight per day (Duron 1978, reported in Davenport and Balazs 1991; Davenport 1998). Consequently leatherbacks must be able to consistently find abundant supplies of these prey items. Aside from the nutritional analysis Davenport and Balazs (1991) undertook for pyrosomas (*Pyrosoma atlantica*), caloric data for known leatherback prey items are lacking. Lutcavage and Lutz (1986) determined the energy content of *Cassiopeia xamachana* which are consumed by leatherback hatchlings, but this prey species is restricted to tropical, lagoon waters (Holland *et al.* 2004), and is likely not a regular prey item for adults in northern waters. Recently, food energy requirements were determined for nesting leatherbacks (Wallace *et al. in review*), but food energy requirements have not been determined for free-swimming adult leatherbacks on northern foraging grounds.

Atlantic Canadian waters, including those off NL, represent important foraging grounds for leatherbacks (James *et al.* 2005b), however we know very little about their energy budget and how they obtain what they require from their gelatinous prey. Investigating known prey items of leatherbacks and their energy requirements would contribute to a greater understanding of their feeding ecology in northern waters, as well as the energetics involved with the life history strategies of these endangered reptiles. Improved understanding is also important in further establishing the niche leatherbacks occupy in the food web of NL waters.

The goal of this study was to determine the caloric content of two common prey items (*Aurelia aurita* and *Cyanea capillata*) of leatherbacks foraging in northern latitude waters using bomb calorimetry. These values were extrapolated to consumption requirements for adult leatherbacks foraging in northern Atlantic waters using a metabolic rate function.

Materials and methods

Jellyfish collection

Jellyfish were obtained by careful dipnetting in the fall of 2004 and the summer and fall of 2005 off the north and east coasts of Newfoundland. Twenty-five jellyfish were collected (7 *Aurelia aurita*; 15 *Cyanea capillata*) (Figure 3.2). Following capture, jellyfish were identified to species and their bell diameters measured (± 0.1 cm) (n=3 for *A. aurita*; n=12 for *C. capillata*) while the jellyfish were laid on a light-coloured tray. No effort was taken to remove any organisms caught within the tentacles. All jellyfish were placed in labelled plastic bags and frozen at -2°C until processed further.

Figure 3.2: Two specimens of jellyfish (*Cyanea capillata*, left and *Aurelia aurita*, right) collected off Newfoundland.

Sample preparation

Jellyfish were removed from the freezer to thaw and then weighed to the nearest 0.001 g to obtain a wet weight value. They were then dried to a constant weight at 105°C in a sample oven for approximately 48 hours. This temperature was chosen to ensure as much water was removed as possible, but also to prevent the oxidation of organics, which occurs at temperatures greater than 200°C (Larson 1986). The jellyfish were subsequently placed in a desiccator (Fisher Scientific Glass Desiccator; 22°C) to cool, after which they were homogenized by hand with a mortar and pestle. Homogenized samples were then reweighed to the nearest 0.1 g to obtain a dry weight value.

Ashing

Triplicate subsamples of each dried jellyfish were used to determine the ash content. Subsamples (range 0.148-1.524 g; average 1.016 g) were placed in a muffle furnace (Thermolyne, model F-A1730) at 450°C for a minimum of 12 hours. After again cooling in a dessicator, subsamples were reweighed to the nearest 0.0001 g and ash content was calculated. Percent ash for each species is presented as means (± SD).

Bomb calorimetry for energy density

Duplicate subsamples (triplicate for three initial *A. aurita*) of the dried jellyfish were used to obtain caloric values using a Parr oxygen bomb calorimeter (model 1241). Each subsample (~0.5 g) was combined with a quantity of mineral oil (~0.55 g) in order to ensure complete combustion. Caloric content for each species is presented as means (± SD).

Leatherback metabolic energy requirement calculations

Energy requirements were calculated for a 500 kg leatherback having a field metabolic rate of 63.936 kJ/kg per day (Wallace *et al.* 2005). This maximum field metabolic rate was chosen under the assumption that free-swimming leatherbacks are more active during northern foraging stages of their lifecycle compared to free-swimming leatherbacks during the nesting season, which have low internesting metabolic rates (Wallace *et al.* 2005). Eighty percent energy assimilation was also assumed (Arai *et al.*

2003). The mean caloric content for each of the two species of jellyfish was used in separate calculations, and the overall energy requirements are presented as kilograms of jellyfish per day for each of the two jellyfish species.

Results

Ashing and bomb calorimetry

Both jellyfish species exhibited extremely high water content (Table 3.1). The mean percent ash for *A. aurita* (79.9 ± 0.33 %; n=21) was significantly higher than that for *C. capillata* (68.8 ± 0.94 %; n=45) (Figure 3.3). Conversely, *C. capillata* (1263.0 ± 78.25; n=30 cal/g) had a significantly higher energy content compared to that found for *A. aurita* (382.5 ± 31.50 cal/g; n=17) (Figure 3.4).

Table 3.1: Size, moisture, organic and energy content of *Aurelia aurita* and *Cyanea capillata* (mean ± SD).

	Aurelia aurita (n=7)	***Cyanea capillata*** (n=15)
Bell diameter (cm)	21.0 cm (n=3)	33.6 cm (n=12)
Wet weight (g)	380.9 (± 163.97)	2436.0 (± 2351.58)
Dry weight (g)	12.1 (± 5.48)	84.6 (± 81.33)
Moisture content as % of wet weight	96.8 (± 0.27)	96.5 (± 0.14)
Organic content as % of dry weight	20.1 (± 0.33) (n=21)	31.1 (± 0.94) (n=45)
Organic content as % of wet weight	0.64 (± 0.08)	1.08 (± 0.17)
Energy density (cal/g) (dry matter)	382.5 (± 31.50) (n=17)	1263.0 (± 78.25) (n=30)
Energy density (kJ/g) (dry matter)	1.60 (± 0.46)	5.28 (± 1.53)
Energy density (kJ/g) (wet matter)	0.051 (± 0.017)	0.18 (± 0.050)

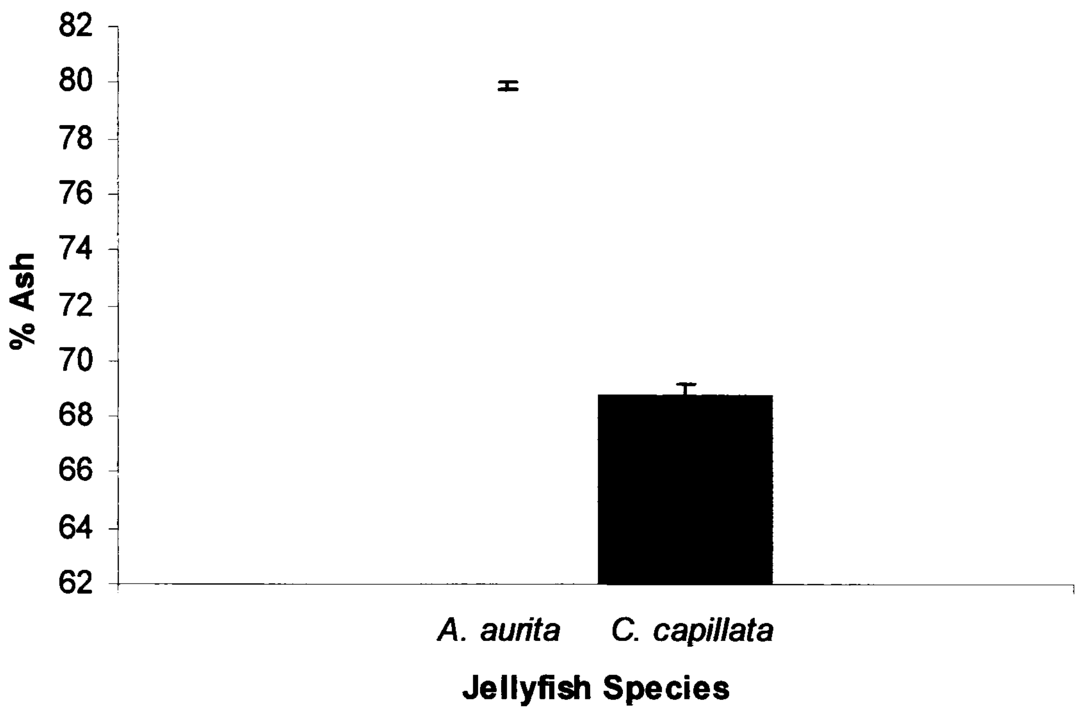

Figure 3.3: Percent ash of *Aurelia aurita* (n=7) and *Cyanea capillata* (n=15) on a dry matter basis. Bars represent 95% confidence interval.

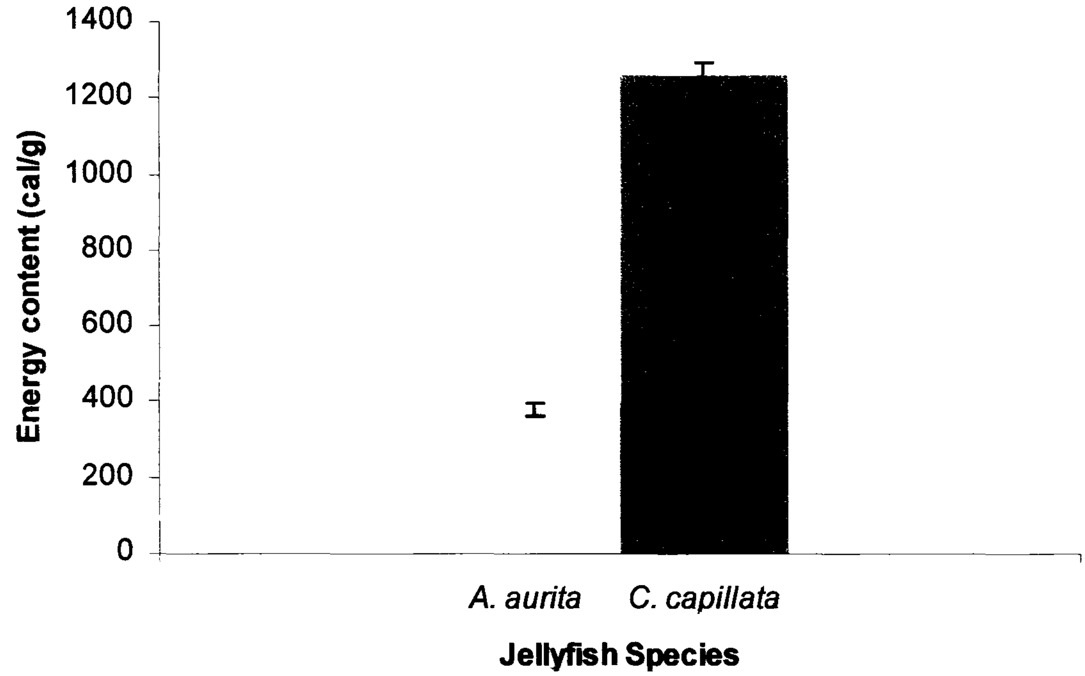

Figure 3.4: Energy content of *Aurelia aurita* (n=7) and *Cyanea capillata* (n=15) on a dry matter basis. Bars represent 95% confidence intervals.

Leatherback energy requirements

The leatherback body mass (500 kg) used in the food energy requirement calculation was chosen on the basis that leatherbacks on northern foraging grounds are approximately 33% larger than those on Atlantic nesting grounds of the same carapace length (James *et al.* 2005b). Eighty percent energy assimilation efficiency was assumed based on the highly digestible nature of gelatinous zooplankton in fish (Arai *et al.* 2003). The maximum metabolic rate calculated by Wallace *et al.* (2005) was chosen in order to represent the higher activity levels and thermoregulatory requirements associated with foraging in northern waters.

A 500 kg leatherback subsisting solely on *C. capillata* would have to consume almost half (218/500 = 43%) its body mass per day to meet its metabolic energy demands (Table 3.2). The same leatherback subsisting solely on *A. aurita* would have to consume one and a half times its body mass. Theoretically, if this 500 kg leatherback was to forage continuously for the entire length of the "turtle season" (i.e., June-October = 153 days), it would consume approximately119,000 kg of *A. aurita*, or just over 33,300 kg of *C. capillata*.

Table 3.2: Daily food energy requirements for a 500 kg leatherback turtle (*Dermochelys coriacea*) foraging off Newfoundland and Labrador with a field metabolic rate of 63.94 kJ/kg.*

	Aurelia aurita	*Cyanea capillata*
Energy content (kJ/kg)**	51.38	183.51
Functional energy content at 80% assimilation efficiency (kJ/kg)	41.11	146.80
Prey mass requirements (kg/day)	778	218
Prey consumption as a percentage of turtle body mass	155.53	43.55
Prey mass consumed during 153-day "turtle season" in NL waters (kg)	119000	33300

* Based on field metabolic rates derived by Wallace *et al.* 2005.
** Based on a wet matter basis.

Discussion

Despite a growing interest in leatherback bioenergetics there is still limited knowledge regarding the turtles' dietary composition, and proximate composition value of these prey. Davenport and Balazs (1991) provided caloric data for pyrosomas (*Pyrosoma atlantica*), which have been suggested as an important component in the leatherback diet while they forage at depth (Davenport 1988). The results here provide a comparison for two medusae, *Aurelia aurita* and *Cyanea capillata*, that are common components of the jellyfish assemblage in NL waters.

The relatively low energy density of *A. aurita* and *C. capillata* are a function of the extremely high water content in these medusae (Bailey *et al.* 1995; Table 3.1). The low caloric quality of this prey is demonstrated by the fact that certain species, which are regularly consumed by people in Asia, are considered a natural diet food (Hsieh *et al.* 2001). *C. capillata* have approximately 25% of the caloric content of larval and juvenile fish, while *A. aurita* have less than 10% of the caloric content (dry matter basis) (Wissing *et al.* 1973). In comparison to other gelatinous zooplankton (see Arai 1988), *A. aurita* are at the lower end of the range (382 cal/g; dry matter) while *C. capillata* appear to be marginally better (1263 cal/g; dry matter), and are comparable to that for the pyrosoma, *Pyrosoma atlantica* (1180 cal/g; dry matter) (Davenport and Balazs 1991).

The higher energy content of *C. capillata* is likely a function of their numerous tentacles and abundant gonadal tissue. Isolated tissue studies of hydro- and scyphomedusae have shown that tentacles and gonads have a higher organic content and lower water content than that of umbrella tissue (Larson 1986; Schneider 1988). The tentacles of *C. capillata*, which are clustered in eight groups of 70-150 (Shih 1977), can grow to several metres long. In contrast, *A. aurita* have less tentacle material since they possess only a fringe of short tentacles along the umbrella edge.

Although not directly measured between species in this study, gonadal tissue may also contribute to the higher energy content of *C. capillata*. Because organic content is high in gonadal tissue, greater proportionate amounts should yield a greater energy content. Since all jellyfish were collected during late summer and fall when gonadal investment is high as a result of increased planktonic food abundance (Lucas 2001), both species should have had mature gonads, or in the case of females, possibly fertilized gametes. It is therefore probable that a large proportion of the organic content stemmed from the gonads of both species.

The efficiency with which each species can capture prey may also factor in to the overall caloric content. Since leatherbacks incidentally ingest the prey caught within the tentacles of the jellyfish they also gain energy from these jellyfish prey. Amphipods are a higher quality prey item which range from 3474-3797 cal/g (dry matter) (Wissing *et al.* 1973). *C. capillata* may have an advantage when it comes to predation because of the area they are able to cover with the length of their nearly invisible tentacles. Bamstedt *et al.* (1994) demonstrated that *C. capillata* is more efficient than *A. aurita* in capturing certain prey items, while it can also capture *A. aurita* in high quantities. Consuming *C. capillata* feeding on *A. aurita* would provide leatherbacks with the caloric content of both species while only having to expend effort to capture one. It may therefore be beneficial for leatherbacks to target *C. capillata* not only for its intrinsic caloric content, but for the prey it may be simultaneously consuming.

Despite these factors, *A. aurita* and *C. capillata* are very low in caloric density necessitating that leatherbacks consume large quantities of these jellyfish to satisfy their energy requirements. Feeding rates have been estimated at approximately 50% of their body weight per day (Duron 1978, reported in Davenport and Balazs 1991), which is close to the 43% reported here. While on an energy content basis it seems counterintuitive that leatherbacks would target jellyfish as a food source, there are clearly other considerations. First, jellyfish can often be found in large aggregations, either for biological reasons or as a result of physical processes in the ocean (Graham *et al.* 2001). If a leatherback locates such an aggregation it can greatly decrease search time for subsequent prey items. Second, jellyfish are relatively easy for leatherbacks to catch. Once captured, escape is nearly impossible due to the numerous backwards pointing papillae lining the leatherback mouth and oesophagus. Finally, jellyfish are digested rapidly (Arai *et al.* 2003), and have relatively low C:N and C:P ratios (Larson 1986; Schneider 1988; Malej *et al.* 1993; Bailey *et al.* 1995) which results in more efficient nutrient metabolism (Malej *et al.* 1993). The nutritious, highly digestible nature of leatherback prey, coupled with the ability of the leatherback to capture prey while simultaneously transporting food through the oesophagus (Bels *et al.* 1998), allow leatherbacks to more effectively fuel their metabolism.

Due to the increased need to thermoregulate, and to warm cold, ingested prey, it is advantageous for leatherbacks in NL waters to spend less energy searching for, handling, and digesting prey. Satellite telemetry and depth recording technology has shown that leatherbacks foraging in northern waters do in fact have lower rates of travel, and make shallower dives, which are of shorter duration, than migrating leatherbacks (James *et al.* 2005a). Leatherbacks also use this foraging time to build up fat reserves; James *et al.* (2005b) found that leatherbacks on northern foraging grounds are approximately 33% larger than those of similar carapace length on nesting grounds. This fattening process is only effective when the calories consumed are greater than those utilized in prey search, capture, handling and digestion. It is not unusual for leatherbacks to associate with swarms of jellyfish (Eisenberg and Frazier 1983; Collard 1990; Penhallurick 1991; Grant and Ferrell 1993; Grant *et al.* 1996; Frick *et al.* 1999) and fish harvesters in NL often speak about jellyfish being thick and plentiful in areas of leatherback occurrence (H. Brock, pers. obs.). A study undertaken in Bonavista Bay, NL, revealed that gelatinous zooplankton ranged from 41-726 individuals per surface hectare (Schneider and Bajdik 1992). Subsequently, if a swarm consists of *C. capillata* of average weight measured in this study (2.4 kg), then a 500 kg leatherback (requiring an estimated 218 kg of jellyfish per day) only needs to locate and consume approximately 91 individual jellyfish. This may not be a difficult task considering the density of the prey swarms. Furthermore, these densities are surface swarms only, and leatherbacks also capture prey at depth (James and Mrosovsky 2004) where less is known about medusae abundance.

In terms of food web dynamics, leatherbacks may be more important to the fisheries of NL than has previously been recognized. A study undertaken off the northeast portion of Newfoundland for a proposed National Marine Conservation Area, found that jellyfish and ctenophores were the most important predators in terms of biomass flow during the summer (Lawson 1998). This area is also frequented by leatherbacks, which feed on these gelatinous organisms. Numerous studies have shown that jellyfish and related gelatinous organisms can have devastating effects on fish and zooplankton populations (Bamstedt *et al.* 1994; Olesen 1995; Lucas *et al.* 1997; Purcell *et al.* 2000; reviewed by Purcell and Arai 2001). Because leatherbacks are major predators on jellyfish and must consume hundreds of kilograms of gelatinous zooplankton a day (Table 3.2), they may in turn provide natural control of jellyfish populations, which could subsequently help in sustaining certain fish stocks. Unfortunately, the trophic dynamics of leatherbacks and jellyfish have not been examined, and jellyfish populations are thought to be mainly bottom-up controlled (Parsons and Lalli 2002). Leatherbacks may still however play an important role in maintaining jellyfish levels, especially as jellyfish blooms become more and more frequent (e.g., Mills 2001). Overfishing is just one of several explanations suggested as a cause of such blooms, which may stem from the reduction in predation of jellyfish by certain species of fish (Arai 2005). As fishing pressure continues and we see a greater decline in our fish stocks, the position leatherbacks occupy in the food web of highly productive fishing areas, including those off NL, may become more apparent and more significant.

Determining prey quality and resource requirements of leatherback turtles is an essential step in further understanding their unique feeding ecology. Although jellyfish are exceptionally low in energy content, they are a relatively good food source because of their high digestibility. Leatherbacks must consume large amounts of these gelantinous prey to sustain their metabolism, and in doing so they undoubtedly serve as an important link in the food web in waters off NL. Most importantly, the determination of leatherback energy requirements in this study serves to strengthen the definition of critical habitat in the previous chapter.

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Chapter 4: Leatherback turtle interactions with anthropogenic activities in Newfoundland and Labrador

Introduction

Leatherback turtles are at risk throughout their entire range and have been classified as critically endangered by the World Conservation Union (IUCN 2006) since 1971 (Pritchard 1971). A dramatic population decline occurring in recent decades saw the number of nesting females drop from 115,000 in 1982 to 34,500 in 1996 (Spotila *et al.* 1996). The Pacific population has been the hardest hit and without intervention is thought to be facing imminent extinction (Crowder 2000; Spotila *et al.* 2000). Years of unsustainable egg collection (e.g., Campbell *et al.* 1996) and poaching (e.g., Pritchard 1982) have contributed to this decline (Spotila 2004). Fortunately, many countries that support nesting females have now implemented protection programs that support beach patrols to dissuade poachers and egg harvesters (e.g., Eckert and Sarti 1997; Sammy and Tambiah 2002). Threats however still exist away from the nesting beaches, such as mortality caused by entanglement in gillnets and longlines. In Trinidad alone, the second largest nesting colony in the western Atlantic, over 3000 leatherback captures were estimated in 2000 (Lee Lum 2003). At the same time 50,000 leatherbacks were estimated to have been taken as bycatch in the worldwide pelagic longline fishery (Lewison *et al.* 2004). While exact post-release mortality is unknown, Lewison *et al.* (2004) suggest the 1% mortality due to fisheries threshold is being exceeded, therefore putting the Pacific leatherback population at risk for significant decline (Spotila *et al.* 1996). Available data on the Atlantic leatherback population is insufficient to determine current abundance trends (DFO 2004).

In Canada leatherbacks have been listed as endangered since 1981 by the Committee on the Status of Endangered Wildlife in Canada (COSEWIC) (Cook 1981). They receive legal protection under the Species at Risk Act (SARA) for which they are listed as endangered under Schedule I. SARA was fully implemented in June of 2004 and prohibits the killing, harming, and harassing of individuals, while also prohibiting the damage or destruction of their habitat. SARA also requires the protection of critical habitat once it has been identified for the species. In addition, SARA requires that endangered species recovery strategies must address the threats associated with survival.

A major threat facing leatherbacks in coastal and pelagic waters off eastern Canada is entrapment in fishing gear. Leatherbacks are susceptible to entanglement in most types of gear (e.g., lines associated with fixed gear, buoy lines, longlines) and can become entangled (Goff and Lien 1988; Lee Lum 2003) or hooked (Witzell 1999; Work and Balazs 2002) resulting in potential injury or death by drowning (Work and Balazs 2002). In some circumstances entangled leatherbacks may be able to drag the gear to the surface in order to breathe, but unfortunately this is not always the case.

In addition to entrapment in fishing gear, leatherbacks are prone to ingestion of plastic and other debris (Carr 1987). There is a significant amount of plastic debris discarded throughout the world's oceans (Barnes and Milner 2005), and analyses of stomach contents have shown that leatherbacks can mistake this debris for their prey (Barreriros and Barcelos 2001; Bugoni *et al.* 2001; Levy *et al.* 2005). Leatherbacks are known to ingest plastic bags, plastic pieces, polystyrene, fishing line and other floating debris (Davenport *et al.* 1993; Barreiros and Barcelos 2001; Bugoni *et al.* 2001; Levy *et al.* 2005). Once the turtle has ingested the debris it can cause necrosis (Barreriros and Barcelos 2001; Levy *et al.* 2005) and/or block the digestive track which may eventually lead to starvation and death (Bjorndal *et al.* 1994). Heavy metal contamination via food sources may also pose a threat to leatherbacks (Caurant *et al.* 1999).

Vessel strikes also represent a potential source of mortality for leatherback turtles. Although no collisions have been documented in Atlantic Canada, numerous turtles are estimated to be killed each year in the U.S. (NRC 1990). Leatherbacks must surface to breath, consume prey at the surface (James and Herman 2001), and also bask at the surface (James *et al.* 2005). Together, these behaviours put leatherbacks at risk for collisions with boats and propellers, which can result in serious injury or death (Lenglet *et al.* 2003).

Other threats may include acoustic and oil pollution. Little is known about the hearing of leatherbacks, but studies have shown that sea turtles are able to hear within the low frequency range (Ridgway *et al.* 1969; Lenhardt *et al.* 1983; O'Hara and Wilcox 1990; Bartol *et al.* 1999). In recent years anthropogenic underwater noise from commercial, industrial, and recreational sources has increased (Curtis *et al.* 1999; Andrew *et al.* 2002), most of which produce low frequency sound levels (Samuel *et al.* 2005). Although the impacts of acoustic pollution on leatherbacks have not been conducted in Atlantic Canada, there is a potential for disruption of their behaviour patterns and foraging habitat.

In terms of oil spills, sea turtles do not seem to show any avoidance behaviour upon contact with such spills (Odell and MacMurray 1986), and they also increase their exposure to the toxic fumes as a result of their rapid inhalation pattern prior to dives (Milton and Lutz 2003). Leatherbacks have also been known to eat tar balls (Balazs 1985).

All of these threats may pose considerable risks to the leatherbacks that forage off eastern Canada. Although these threats have been identified as potential sources of mortality, our current understanding of them is poor, especially in Newfoundland and Labrador (NL). It is therefore important to gain a better understanding of these threats in order to reduce their impact and focus efforts on recovery. Leatherback entrapment and stranding reports were collected in order to examine the potential threats leatherbacks face from these sources in NL waters. A necropsy on a leatherback that stranded in 2004 was undertaken to determine its cause of death.

Materials and methods

Data collection

Leatherback entrapments and stranding reports were collected from waters off NL between the years of 1972-2005. Entrapments and strandings (1976-2005) were collected from the Whale Research Group (Memorial University of Newfoundland) (J. Lien, pers. comm.), the Whale Release and Strandings Group (W. Ledwell, pers. comm.), the Department of Fisheries and Oceans, Newfoundland and Labrador Region (DFO) (aerial surveys and reporting information) (J. Lawson DFO, pers. comm.), personal observation, information solicitation from fish harvesters and fisheries officers during trips around the province, or by directed phone and mail surveys (conducted by H. Brock). Leatherback entrapments prior to 1976, but after 1972, were collected from the literature (Steele 1972; Threlfall 1978). Entrapments reported came from a diversity of fishing sectors throughout the province. Entrapment and strandings were reported as means (± SD).

When available, the location, date, and type of gear were collected for leatherback entrapments, as well as the condition of the turtle if it was released, and any other related information. For leatherback strandings, date, location, and turtle morphometrics were recorded along with any other related observations. Leatherbacks were scanned for implanted passive integrated transponders (PITs) if a scanner was available. If the turtle was freshly dead it was transported for necropsy; if it was badly decomposed a necropsy was performed at the location with tissue samples collected.

Mapping

All entrapments and strandings with associated location information were entered into an Excel spreadsheet. In cases where the exact location was unknown, entrapments and strandings were assigned a geographic reference using descriptive details from the entrapment or stranding event in order to extrapolate a position. All entrapments and stranding locations were then overlaid on a geodetic datum (NAD 83 - North American Datum 1983) projection map of Newfoundland and Labrador using a GIS program (MapInfo Professional 7.0).

Results

Entrapments

Seventy-two leatherback entrapments were documented between 1972 and 2005 (Figure 4.1) with a mean of 2.1 (± 2.6) reported entrapments annually. Of these entrapments, approximately 35% of leatherbacks died as a result of their entrapment, while 61% were released alive. The fate of the remaining 4% and the degree of post release survivorship is unknown. In the last ten years, twenty entrapments were reported with just 5% of the turtles discovered dead in gear. Fifty-five percent of these entrapments were reported in the last two years.

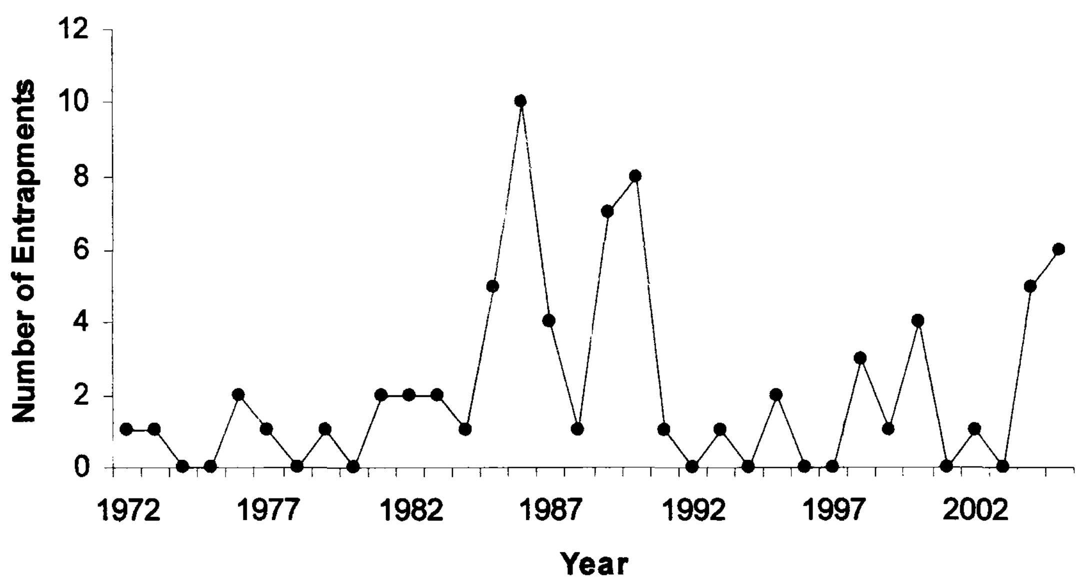


Figure 4.1: Reported entrapments of leatherback turtles (*Dermochelys coriacea*) off Newfoundland and Labrador between 1972-2005 (n=72).

The predominant gear type involved in the entrapments were groundfish gillnets (42%) (Figure 4.2), with the majority of the entrapments occurring in the months of August (35%) and September (36%) (Figure 4.3). Entrapments were most prevalent along the southern coast of the island (44%), followed by the eastern (31%), and northern (15%) coasts (Figure 4.4). Three (4%) of the entrapments recorded during this time were off the coast of Labrador.

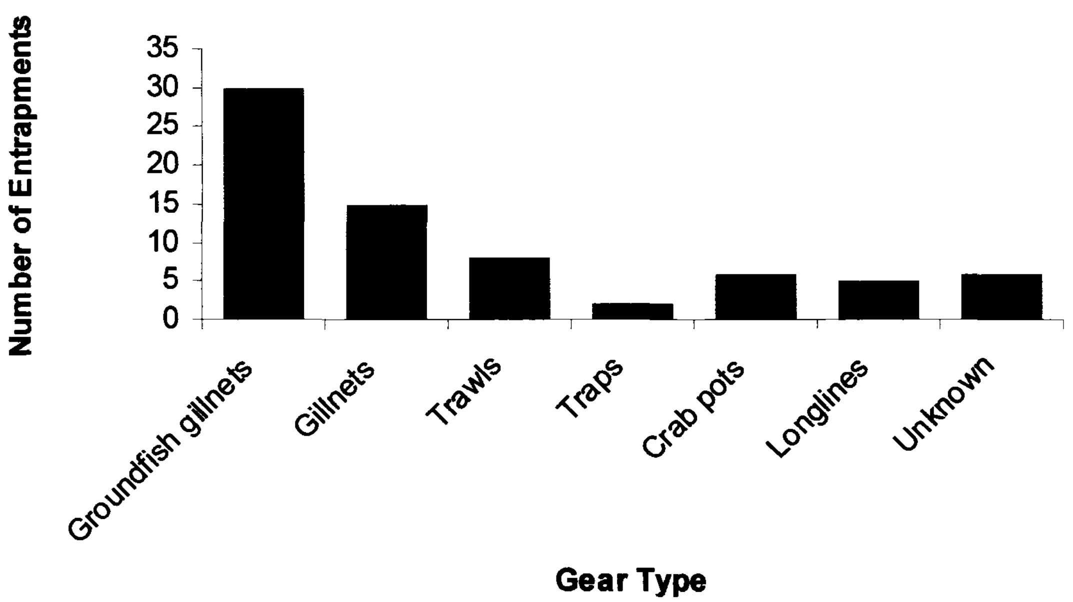


Figure 4.2: Reported leatherback turtle (*Dermochelys coriacea*) entrapments throughout Newfoundland and Labrador between 1972-2005 in relation to gear type (Gillnets = all other gillnets aside from groundfish and includes salmon, herring, and mackerel nets; unknown = no gear type specified with report) (n=72).

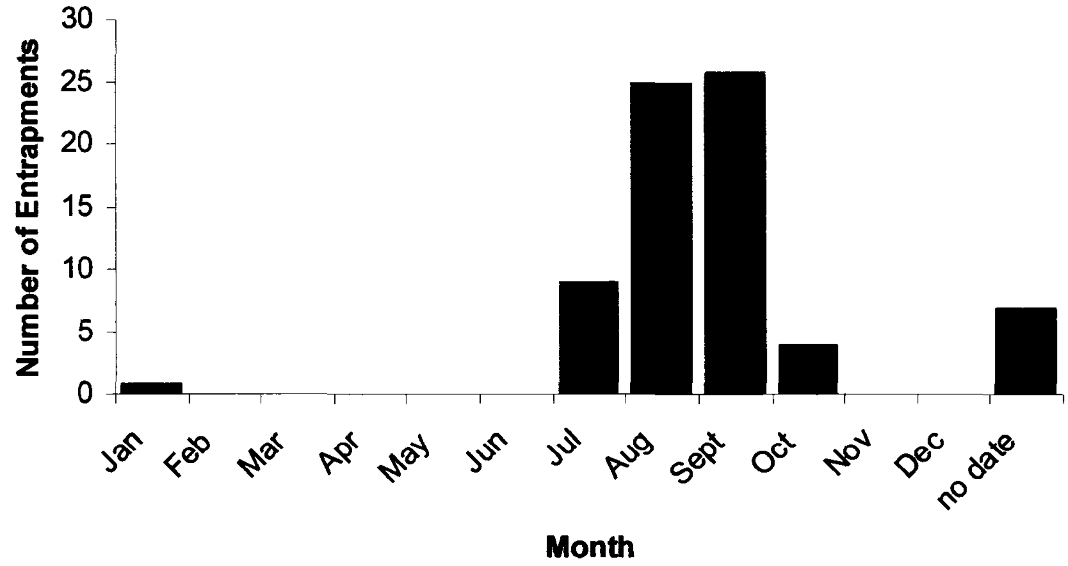


Figure 4.3: Reported leatherback turtle (*Dermochelys coriacea*) entrapments off Newfoundland and Labrador occurring between 1972-2005 in relation to month of occurrence (no date = no month was given for the reported entrapment) (n=72).

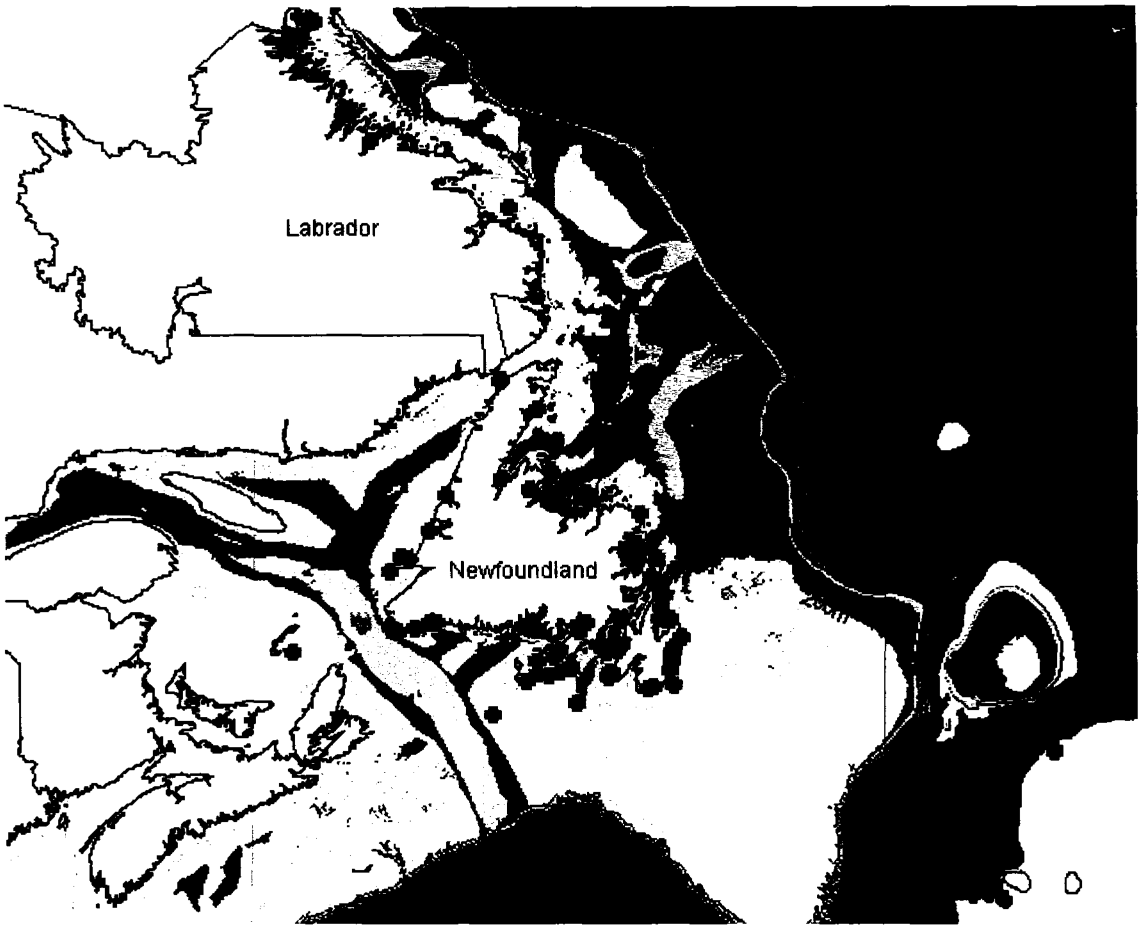


Figure 4.4: Distribution of reported leatherback turtle (*Dermochelys coriacea*) entrapments and strandings around Newfoundland and Labrador between 1972-2005 (n=83). Red circles represent entrapments; blue circles represent strandings.

Strandings

There were a total of eleven leatherback strandings reported between 1972-2005 (Table 4.1) with a mean of less than one (0.3 ± 0.9) reported per year. Over half (60%) of these strandings have been reported in the last three years. All stranded turtles were found dead except for two, one each in 1998 and 2003. The latter was reported stranded on the west coast of Newfoundland in October. It was towed back out to sea several times before it eventually swam away.

Table 4.1: Details of reported leatherback turtle (*Dermochelys coriacea*) strandings in Newfoundland and Labrador between 1972-2005 (n=11).

Date	Location	Condition	Curved carapace length (cm)	Comments
1981/10/21	York Harbour	Dead	165	
1984/08/26	Southern Harbour	Dead	n/a	
1994	Western Bay	Dead	n/a	
1998	Grand Beach	Alive	n/a	came ashore
2001	Grand Bruit	Dead	n/a	washed ashore in summer
2003/10/11	Lobster Head Cove	Alive	152	towed back out
2004/09/19	St. Brendan's	Dead – fairly decomposed	n/a	not sampled
2004/10/07	Port Rexton	Dead – fresh dead	157	female; necropsy performed; plastic in gut and foreign body
2004/10/11	Point May	Dead – badly decomposed	135	female; bruised blood around flippers; broken skull; no plastic in gut
2004/10/26	St. Lawrence	Dead – badly decomposed	n/a	washed away before sampled
2004/11/12	Picadilly Point	Dead – badly decomposed	120	female?; hole in carapace; no plastic in gut

Seventy percent of the strandings were reported in the fall (September to November) (Figure 4.5). In 2004, five leatherbacks were reported stranded; a five-fold increase compared to previous years (Figure 4.6). Four (40%) of these strandings were reported in October with one in November. Due to the decomposed condition of four out of the five leatherback strandings reported a full necropsy was only performed on one; no data on whether necropsies were performed was available on the strandings that took place prior to 2003. All stranding events that took place between 1972-2005 occurred on the west (27.3%), south (45.4%) and east (27.3%) coasts of the island (Figure 4.4). No PIT or flipper tags were found on any of the turtles, and none of the individuals found stranded after 2003 showed evidence of previously having carried a tag.

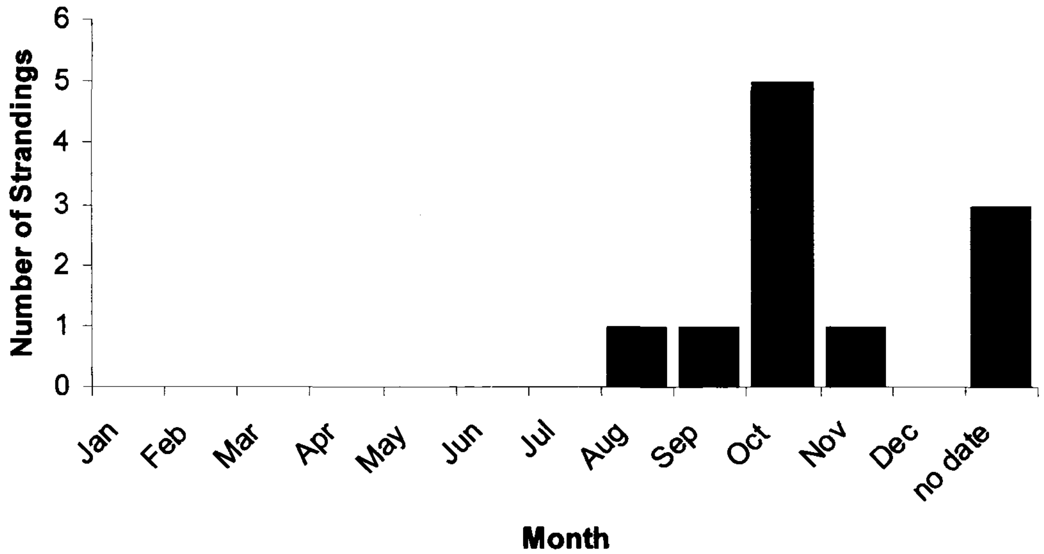


Figure 4.5: Reported leatherback turtle (*Dermochelys coraciea*) strandings in Newfoundland and Labrador occurring between 1972-2005 in relation to month (no date = no date was reported for the stranding) (n=11).

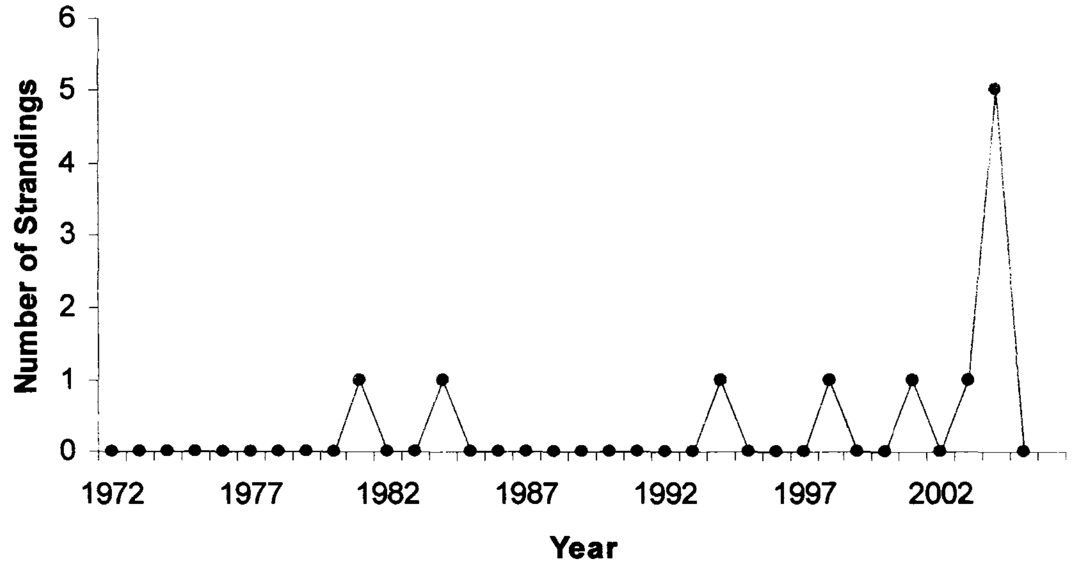


Figure 4.6: Reported leatherback turtle (*Dermochelys coriacea*) strandings in Newfoundland and Labrador between 1972-2005 (n=11).

Necropsy

A mature female leatherback turtle found stranded (dead) on the east coast of Newfoundland (Port Rexton) in October of 2004 was transported to the Post Mortem Building, Animal Health Division, Department of Natural Resources (St. John's, NL) and kept frozen until a necropsy was performed a month later (Table 4.2). A fibreglass cast of the dorsal surface and the plastron was completed prior to the necropsy, and the turtle was therefore kept at room temperature for seven days prior to the necropsy.

Table 4.2: Measurements of an adult female leatherback turtle (*Dermochelys coriacea*) stranded in Newfoundland and Labrador in October 2004.

Total dorsal curved length (nose to tail)	183.0 cm
Curved carapace length (CCL)	157.0 cm
Straight carapace length (SCL)	143.0 cm
Total dorsal curved foreflipper span	226.8 cm
Weight (kg)	298.0 kg

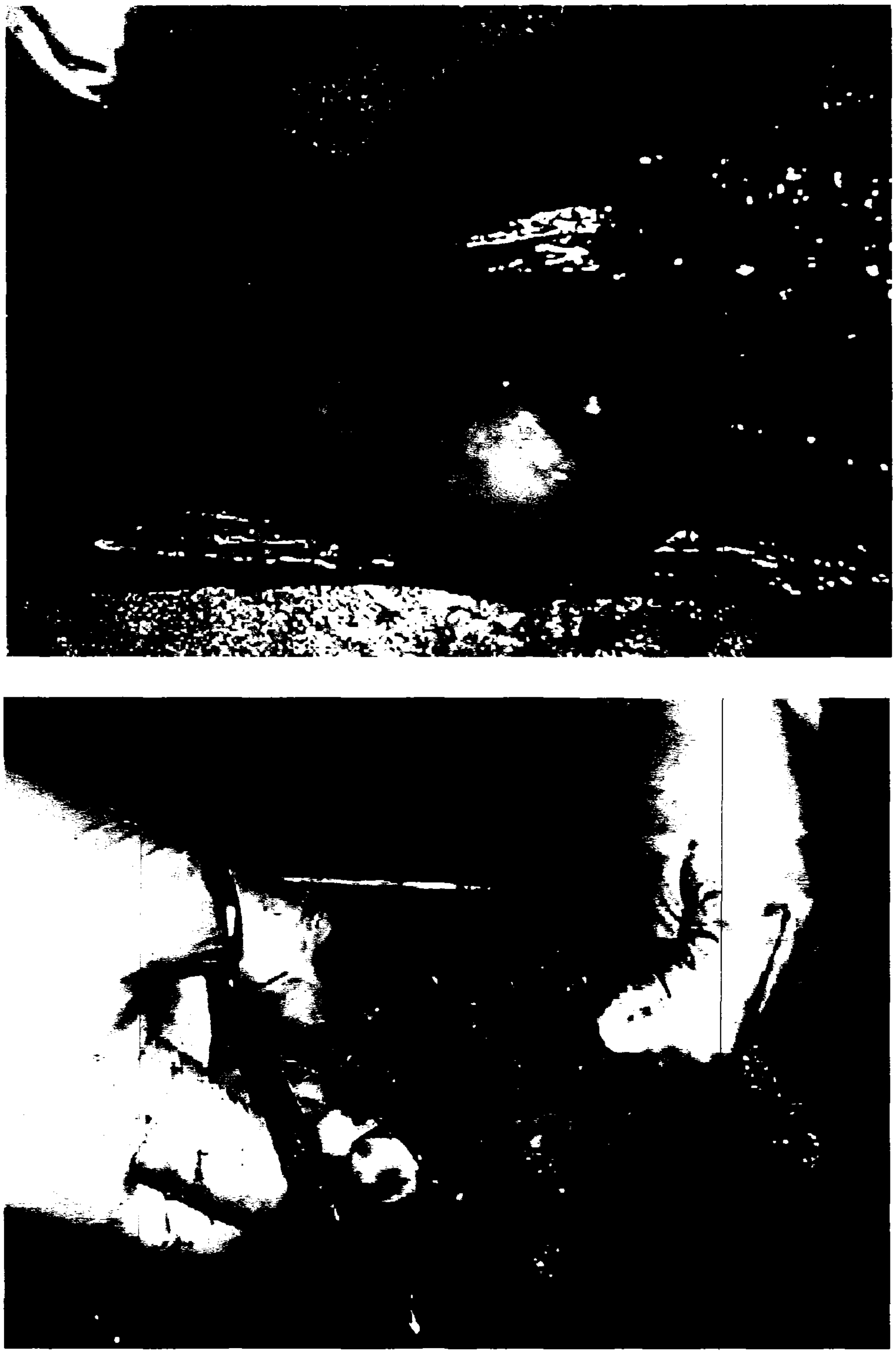
This turtle was a mature female, evident by the numerous follicles in the ovaries and the appearance of the oviduct. The upper jaw was deviated to the right side which appeared to have caused uneven wear on the oral papillae (Figure 4.7).

a

b

Figure 4.7: Adult female leatherback turtle (*Dermochelys coriacea*) found stranded in Newfoundland and Labrador in October 2004 with a) deviation of jaw and b) associated uneven wear of oral papillae.

In addition to the jaw, a number of abnormalities were observed internally which included a large amount of free blood in the body cavity (50+ litres), a haemorrhage associated with the kidney, a foreign body and associated ulcers in the gastrointestinal tract, lack of any identifiable food, a bile-stained stomach, and lack of body fat. The foreign body was partially blocking and slightly embedded into the intestinal tract (Figure 4.8). The stomach contained a few small pieces of transparent plastic, while the intestinal tract was filled with fluid which contained occasional bits of seaweed and plastic. Toxicological analysis was not undertaken on any tissues due to the advanced state of decomposition.



a

b

Figure 4.8: Foreign body found in gastrointestinal tract of adult female leatherback turtle (*Dermochelys coriacea*) a) externally and b) internally.

Discussion

Entrapments

Leatherback turtles face the threat of entrapment in fishing gear throughout their range including the northern foraging waters off NL. While reduced fishing effort around the province has likely lead to fewer leatherback bycatch occurrences, the threat still exists as evidenced by the continued reports of entrapments. The number of reported entrapments appears to have peaked in the middle to late eighties when fishing effort was presumably at its highest, and decreased around the time of the northern cod moratorium in 1992 (Figure 4.1).

While the number of entrapments has remained relatively low since that time, it is known that these numbers underestimate the actual number of leatherback-fishing gear interactions occurring around the province as entrapments often go unreported (C. Ward, W. Ledwell pers. comm.). An attempt to quantify under-reporting tendencies has been largely unsuccessful in the past (Lien *et al.* 1994), and therefore entrapment rates in this study should be considered minimums due to variations in fishing effort and the tendency of fishermen to underreport (Lien 2001). One might expect that the degree of under-reporting may be affected by the recently-implemented Species at Risk Act (SARA) for fear that leatherback entrapments might lead to additional fishery closures. Despite this expectation there have actually been increased reports of leatherback entrapments in 2004 and 2005, with five and six entrapments reported *per annum*, respectively. This is double and triple the number of entrapments reported *per annum* by Goff and Lien (1988) between 1976-1985, as well as above the average found between 1972-2005 for this study. A genuine increase in leatherback entrapments in the past two years can not be ruled out, but this increase might also be the by-product of the active solicitation of entrapment event reports and/or the distribution of education materials recently produced by DFO, which both coincided with the implementation of SARA. Such may have also been the case in 1986 and 1989 in which "awards" were presented to fishermen who reported their leatherback entrapments (Lien *et al.* 1989).

The overall 32% mortality associated with fishing gear entrapments between 1972-2005 was similar to the data reported by Goff and Lien (1988) for the period of 1976-1985. This long-term measure of mortality is likely due to the longer soak times, which are uncharacteristic of current fishery practices in NL (Lien 2001). Only two (11%) leatherbacks were found dead in fishing gear in the last ten years (n=19 entrapments). Unfortunately, without studies into the post-release survivorship of leatherbacks released alive following entrapment events, it is not possible to determine post-release mortality in these entrapments in NL.

Leatherbacks are at risk for entrapment in a variety of types of fishing gear (Figure 4.2), with entrapments being greatest in the months of August and September (Figure 4.3). This is not surprising since leatherbacks are likely at their highest local abundance during this period (Bleakney 1965; Goff and Lien 1988; Chapter 2), which coincides with increased fishing effort as well. Leatherbacks appear to be most at risk for an entrapment along the southern coast of the island (Chapter 2), which may be due to the relatively higher amount of fishing effort taking place along this coast. The distribution of leatherbacks was also highly concentrated along the southeastern coasts (Chapter 2). Entrapment in fishing gear is therefore a considerable threat to leatherbacks in NL and will continue to be a threat as long as there is fishing gear in the water.

Fish harvesters should be urged to check their gear as often as possible, especially during August and September, be informed of proper removal techniques, and be encouraged to use the Whale Release and Stranding Group for assistance. Particular attention should be focused on the south coast where entrapments were highest. This region may be an ideal candidate for a post-release survivorship study in order to gain more insight into the impact entrapments have on leatherbacks in NL.

Strandings

Fishing gear entrapment

Although there were only five leatherbacks reported stranded in 2004, this number is higher than what has been reported for the last twenty years in NL (Figure 4.6). An estimate of at-sea mortality based on these reports would be too low since not all dead turtles wash ashore (Epperly *et al.* 1996), and not all will be discovered and reported, especially with a coastline of over 9,500 km in this study area. Reasons for stranding events vary, although it is assumed that most stem from leatherbacks drowning in fishing gear and subsequently washing ashore (Davenport *et al.* 1993). Lacerations, chaffing, or bruising on stranded leatherbacks may indicate interaction with fishing gear. Due to the poor external condition of four out of the five stranded turtles in 2004 it was impossible to tell if this was the case. The leatherback turtle that stranded in Point May did have bruised blood around the flippers which strongly suggests it had been entangled in fishing gear of some type. In an unrelated event, a couple of fish harvesters reported watching a leatherback struggle and eventually break out of a gillnet over the course of an hour (J. Lawson DFO, pers. comm.), which could have resulted in a similar injury observed in the Point May turtle.

The increase in reported strandings in 2004 may be connected to the increase in entrapments observed in the same year (Figure 4.1). Since strandings likely underestimate the number of fishery-induced mortalities (Epperly *et al.* 1996) it is possible that a higher number of strandings would correspond with increased entrapments. On the other hand, the increase in reported strandings may be a combination of several factors including increased public awareness resulting from the initiation of this project, the Whale Release and Strandings Group, and educational materials distributed by the DFO. In previous years fish harvesters and other members of the public may have been less likely to report a stranded leatherback because they were unaware of the importance of doing so, or that there were organizations interested in this information.

Weather may also play a role in the increase of stranding events since wind and currents are highly influential on the stranding of dead turtles (Epperly *et al.* 1996). The majority (70%) of the reported strandings occurred in the months of September to November. It is possible that heavy winds might wash ashore leatherbacks that have died at sea in higher proportions than other times of the year, as storms have been indicated in the beaching of dead leatherbacks (Velez-Zuazo *et al.* 2003; Prince 2004). The location of stranded turtles unfortunately does not provide any insight into the place of its death due to the displacement effect of wind and currents (Epperly *et al.* 1996). The effect of winds on the stranding of dead leatherbacks would be difficult to determine without long-term monitoring of both strandings and weather patterns. This would require systematic beach surveying, and a significantly greater level of voluntary reporting by fish harvesters and other members of the public. It should be noted that leatherbacks are not susceptible to cold stunning, which is a common cause of strandings in other species of sea turtles during the fall (Meylan and Sadove 1986).

Marine pollution

The ingestion of marine debris and associated morbidity and mortality may also provide an explanation for leatherback strandings since plastic bags, latex, and other anthropogenic debris are a common occurrence in waters off NL, especially in areas of jellyfish abundance (H. Brock, pers. obs.). The adult female leatherback that was discovered stranded on the eastern coast of the island in October of 2004 appeared to be healthy based on external examination. Upon internal examination the lack of food and bile-stained stomach indicated the turtle may not have been eating (H. Whitney, pers. comm.). This is further evidenced by her lack of body fat, which is uncharacteristic for leatherbacks known to be actively foraging at this time of year (Goff and Lien 1988; Goff and Stenson 1988; James *et al.* 2005). The nature of the foreign body could not be determined; it may have been similar to the foreign bodies observed in other leatherbacks (Eckert and Luginbuhl 1988; Davenport *et al.* 1993; Levy *et al.* 2005). It has yet to be determined whether these foreign bodies, or faecoliths, are of a pathological nature (Davenport *et al.* 1993). The free blood present in the body cavity was thought to be related to the kidney haemorrhage. Accordingly, a number of organ surfaces displayed white crystal deposits indicative of visceral gout, which is a precursor of kidney failure or dehydration seen in other reptiles (Frye 1981). Ultimately this leatherback appeared to have experienced complications resulting from this occlusion (i.e., starvation or dehydration) which may have subsequently led to the stranding. It has been shown that ingestion of plastic and latex has resulted in reduced blood glucose levels in sea turtles, which suggests a potential metabolism disruption (Lutz 1990). Because necropsies were not performed on the two other stranded leatherbacks from 2004, ingestion of plastic debris can not be ruled out in their cause of death, especially when 44% of adult leatherbacks are estimated to have plastic in their stomachs (Mrosovsky 1981). Consequently, ingestion of marine debris should be considered a serious threat to leatherbacks in NL, particularly since they use these waters for seasonal foraging.

Vessel strikes

Individuals may strand as a result of collisions with vessels (Davenport *et al.* 1993) or propeller strikes (Lenglet *et al.* 2003). The leatherbacks that stranded in Point May and Picadilly Point in 2004 had external injuries (broken skull in the area of the pink spot; large puncture in the anterior portion of carapace), but because these turtles had been decomposing at the time of discovery it was unknown whether these injuries were caused pre- or post-mortem, and what may have caused them. It is not unreasonable to consider vessel collisions as a cause of death due to the amount of vessel traffic around NL, especially in coastal waters. In addition, fish harvesters have noted the curious nature of some leatherbacks in that some have been reported to approach boats or fishing gear, while other fish harvesters travelling on the water report failing to notice leatherbacks until the last minute and having had to quickly avoid them. For example, a passenger ferry operator on the south coast had to stop the vessel's engines to avoid colliding with a leatherback in the summer of 2004 (C. Dominix, pers. comm.). Vessel collisions should therefore be considered a threat to leatherbacks in NL, especially off the south coast where vessel traffic is high.

Acoustic and oil pollution

Acoustic and oil pollution may be significant threats in NL that result from the emergent offshore oil and gas industry, and numerous shipping routes. The impact of acoustic pollution on leatherbacks is difficult to ascertain without evidence of avoidance behaviour. Some studies have shown that low frequency sounds may cause displacement and increased swimming behaviour in sea turtles (Lenhardt *et al.* 1983; O'Hara and Wilcox 1990; Lenhardt 1994; McCauley *et al.* 2000). Aside from the potential physical displacement acoustic pollution may cause, it is unknown whether it had any role in the strandings observed in 2004 as none of the stranded leatherbacks were examined for damage to the hearing apparatus. Although no oil remnants were found in any of the post-mortem examinations, oil spills should be considered a serious threat, especially in

NL where the level of chronic oil pollution downwind of a major shipping route is among the highest in the world (Wiese and Robertson 2004).

All of these threats have the potential to negatively impact leatherback turtles while they forage off NL. An apparent decrease in fishing-related mortality is encouraging, yet a post-survivorship study would be useful in determining the survivorship and health of turtles released from entrapments. In the interim, DFO and the Whale Release and Strandings Group should continue to support the release of leatherbacks through public education and assistance. Stranding events should be well-documented in order to monitor the potential impacts of these threats and subsequently aid in recovery strategies.

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Chapter 5: The use of education in the promotion of leatherback turtle recovery in Newfoundland and Labrador

Introduction

Conservation biology is one of the most rapidly expanding fields of science with a truly interdisciplinary nature. It is therefore not uncommon for biologists to use a variety of resources in order to accomplish conservation outcomes. One such resource is public education. When science is conveyed to the public, not only does the public gain a heightened awareness, but science has the potential to become far more effective. With regards to species at risk, the use of education has become not only a useful method in furthering recovery efforts, but an essential tool. This is evident in countries where sea turtles come ashore to nest such as Mexico and Trinidad, both of which have experienced success in helping to conserve endangered sea turtles as a result of public education and community involvement in recovery efforts (Bird *et al.* 2003; Sammy and Tambiah 2003).

Due to the highly migratory nature of leatherback sea turtles, education initiatives in support of recovery must extend beyond the southern nesting beaches to northern foraging grounds such as waters off Newfoundland and Labrador (NL). Some of the threats that leatherbacks face in the waters off eastern Canada are different than those in the tropics, and public education has the potential to increase the awareness of these threats. This is especially important in NL where many residents are unaware that leatherback turtles reside in their waters. Education also has the ability to instill a sense of stewardship and pride for this unique species in both the public and in stakeholders.

Public education and awareness is so important that it has been recognized as an essential element in the recovery of leatherbacks in Atlantic Canadian waters. As a result, education initiatives targeting a variety of audiences, have been set forth as an objective in the National Recovery Strategy for leatherback turtles in Atlantic Canada (Atlantic Leatherback Turtle Recovery Team 2006).

At present, the Department of Fisheries and Oceans, Newfoundland and Labrador Region (DFO), has developed leatherback educational materials as part of a Species at Risk Act (SARA) initiative that have been distributed throughout the province in schools and to fish harvesters. The nature of other leatherback educational programmes within the Department has not been investigated. Such an investigation is needed in order to determine the extent of leatherback education in NL and because of the importance of expanding leatherback education throughout its entire range.

In terms of school-based education, it is unknown whether the NL curriculum (K-12) specifically addresses leatherbacks or species at risk. Teachers do have access to the Marine Environmental Education Programme (MEEP), coordinated by Julie Huntington. This programme, funded through the Habitat Stewardship Programme, is available throughout the province. The programme can be tailored to meet the educational levels of kindergarten through to grade twelve students, and focuses primarily on marine species at risk in Atlantic Canada. Issues of general biology, distribution, threats, and habitat protection are discussed, while hands-on educational materials (e.g., bones, baleen, life-size silhouettes) are used wherever possible.

Systematic evaluations of educational programmes are necessary not only to ensure that the programmes are effective, but also to gauge their impact and periodically highlight areas of needed improvement. Without the formal evaluation of students in the classroom, measuring the success of an education programme is often difficult. This necessitates the use of proxies in order to evaluate success, which includes the measurement of particular outcomes (Trewhella *et al.* 2005). According to the Society for Conservation Biology (SCB), the development of knowledge, skills, and attitudes are what deem conservation education most successful (Trombulak *et al.* 2004), and thus these outcomes were used for the basis of the MEEP evaluation. The objectives of this study were to a) examine the current status of leatherback education in NL at the Federal (DFO) and Provincial (Ministry of Education) levels, and b) evaluate the success of the MEEP using feedback gained through a survey. Recommendations are made for improving each educational component.

Materials and methods

Status of Federal and Provincial Species at Risk educational initiatives

Aside from the use of educational materials, the education initiatives currently being implemented by DFO were examined by speaking directly with the Species at Risk Coordinator and the SARA Communications Coordinator (Newfoundland and Labrador Region) about what programmes were in place to address leatherback turtles and other species at risk (E. Pittman and D. Osborne, pers. comm.).

To examine the status of leatherback education in schools across the province the online version of the Newfoundland and Labrador Curriculum (K-12) was examined for any reference to leatherbacks, species at risk, and concepts of endangered species (http://www.ed.gov.nl.ca/edu/sp/main.htm).

Assessment of the Marine Environmental Education Programme (MEEP)

A one-page written survey (Appendix B) was distributed to students and teachers to whom a presentation had been made by the MEEP. Presentations were made in the fall of 2004 and surveys were distributed the following spring. Surveys were handed out to teachers, which included one teacher copy and two or three student copies. Teachers were relied upon to make additional copies for other students at their own discretion. The survey was designed to generate feedback on the quality of the presentation and differed slightly depending on whether it was designed for student or teacher (J. Huntington, pers. comm.). Two specific questions were selected from the surveys (Questions 3 & 4 – Teacher Survey; Questions 2 & 3 – Student Survey) to evaluate the success of the educational program, with success being defined as 1) increasing the awareness of leatherback turtles and 2) instilling stewardship in the participants.

Results

Status of Species at Risk educational initiatives

DFO

DFO has produced leatherback posters, ID cards (Appendix C), key rings, and temporary tattoos that have been distributed to schools and other organizations throughout the province. These materials have also been distributed to fish harvesters during survey trips to collect leatherback sightings. During such trips fish harvesters were engaged in conversation about leatherbacks and the human activities that threaten them. They were given leatherback sighting booklets to fill out which they were encouraged to send back to DFO at the end of the fishing season. Efforts were also made to ensure that they were aware of the Whale Release and Stranding Group that is available to them in case of a leatherback entanglement. In the summer of 2005 a new sightings programme was implemented that saw 120 leatherback sighting postcards (Appendix A) sent out to fish harvesters and fisheries officers around the province. Included with the postcards was a letter briefly describing leatherbacks and the research currently being conducted by DFO.

DFO does not currently have an education programme designed specifically for leatherbacks directed towards either the public or stakeholders (E. Pittman and D. Osborne, pers. comm.). However, there are presentations given to school children throughout the school year, and in celebration of World Oceans Day (June 8th), in which species at risk, including leatherbacks, are discussed. There is also funding to produce a

SARA education kit this fall (2005) that will be available to two age groups (primary and elementary) in schools across the province. The kit will have the capability to be used as a whole, or it can be broken down into several activity components that could be used alone (i.e., games, colouring books, lessons). The only active education initiatives aimed at fishermen with regards to SARA are workshops specific to the handling of the endangered wolffish.

Ministry of Education (NL)

No specific reference to leatherbacks was found in any of the online versions of the Newfoundland and Labrador Curricula (K-12). The first mention of endangerment occurs in the Elementary Science Curriculum Guide (2002) for Grade 4 (p. 38), in which the desired goal is for students to gain an understanding of the link between habitat loss and the endangerment/extinction of plants and animals (Government of Newfoundland and Labrador 2002). This issue is furthered in the Elementary Science Curriculum Guide (2002) for Grade 6 (p. 172) with students expected to understand various reasons why animals are endangered and what is being done to ensure their survival (Government of Newfoundland and Labrador 2002). It is not until the senior high school level (level II and III) that species at risk are discussed more extensively (Science 2200 Curriculum Guide Interim 2004, p. 32; Environmental Science 3205, p. 26), and in both instances the examples given refer to the endangered Newfoundland pine marten (Government of Newfoundland and Labrador 1993, 2004).

Assessment of Marine Environmental Education Programme (MEEP)

Teacher surveys

A total of thirteen teachers responded from six different schools (Clarenville Primary – 2; Our Lady of Mercy – 6; Paradise Elementary – 1; Catalina Elementary – 1; St. James Elementary – 1; Goulds Elementary – 2). All of the teachers that participated in the MEEP reported that they had learned something new (Table 5.1), with the majority of teachers developing a new interest in marine animals and helping to protect their environment (Table 5.2). Only a very small number of teachers did not develop a new interest. Many of them remarked on the size of leatherback turtles as being something that they learned after hearing the presentation. Numerous teachers also commented on how well the presentation was put together and were quite interested in having similar presentations on other marine species.

Table 5.1: Percentage of responded teachers (n=13) and students (n=27) that learned something new after hearing the presentation by the MEEP.

	Strongly Agree	Agree	Disagree	Strongly Disagree
Teachers	53.8	46.2	0	0
Students	81.5	18.5	0	0

Table 5.2: Percentage of responded teachers (n=13) and students (n=27) that developed a new interest in marine animals and helping them live in a healthy environment after hearing the presentation by the MEEP.

	Strongly Agree	Agree	Disagree	Strongly Disagree
Teachers	30.8	61.5	7.7	0
Students	70.4	22.2	0	7.4

Student surveys

Twenty-seven students (K-8) from six different schools responded (Kindergarten – 2; Grade 1 – 2; Grade 2 – 5; Grade 3 – 12; Grade 4 – 5; Grade 5 – 0; Grade 6 – 0; Grade 7 – 0; Grade 8 – 1). Because the student surveys did not request school information, the return rate per grade per school could not be tabulated. The student survey results showed a similar trend to that of the teachers with all of the students that participated in the MEEP learning something new (Table 5.1), and 93% developing a new interest in marine animals, and helping them live in a healthy environment (Table 5.2). Again, only a small number of students disagreed with the statement that they had developed a new interest in marine animals and helping them live in a healthy environment. Besides learning about the size of leatherback turtles, the students also commented on how they learned the dangers of human debris, especially plastic bags, getting into the water, and that leatherbacks are endangered in part because of humans littering and habitat destruction. One student (grade 4) was particularly disturbed by the concept of leatherbacks being endangered and dying off quickly, whereas students in grade 3 wanted to see live animals and know how to save them.

Discussion

Although DFO does not currently implement any specific leatherback education programme in conjunction with their educational materials, the issue of species at risk is becoming more prominent which will likely result in the establishment of specific programmes. DFO should continue to develop their SARA education programme with more emphasis on leatherback turtles. SARA Coordinators may want to consider incorporating leatherback release workshops into the wolfish release workshops, which are already taking place, in order to increase awareness throughout the fishing community. This is vital in an industry that comes in direct contact with leatherbacks, and could be extremely beneficial to scientists at DFO. Fish harvesters are one of the best resources to have in terms of collecting leatherback distribution data, and this type of work could help foster alliances between DFO and fish harvesters. Collaboration between fish harvesters and researchers has the potential to translate into long-term conservation initiatives such as that achieved in Baja California, Mexico (Bird *et al.* 2005). The effectiveness of public education and outreach programmes can be enhanced through regular announcements over media such as CBC's "Fisheries Broadcast" during the summer and fall reminding fish harvesters of the presence of leatherbacks in NL waters, and the actions to take if they see one, or get one entangled in their gear. A similar reminder could be placed in local papers throughout the province along with space to write down and submit leatherback sightings to DFO (comparable to the postcards sent out in 2005).

The evolution of the concept of endangerment and extinction from the elementary grades to the high school level is indicative that there is an effort being made to incorporate species at risk considerations into the curriculum in NL. The absence of any direct mention of leatherbacks in the text of the curriculum does not mean that students are not gaining exposure to this species. The curriculum merely acts as a guide and teachers do have the freedom to incorporate different resources into their lessons. Furthermore, the examples given in the curriculum are not the only ones that are being used currently. The use of the pine marten in the secondary level curriculum is most likely due to the increased exposure and familiarity of this animal in NL. As leatherbacks continue to gain more attention throughout the province it is only a matter of time before they too become prime examples of a species at risk. For example, a new text book is currently being produced for the high school level Environmental Science (3205) course in which endangered species will be included. At the present time the species to be profiled have not been decided, but the writer for this section will be considering leatherbacks as a possibility (S. Porter, pers. comm.). It is recommended that the Ministry of Education continue to address the issue of species at risk in the provincial curriculum, with a wider range of examples provided that should include leatherback turtles. The Ministry could also consider introducing species at risk concepts at an earlier age. Rivas and Owens (1999) believe that earlier is better than later when it comes to instilling ecologically responsible attitudes because younger children are more receptive than the audiences that are typically targeted today. Teaching people to care, at all levels, may be the real issue in terms of conserving species at risk.

The feedback generated by the surveys in this study indicated that the MEEP has been effective in increasing awareness about leatherbacks for both students and teachers (Table 5.1). In addition, the MEEP has appeared to have helped instill a sense of stewardship among teachers and students by helping participants develop a new interest in protecting marine animals (Table 5.2), which thereby develops new attitudes.

Together these outcomes, as outlined by the SCB, characterize the MEEP as a successful education programme.

It should be noted that the primary purpose of the surveys was to generate feedback on the MEEP presentation, and that they were used secondarily in an attempt to answer the question of increased awareness and stewardship. Although the small survey size indicates a high degree of uncertainty, the low degree of variation within the population (i.e., same programme and curriculum across province) offsets this to some degree. A directed study using a tailored survey would be needed to determine whether the MEEP presentation does in fact truly increase awareness and help instill stewardship. In general, the surveys seemed to be an effective medium to gather feedback from the programme and therefore they should be regularly distributed to each group of teachers and students that participate.

The success of the MEEP is indicative that it should continue to be used to teach students about species at risk and leatherbacks. One suggested improvement is to include video footage (e.g., an educational video) of leatherbacks as some of the children that responded to the surveys indicated they wanted to see a live leatherback. This would compliment the rest of the educational materials and allow the students to make an even better connection between leatherbacks and their natural habitat. The MEEP should also consider developing a lesson plan that could be submitted directly to the Ministry of Education to include in the curriculum as was done with endangered fruit bats in India (Trewhella *et al.* 2005). Information about World Turtle Day (May 23rd) and World Sea Turtle Day (June 16th) could be included as components of lesson plans, as well as information regarding beach cleanups, which would provide opportunities to discuss the impact marine debris has on leatherbacks.

Education is playing a more prominent role in conservation biology, and more specifically in the recovery of species at risk. This is becoming apparent in regards to leatherbacks in NL, as both DFO and the provincial Ministry of Education are making efforts to incorporate leatherbacks and species at risk into their public outreach programmes and curricula. In addition, the MEEP represents a highly successful conservation education programme which helps develop environmental awareness and attitudes in students across the province. If progress continues in developing all of these education programmes, they have the potential to promote and enhance the long-term survival of leatherbacks in the waters off NL, and establish themselves as an example of how conservation education can be used successfully to promote species at risk recovery.

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Chapter 6: Summary: Leatherback turtles off Newfoundland and Labrador

Leatherback turtles are critically endangered throughout their range, which extends north into waters off Newfoundland and Labrador (NL) in the northwest Atlantic (Chapter 2). It is northern waters such as these that leatherbacks migrate long distances to reach in order to forage on abundant gelatinous organisms. Little is known about leatherbacks during this particular portion of their annual cycle. Such knowledge gaps hinder the development of effective recovery efforts. This thesis aims to further our understanding of leatherbacks while they forage off eastern Canada by examining their distribution, diet, and threats. A brief examination of curricula in Newfoundland schools and other education initiatives are included to acknowledge the important role education plays in the conservation of this species.

In order to promote the recovery of leatherbacks, it is essential to identify and delineate the habitat they require. Once this habitat is defined it can then be protected. Leatherbacks are known to occur around the entire island of Newfoundland as well as off Labrador. June through to October represents the normal period of leatherback occurrence, with a seasonal peak during August and September. Shallow coastal waters (< 50 m depth) appear to be important leatherback habitat, which is likely a function of the warm seasonal water layer that develops coastally and continues out across the shelf (Schneider and Methven 1988). Because leatherbacks maintain a warm core with passive mechanisms (Friar *et al.* 1972; James and Mrosovsky 2004), there is a reduced risk of compromising this core by migrating north with the warm layer. Furthermore, this layer may serve to provide metabolic savings if leatherbacks utilize active thermoregulation, such as increased swimming activity if the core begins to cool. In addition to thermal benefits, coastal areas provide suitable habitat for gelatinous organisms, which leatherbacks require in large quantities. Together, these features, both abiotic and biotic, contribute to leatherback distribution off Newfoundland and Labrador (NL), and are key components of leatherback critical habitat.

Investigating leatherback foraging ecology is important in understanding their predator/prey relationship, as well as the energetics involved with the life history strategies of these endangered reptiles. Derivation of energy requirements also lends support to the critical habitat definition (Chapter 2). Despite the fact that jellyfish are approximately 95% water (Lutcavage 1996; Chapter 3) leatherbacks are able to subsist on this low energy-density diet. In order to do so they must consume substantial amounts, which I estimate in this thesis to range from almost half, to one and a half times the body weight of a 500 kg turtle per day depending on the species of jellyfish (Chapter 3). Large swarms of jellyfish found off NL, combined with the ease with which jellyfish are captured and digested by leatherbacks, serve to make these prey a good option to exploit. In doing so, leatherbacks serve as an important link in the food web off of NL.

Unfortunately, as leatherbacks forage in waters off NL they face a multitude of anthropogenic threats. A better understanding of these threats is essential in order to reduce their impact and focus efforts on recovery. One such threat facing leatherbacks off NL is entrapment in fishing gear. Leatherbacks are at risk for entrapment in a variety of types of fishing gear, with entrapments being greatest in the months of August and

September (Chapter 4). Furthermore, leatherbacks appear to be most at risk for an entrapment along the southern coast of the island (Chapter 2), which may be due to the relatively higher amount of fishing effort taking place along this coast. A post-release survivorship study is needed in order to gain more insight into the survival of leatherbacks following extrication from these entrapments. Other threats may include the ingestion of plastic and marine debris, such as indicated through the necropsy of a stranded leatherback (Chapter 4), vessel strikes, and acoustic and oil pollution.

Education is becoming an essential tool in conservation biology and the recovery of endangered species such as sea turtles (e.g., Bird *et al.* 2003; Sammy and Tambiah 2003). In NL, public outreach involving leatherbacks is currently being administered through the Department of Fisheries and Oceans (Newfoundland and Labrador Region) in the form of educational materials, and the Marine Environmental Education Programme (MEEP). Although the provincial Ministry of Education does not directly include leatherbacks in their curricula, the topic of species at risk is explored at the high school level. The MEEP appears to have been successful in increasing awareness of leatherbacks and instilling stewardship among students and teachers however a more directed study is needed to determine if these are in fact the outcomes. Together these education initiatives are an important part of the overall recovery efforts of leatherbacks if they result in reductions in the sources of risk (e.g., pollution and entrapments) for these reptiles.

The survival of leatherback turtles will depend upon an integrated approach utilizing both scientific knowledge and public education. The more we understand about leatherbacks and their ecology, the better equipped we are to make decisions regarding their management and come up with effective solutions for the threats they face. This knowledge, together with public education and involvement, will hopefully guarantee the future for this ancient animal that has already escaped extinction for the last one hundred million years.

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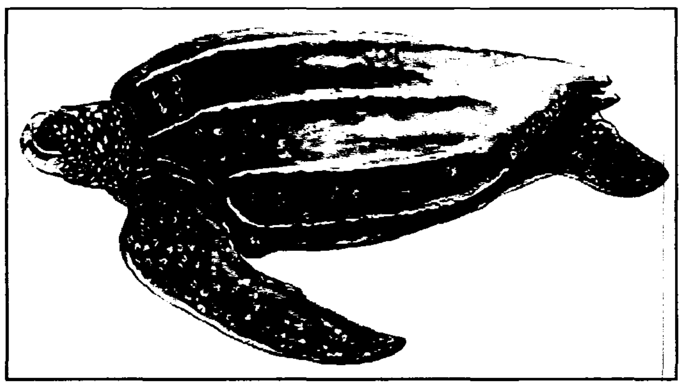
Appendix A: Postcard developed for the collection of leatherback sightings, strandings, and entrapments and sent to fish harvesters during 2005

Have you seen this sea turtle?



Let us know if you see a leatherback sea turtle!

Location: ______________________

Date & Time: ____________________

○Feeding ○Swimming ○Basking

○Interacting with fishing gear ○Dead

Location: ______________________

Date & Time: ____________________

○Feeding ○Swimming ○Basking

○Interacting with fishing gear ○Dead

Location: ______________________

Date & Time: ____________________

○Feeding ○Swimming ○Basking

○Interacting with fishing gear ○Dead

Name: ______________________

Town: ______________________

Thank you for helping us learn more about leatherback sea turtles.
Please drop this card in the mail or call Dr. Lawson (709) 772-2285

Sightings, entrapments & strandings can also be reported at [illegible]-895-3003 or whalesighting@dfo-mpo.gc.ca

To:

Dr. Jack Lawson
Marine Mammal Section
NAFC, 80 E. White Hills Rd.
Fisheries and Oceans Canada
P.O. Box 5667
St John's, NL A1C 5X1

Appendix B: One-page assessment survey distributed by the Marine Environmental Education Programme to teachers and students

Teacher Survey:

Share Your Thoughts With the Marine Environmental Education Programme

School____________________________________
Location___________________________________
Grades presented to__________________________
Number of students presented to__________________
I teach grade ____ The students are ____ years old.

Your comments will help us improve the quality of the presentation. Thank you!

Please check the box that best matches your thoughts about the presentation.

1. The presentation was presented at a level the students could understand.

Strongly Agree	Agree	Disagree	Strongly Disagree
☐	☐	☐	☐

2. The presenter encouraged the children to participate and be involved.

Strongly Agree	Agree	Disagree	Strongly Disagree
☐	☐	☐	☐

3. I have a new interest in marine animals (whales, leatherback turtles, wolfish) and helping them live in a healthy environment.

Strongly Agree	Agree	Disagree	Strongly Disagree
☐	☐	☐	☐

4. I learned something new.

Strongly Agree	Agree	Disagree	Strongly Disagree
☐	☐	☐	☐

One thing I learned is:

____

____

5. Would you recommend this presentation to other teachers?

____

____

6. What could the presenter do to improve the presentation?

____

____

7. What other types of programmes regarding marine stewardship would you like to have presented in your school?

____

____

Any additional comments:

____

____

Student Survey:

Share Your Thoughts With Us

My age is _____ My Grade is _____

Your comments will help us improve the quality of the presentation. Thank you!

Please check the box that best matches your thoughts about the presentation.

1. I really enjoyed the presentation.

Strongly Agree	Agree	Disagree	Strongly Disagree
☐	☐	☐	☐

2. I learned something new.

Strongly Agree	Agree	Disagree	Strongly Disagree
☐	☐	☐	☐

One thing I learned is:

____

____

3. I have a new interest in marine animals and helping them live in a healthy environment.

Strongly Agree	Agree	Disagree	Strongly Disagree
☐	☐	☐	☐

4. The material was presented on a level that I could understand.

Strongly Agree	Agree	Disagree	Strongly Disagree
☐	☐	☐	☐

5. The part of the presentation I liked the most was:

____

____

6. The part of the presentation I liked the least was:

____

____

7. Any suggestion on how to make the presentation more enjoyable:

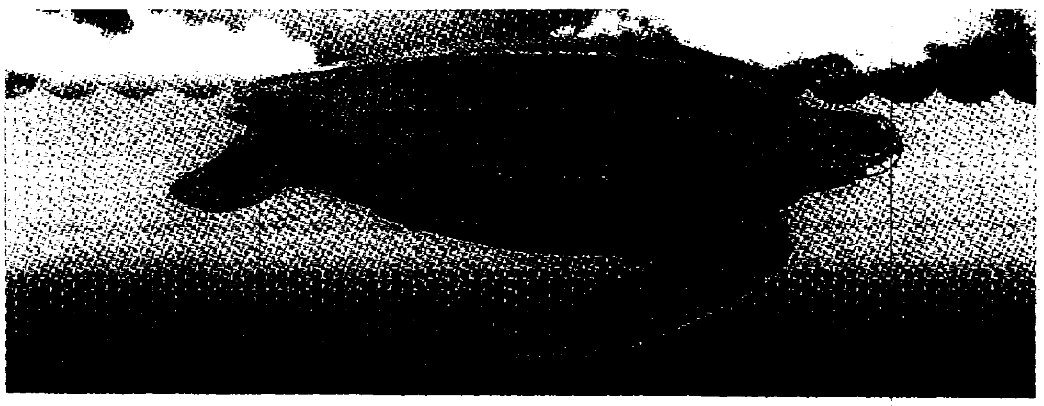
____

____

____

____

Appendix C: Leatherback turtle species at risk identification card developed by the Department of Fisheries and Oceans, Newfoundland and Labrador Region, for public education



Leatherback Sea Turtle

Name:
Leatherback Sea Turtle
(Dermochelys coriacea)

Local Names:
Sea turtle, Leatherback

SARA Status:
Endangered

Size:
Adults are up to 1.8 metres long and weigh 725-900 kg

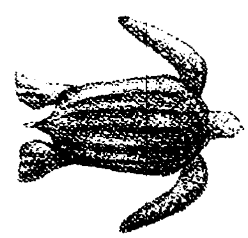
Diet:
Primanly jellyfish

When you might see it:
during most of the year except late winter and early spring, although they are more commonly seen in nearshore waters during the summer when waters are warmer and jellyfish are present.

Where you might see it:
throughout the region, with sightings more common in southern Newfoundland.

Notes:
This is the largest turtle. It has thick leathery skin on its back rather than a hard shell. Unlike many reptiles, leatherbacks can keep their body temperature slightly warmer than the water in which they swim. While they are often seen floating or feeding near the surface, these turtles can swim as fast as 25 km/hr and dive to 1,300 metres.

Top view



Leatherback Sea Turtle

Canada

Newfoundland and Labrador

Fisheries and Oceans Canada | Pêches et Océans Canada