AN ABSTRACT OF THE THESIS OF

Tonya K. Zeppelin for the degree of Master of Science in Wildlife Science presented on June 11, 1998. Title: Habitat Utilization by Minke Whales (*Balaenoptera acutorostrata*) in the St. Lawrence Estuary, Canada.

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Abstract approved: ______________________________

Bruce E. Coblentz

Characteristics of minke whale (*Balaenoptera acutorostrata*) habitat at the head of the Laurentian Channel in the St. Lawrence Estuary, Canada were identified by quantifying environmental and temporal habitat variables and comparing them to the presence or absence of minke whales during the summer of 1996. Identification photographs of minke whales taken during the summers of 1995 and 1996 were used to examine intra-annual and year to year habitat use by individual minke whales.

Minke whales were primarily distributed between the 50 m and 100 m bathymetric contours which corresponds to the ridge of the Laurentian Channel. This region is characterized by a steep slope in bottom topography which causes predictable accumulations of euphausiids and capelin (*Mallotus villosus*), the principal prey species of minke whales. Tide phase, lunar phase and time of season, all of which cause slight fluctuations in prey abundance did not appear to have a significant influence on minke whale presence or movements. Individual minke whales exhibited site tenacity in returning to a localized area both within a season and in consecutive years.

Habitat Utiliztion by Minke Whales (*Balaenoptera acutorostrata*) in the St. Lawrence Estuary, Canada

by

Tonya K. Zeppelin

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Tonya K. Zeppelin, Author

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DEDICATION

This thesis is dedicated to Divot, Broken Fin, Sans Fin and many other friends of the St. Lawrence.

Habitat Utilization by Minke Whales (*Balaenoptera acutorostrata*) in the St. Lawrence Estuary, Canada

1. INTRODUCTION

Despite exploitation by the whaling industry in recent years, and indications that exploitation might increase in the future, little information exists on habitat utilization by minke whales (*Balaenoptera acutorostrata*). In order to properly manage minke whale populations and habitat, it is necessary to gain a more thorough understanding of their use of an area.

The minke whale is the smallest member of the genus *Balaenoptera*; an average adult from the North Atlantic stock is estimated to be 4,000 kg. (Blix & Folkow 1995). Because of their small size in comparison with other rorqual whales, minke whales were historically ignored by the whaling industry. However, many of the larger whale stocks have been depleted and are now protected. Since the early 1980s the minke has become the most heavily hunted whale in the world (Hoyt 1990).

Minke whales are distributed throughout the world ocean. The North Atlantic population is currently estimated to be 130,000 (Hoyt 1990); part of that population commonly summers around the maritime provinces of Canada including the Bay of Fundy, the St. Lawrence River and the Gulf of the St. Lawrence (Hoyt 1990). Minke whales migrate to the lower latitudes in the winter months for birthing (Horwood 1989, Mitchell 1991); however, specific breeding grounds have not yet been identified.

Relatively few studies have been conducted on free ranging minke whales. They have been observed to exhibit site tenacity for presumed feeding sites (Dorsey 1983). Defining site tenacity as the return and reuse of a previously occupied area both within a season and in consecutive years, Dorsey (1983) found that minke whales in the San Juan Islands of Puget Sound, Washington displayed such patterns. The whales were reported to exclusively occupy adjoining ranges within a 600km^2 area (Hoelzel et al. 1989). Minke whales observed to the north and west of Mull in Scotland also exhibited feeding site tenacity both within a season and in consecutive years (Gill and Fairbains 1995); however, there was no evidence that they used exclusive ranges, and considerable overlap between home ranges of individuals occurred.

To date, little research has been done to determine the factors which affect habitat selection by minke whales. Several studies have shown that minke whales tend to stay in coastal ocean environments (Dorsey 1983, Edds and Macfarlane 1987, Piatt et al. 1989). Hoelzel et al. (1989) recorded 80% of all minke whale feeding observations over submarine slopes of moderate incline and depth (20-100m). In the western North Atlantic, minke whale distribution has been related to their primary food source, the capelin (*Mallotus villosus*) (Sergeant 1963, Mitchell and Kozicki 1975, Piatt 1989). Piatt and Methven (1992) found that minke whales in Witless Bay, Newfoundland were usually found only in areas where capelin school abundance exceeded 5.0 schools km^{-1} (23 t km^{-2}). Habitat use by minke whales has been explained as a result of competition with larger sympatric species (Tershey 1989) and as a function of predictability of prey (Darling et al. 1995), in the latter case because the minke is not as well adapted as other baleen whales for long distance travel or prolonged food deprivation due to its smaller size.

From spring to fall, a number of minke whales regularly utilize the headwaters of the Laurentian Channel in the St. Lawrence Estuary, Canada as a feeding ground (Edds and Macfarlane 1987). Anecdotal observations indicated that the presence of whales was more predictable in some areas of the estuary than others, but this pattern of distribution and any reasons for it have not previously been quantitatively substantiated.

The objectives of this study were to determine if there were discernible patterns of habitat use by minke whales at the headwater area of the Laurentian Channel and to determine if any of several possible environmental or temporal variables (tide phase, lunar phase, time of season seafloor topography) might influence any patterns of habitat use observed. In addition, the occurrence of several recognizable whales with nicks in the dorsal fin, body scars or distinctive pigmentation patterns made it possible to examine habitat selection by individual minke whales.

2. MATERIALS AND METHODS

2.1 Study Area

The study was conducted from June through September, 1996 in a 423 km^2 area in the middle estuary of the St. Lawrence River, Canada (Fig. 1). The study area was approximately bound by 48°03'00" - 48° 17'24" N latitude and 69°40'00" - 69°25'00 W longitude. Preliminary observations done during 1995 had shown that minke whales were common in the area and that the area was easily accessible for research.

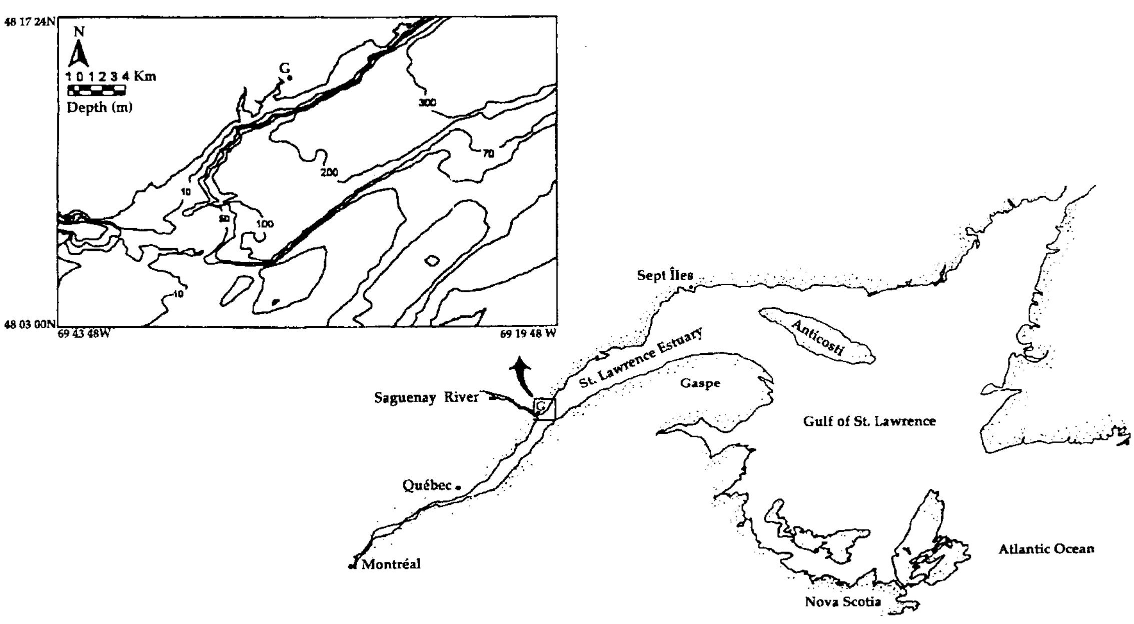

Figure 1. Bathymetric chart of the study area located in the middle estuary of the St. Lawrence River, Canada. (G, town of Grandes Bergeronnes located near the mouth of the Saguenay River)

2.1.1 Abiotic Factors

The dominant geophysical structure of the St. Lawrence is the Laurentian Channel, a 200-300 m deep glaciated valley which originates along the continental shelf southeast of Newfoundland. The channel permits intrusion of nutrient rich continental shelf and slope water into the estuary (El-Sahb 1979). Two water currents flow in permanent layers upstream from east to west: the Atlantic deep layer (T= 3 to 6°C; S > 33 $^{o}/_{oo}$) and a cold intermediate layer (T= -2 to 2°C; S > 32$^{o}/_{oo}$) (Rainville and Marcotte 1985). From late spring to early fall, freshwater outflow from the Saguenay and St. Lawrence rivers results in a surface mixed layer (T = 3 - 19°C; S = 18 - 31$^{o}/_{oo}$) (Rainville and Marcotte 1985).

The Laurentian Channel ends within the study site, rising at a steep slope to a depth of 50 m at the mouth of the Saugeny River, causing nutrient rich waters from the cold intermediate layer to rise to the surface. Steven (1974) referred to the area around the mouth of the Saguenay River as a "nutrient pump" because of the high levels of nutrients in the surface layer compared to other areas in the estuary. For the purpose of this study, the mouth of the Saguenay River is defined as the region right at the confluence of the Saguenay River and St. Lawrence Estuary. The upwelling of high nutrient concentrations in this area increases primary productivity and provides an optimal summer feeding ground for baleen whales.

2.1.2 Biotic Factors

From spring to fall, minke whales from the North Atlantic stock travel into the estuary where they feed primarily on capelin and euphausiids (krill).

Finback whales (*Balaenoptera physalus*), and to a lesser degree, blue whales (*Balaenoptera musculus*) also use this area as a feeding ground during the summer months (Mitchell 1975, Edds and Macfarlane 1987). A resident and endangered population of 500 beluga whales (*Delphinapterus leucas*) lives in the Saguenay Fjord and St. Lawrence Estuary year round (Sergeant 1986). There is considerable overlap in the prey bases among blue, finback, beluga and minke whales; however, no information currently exists on the way in which they partition the area.

Three dominant species of euphausiids are present in the study area: *Maganyctiphanes norvegica*, *Thysanoessa raschi* and *T. iermis* (Simard 1986a, 1986b). Using a high frequency echosounder, Simard (1986a) found that euphausiids were primarily aggregated in a patch 1 - 7 km wide along the northern side of the Laurentian Channel. The biomass within the patch was greater than 1 g dry wt/m^2 and concentrations up to 57 individuals/m^3 were observed in net samples (Simard 1986a,b). Euphausiid densities shoreward of the patch and in mid-channel were typically less than 0.25 g dry weight/m^2, but increased along the southern channel edge (Runge and Simard 1990).

Capelin are abundant between late April and early May along the north shore of the estuary (Bailey et al. 1977). Spawning occurs between mid-April and the end of June primarily on beaches along the north shore, but also along the south shore near the mouth of the Saguenay River (Gagné and Sinclair 1990). Capelin gradually drift downstream to the northwestern Gulf from June through the middle of August. There is a year-round concentration of juvenile capelin at the confluence of the Saguenay River and St. Lawrence Estuary which is supported by zooplankton production in the river (Bailey et al. 1977). All of the above cited biotic factors potentially influence the distribution of minke whales within the study area.

2.2 Observation Procedures

Six line transects, each 5 km in length, were defined within the study area to provide a systematic method of data collection (Fig. 2). Line transects were distributed across the study area so that inshore areas with a steep gradient in undersea topography (transects 1,3,5) could be compared to offshore areas with little or no topographic variation (transects 2,4,6) (Fig. 3).

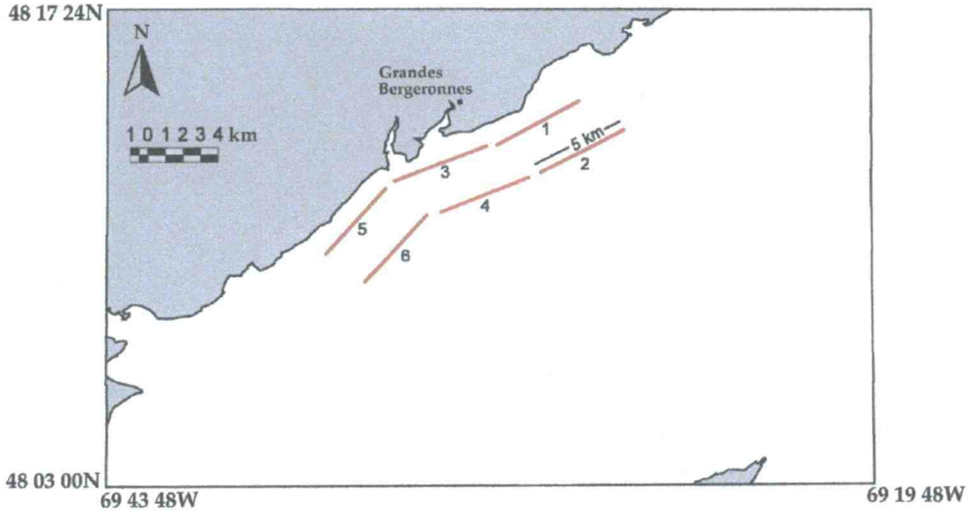

Figure 2. Location of line transects run July - September 1996 in the middle estuary of the St. Lawrence River.

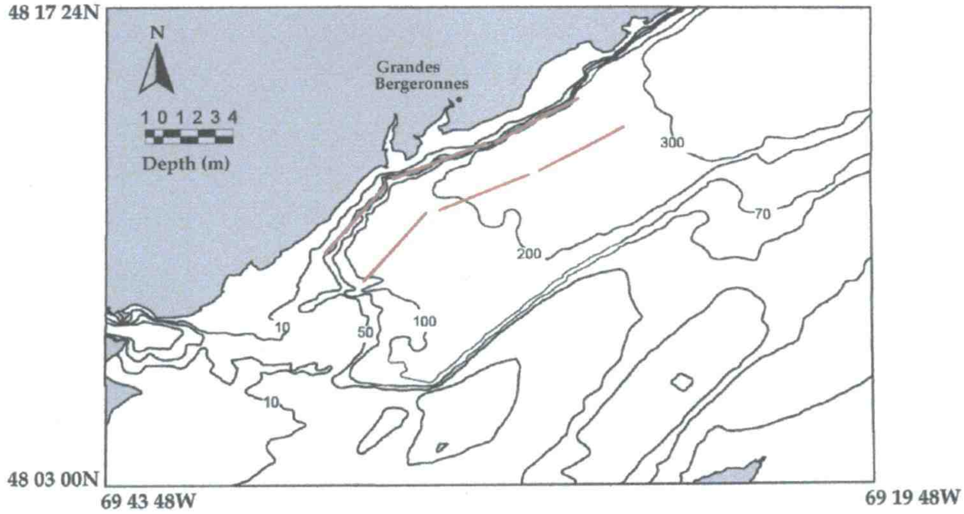

Figure 3. Location of line transects run July - September 1996 in the middle estuary of the St. Lawrence River with respect to seafloor topography. Inshore transects (1,3,5) are located along the ridge of the Laurentian Channel where there is a steep grade in the undersea topography. Offshore transects (2,4,6) are located in the middle of the channel where there is little or no topographic variation.

Weather permitting, one to three transects were run daily throughout the study season. To avoid bias, the transects which were run each day were selected randomly. Transects were run using a 15 ft (4.6 m) inflatable boat at a speed of 5 kn (9.25 km / h). A minimum of four crew members were aboard the boat to ensure a 360-degree visual scan of the area. Transects were only run if the visibility in any one direction was greater than or equal to 1.5 km and waves were less than 1/2 m in height.

When a minke whale was sighted within 1 km of the transect, the boat would leave the transect and move to within 30 m of the whale. When the boat was within close proximity to the whale, a latitude/longitude position of the whale was recorded using a Global Positioning System (GPS) receiver and an identification photograph was taken. Once the identification-photograph was taken, the boat would return to the position at which it left the transect and continue on with the survey.

If additional whales moved into the area during sampling, their presence was recorded. If discrimination among subjects was too difficult, all whales were counted and GPS positions and identification photographs were recorded for as many whales as possible within 1 km of the transect.

In order to maximize the total number of sightings, if there were no whales seen after two transects were run, the boat would search for whales in other regions of the study area. When whales were sighted, identification photographs and GPS positions were recorded. Although these searches were non-random, the entire study area was generally covered every two weeks. Opportunistic data consisting of GPS positions and identification photographs taken during the 1995 preliminary season were also used to examine habitat selection by individual minke whales.

3. ANALYSIS

3.1 Transect Locations

The transect data were used to determine whether there was a relationship between minke whale presence and several explanatory variables. The explanatory variables examined were: distance from shore - a categorical variable defined as either inshore (transects 1, 3, 5) or offshore (transects 2, 4, 6), lunar phase - a categorical variable defined by either the 2-week period around the full moon or the 2-week period around the new moon, time of season - a continuous variable defined by five 2-week time periods from July 8, 1996 through September 19, 1996 and tide phase - a categorical variable defined as either the 4-hour period around the daily high tide or the 4-hour period around the daily low tide.

Each transect run was defined as a sampling unit. Even though each transect was run several times during the course of the study, it was assumed that they were independent because the transects which were run each day were selected randomly. Photographic identification of whales revealed that many individuals were encountered along each transect, as opposed to just a few always being present at a single location. This also suggests that the data are independent. Though a repeated measures analysis was considered, the low number of observations made it impossible to run this type of analysis.

Logistic regression models were used to analyze the data using the PROC GENMOD program in SAS (SAS Institute Inc. 1992). Because there were sometimes no whales seen along a transect, a binary response variable in which whale presence was equal to one and whale absence was equal to zero was used in place of the count data (number of whales along a transect).

Logistic regression models which included each explanatory variable independently and all explanatory variables (distance from shore, lunar phase, time of season and tide phase) were constructed to determine if there was a significant relationship between the explanatory variables and the response variable.

A Wald's test (Ramsey and Schafer 1997) was used to determine whether there was a relationship between whale presence and any of the explanatory variables when the explanatory variables were included in the model independently. A Drop in Deviance F-Test (Ramsey and Schafer 1997) was used to determine which variables were related to whale presence after accounting for the other variables in the model.

3.2 Opportunistic Data

In order to determine whether the minke whales were dispersed randomly within the study area, the study area was divided into a grid of 47 $3km^2$ quadrants. The grid was overlaid with a point plot of all of the whales sighted opportunistically (not on transects) during 1996. The null hypothesis that minke whales were dispersed randomly was tested. The number of sightings per individual quadrant, $F(x)$, was compared with the expected number from the $f(x)$ from the Poisson series using a X^2 goodness-of-fit test (Zar 1984). For this analysis it was assumed that each quadrant received equal effort.

GIS (Geographic Information System) software (PC-Arc/Info and ArcView) was used to visualize the distribution of whales within the study area. A point plot was generated of all of the whales sighted opportunistically during the 1996 season. In order to determine whether there was a relationship between whale presence and sea floor topography, GIS software was used to overlay the plot of opportunistic whale sightings with a map of the bathymetry.

3.3 Individual Data

Identification photographs (Fig. 4) were analyzed to determine individual minke whale identification using distinguishing features such as dorsal fin profile, presence of nicks in the dorsal fin, body scarring and skin pigmentation patterns (Dorsey 1983, Gill and Fairbains 1995). A catalog of identified whales was established containing all the photographs from the identified sighting and any subsequent resightings.

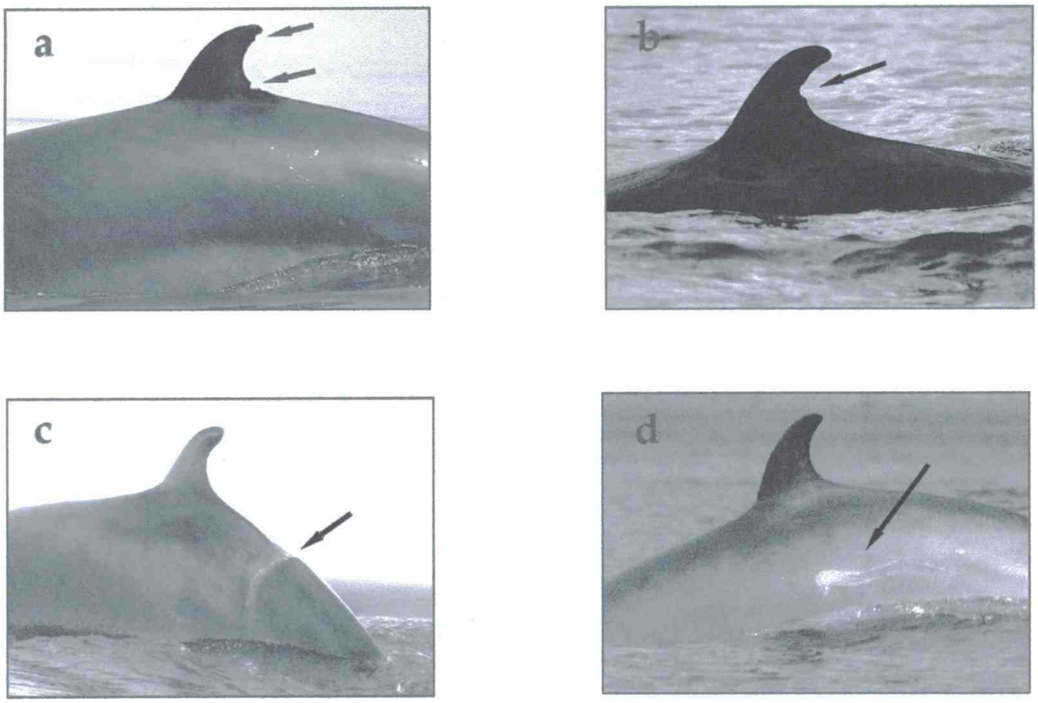

Figure 4. Examples of identifying features of minke whales photographed during 1995 and 1996 in the St. Lawrence Estuary: (a,b) two distinctive dorsal fin profiles, (c) body scar and (d) unique body pigmentation pattern.

GIS software was used to plot individual whale positions on a map of the study area. Plots of individual whales were used to determine whether whales were returning to the study area in successive years, whether they were seasonally resident or transient and to determine the ranges of individual whales in the survey area.

4. RESULTS

4.1 Transect Locations

Due to weather constraints, inshore transects were sampled more frequently than offshore transects. Fifty-two transects were run over the course of the 10 week study period, 32 inshore and 20 offshore. Eighty-nine minke whales were sighted along those transects, 79 on inshore transects and 10 on offshore transects (Fig 5).

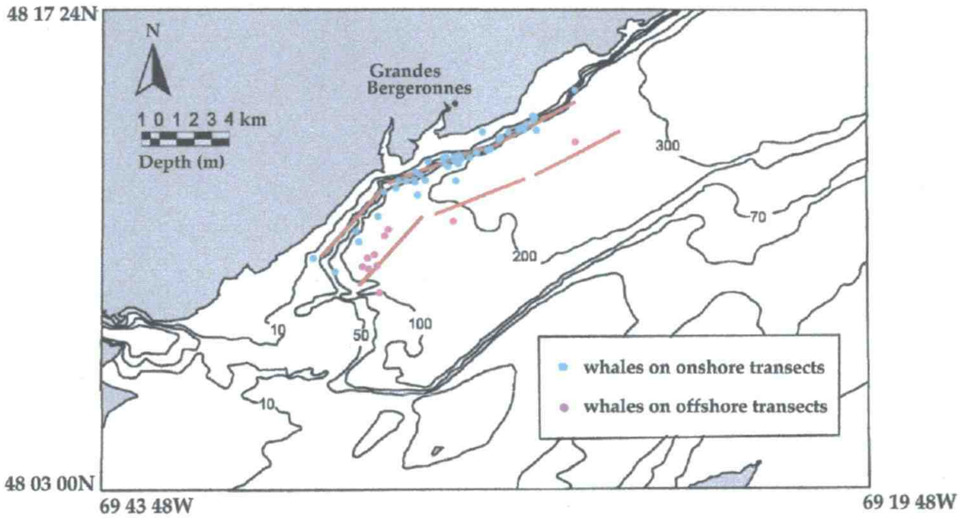

Figure 5. Distribution of minke whales observed on inshore and offshore transects July - September 1996 in the middle estuary of the St. Lawrence River.

There was significant evidence that whale presence was associated with distance from shore (2-sided p-value = 0.0189; Wald's Test). The odds of a whale being inshore were estimated to be 4.164 times the odds of a whale being offshore after accounting for time of season, tide phase and lunar phase

(95% confidence interval = 1.152 to 15.054). The logistic regression model which includes all explanatory variables is logit(π) = -2.605 + 0.801high tide +0.340full moon + 1.427in shore + 0.372week period, where π is equal to the population mean proportion or probability.

There was no evidence that whale presence was associated with tide phase (2 sided p-value = 0.1936; Wald's Test), lunar phase (2-sided p-value = 0.4168; Wald's Test) or time of season (2-sided p-value = 0.1955; Wald's Test) when each explanatory variable was included in the model independently. There was also no evidence that whale presence was associated with tide phase (2-sided p-value > 0.1; Drop in Deviance F-Statistic = 1.3178 with 1 and 47 DF), lunar phase (2-sided p-value > 0.1; Drop in Deviance F-Statistic = 0.2140 with 1 and 47 DF) or time of season (2-sided p-value > 0.1 from a Drop in Deviance F-Statistic = 1.772 with 1 and 47 DF) when all the explanatory variables were accounted for in the model.

4.2 Opportunistic Data

In addition to minke whales sighted along transects, there were 137 opportunistic sightings during the 1996 season. A point plot of all the opportunistic sightings from 1996 shows a U-shaped distribution of points (Fig. 6). When the point plot of sightings was overlaid with a plot of the bathymetry using GIS software, the U-shape in the distribution of points strongly corresponded to the ridge of the Laurentian channel (Fig 7).

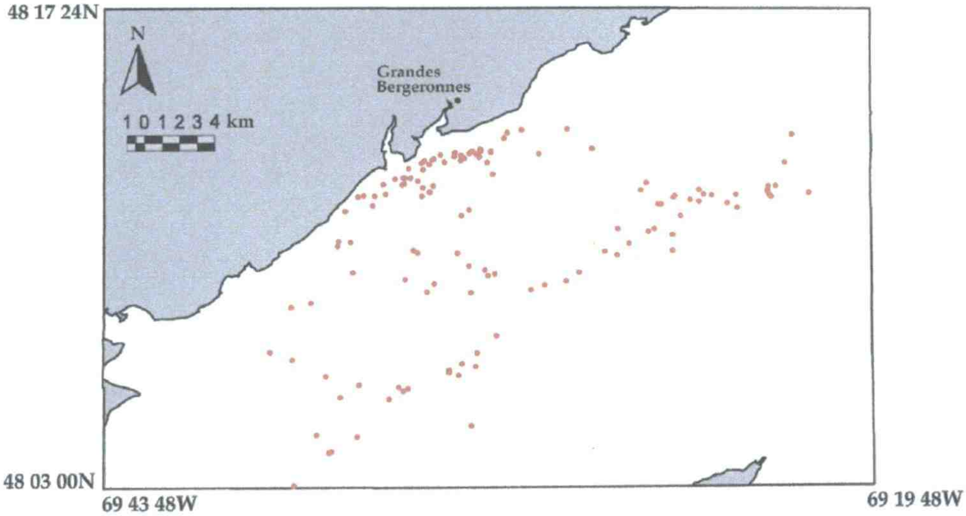

Figure 6. Distribution of minke whales observed opportunistically June - September 1996 in the middle estuary of the St. Lawrence River.

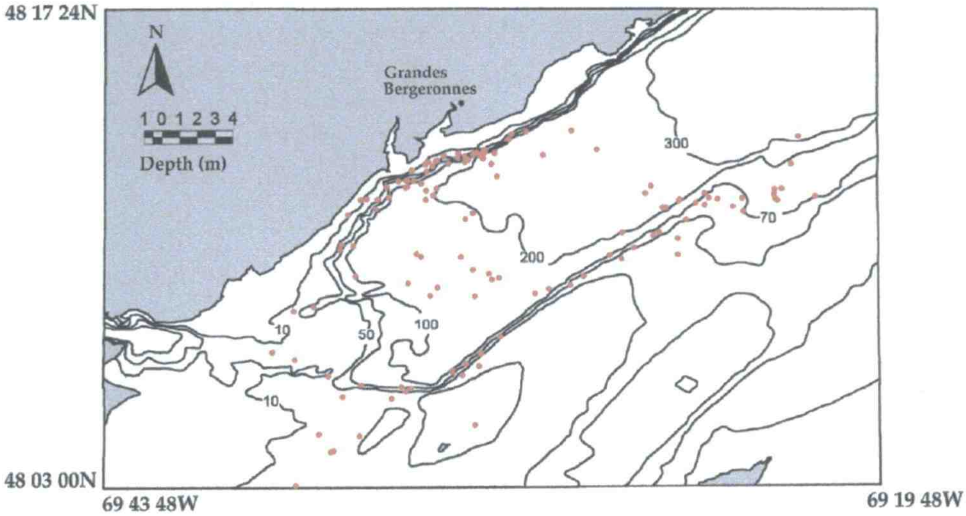

Figure 7. Distribution of minke whales observed opportunistically June - September 1996 in the middle estuary of the St. Lawrence River with respect to sea floor topography, illustrating the relationship between minke whales and areas with a steep grade in the seafloor topography.

The null hypothesis of random dispersion of whale sightings among the quadrants was rejected ($X^2 = 30.30$, df = 4, $p<0.0005$) suggesting that there was a highly significant clustered distribution of whale sightings.

4.3 Individual Data

Twenty-four of the whales photographed during the 1995 and 1996 season were recognizable. Eight of the 24 whales were sighted in both 1995 and 1996, indicating at least some of the whales in this area exhibit temporal site tenacity across successive years. Eighteen of the 24 whales were sighted at least twice within a given season suggesting that many of the whales may be resident seasonally.

There was considerable spatial overlap among individual whales, suggesting that minke whales do not have exclusive ranges in this area. The low number of sightings of individual minke whales made it impossible to determine home range size. Although one whale was sighted on 15 occasions during the two year study period, several whales were only sighted once. The average number of sightings per identified individual whale over the course of the two year study period was 3.75. Although there may be some differences depending on species and habitat; in order to measure a home range accurately, a minimum of twenty capture points is suggested (Mares et al. 1980). Using simulations of space use by animals, Bekoff and Meck (1984) found that an accurate estimate of home range size requires 100 - 200 locations.

Table 1. Whales identified by year, showing the year of sighting and the total number of sightings for each whale.

ID no.	mark	1995	1996	Total
1	anterior and posterior nicks	2	5	7
2	deformed dorsal	2	3	5
3	one nick posterior upper half	1	4	5
4	one nick posterior upper half		4	4
5	ragged edge dorsal	2	4	6
6	one nick posterior upper half		7	7
7	one nick posterior upper half		3	3
8	one nick posterior upper half		1	1
9	two nicks posterior upper half		1	1
10	body wounds visible	4	4	8
11	no body marks visible		2	2
12	body wounds visible	6	9	15
13	deformed dorsal	5		5
14	body pigmentation visible		3	3
15	two nicks posterior lower half	3	1	4
16	one nick anterior upper half		2	2
17	three or more nicks		1	1
18	one nick anterior upper half		2	2
19	body wound visible		2	2
20	one nick posterior upper half		2	2
21	three or more nicks		1	1
22	one nick posterior lower half		2	2
23	one nick posterior lower half		1	1
24	two nick posterior lower half		1	1
Total		25	65	90

5. DISCUSSION

5.1 Environmental Characteristics of Minke Whale Habitat

Minke whale sightings were distributed nonrandomly within the study site, presumably the whales were aggregating in response to a physical or biological characteristic of the environment. Cetacean distributions are usually neither regular nor random and are typically associated with patchy prey distribution (Katona and Whitehead 1988, Woodley and Gaskin 1996). In the western North Atlantic, minke whale distribution has been related to their primary food source, the capelin (Sergeant 1963, Mitchell and Kozicki 1975, Piatt 1989). Within the study area, bottom topography, time of season, tide phase and lunar phase all have an influence on the distribution and availability of prey and probably affected minke whale presence and movements in this region.

5.1.1 Bottom Topography

Both the transect data (Figure 5) and the opportunistic data (Figure 7) indicate that there is a strong relationship between minke whale presence and areas with steep undersea topography. Whales were observed to be primarily utilizing areas with a steep grade in bottom topography along the 50 m - 100 m bathymetric contours. This region corresponds to the ridge of the Laurentian Channel. The high number of minke whale sightings along the channel ridge is likely associated with increased abundance and predictability of prey in this part of the study area. In the Bay of Fundy, Woodley and Gaskin (1996) also found that both Northwest Atlantic right whales

(*Eubalaena glacialis*) and finback whales were associated with unique bottom topography which for both species coincided with high densities of their principal prey species.

In the St. Lawrence estuary, the channel ridge causes an interaction of physical oceanographic forces which results in a highly productive environment. When the incoming tide meets the abrupt shelf break of the Laurentian Channel, nutrient rich waters from the intermediate water layer are upwelled to the surface. Tidal velocities increase as the Laurentian Channel shoals, resulting in dissipative processes such as mixing (Mertz and Gratton 1990). Mixing of the Upper estuarine waters, Saguenay waters, and Gulf of St. Lawrence waters upwelled from the intermediate layer in this region of the study area results in what Steven (1974) refers to as a "nutrient pump".

High nutrient concentrations along the channel ridge support large aggregations of euphausiids and capelin. Although prey abundance was not directly measured in this study, Runge and Simard (1990) found that the highest densities of euphausiids were along the northern edge of the Laurentian Channel and near the mouth of the Saguenay River; densities were lowest in midchannel and increased along the southern channel edge. The krill scattering layer in the St. Lawrence Estuary has been estimated to be about 2 to 3 km in width, elongated along the 100 m bathymetric contour and absent when the bottom depth was less than 50 m (Simard 1986b).

Simard (1986a) proposed that the spatial distribution of euphausiid aggregations in the St. Lawrence Estuary results from the upstream advection of deep water containing euphausiids at the head of the Laurentian Channel. As a result, euphausiids accumulate in dense aggregations at the channel head where they are pushed towards the north and south shores by cross channel currents (Runge and Simard 1990) and are trapped along the steep side slopes of the channel (Lynas pers comm). Simard (1986b) also suggests that the disappearance of the scattering layer when the bottom depth is shallower than 50 m (the upper day depth for the krill scattering layer) may be an indication that euphausiids are accumulating along this barrier.

The distribution of capelin in the St. Lawrence Estuary closely parallels the euphausiid distribution (Bailey et al. 1971). Both juvenile and adult capelin in the St. Lawrence Estuary feed almost exclusively on zooplankton with euphausiids being the most dominant component of their diet in terms of biomass (Vesin et al. 1981). In fact, zooplankton biomass near the mouth of the Saguenay River is stable enough to support a year round population of juvenile capelin (Bailey et al. 1971).

5.1.2 Tidal and Lunar Patterns

Although tidal and lunar changes have been shown to influence habitat use by some baleen whales (Gaskin 1982 (Finback whales), Norris 1983 (Grey whales)), neither had any measurable effect on minke whale presence or movements in the St. Lawrence estuary. Similarly, Edds and Macfarlane (1987) also found that there was no apparent movement pattern of minke whales in the St. Lawrence Estuary with respect to strength or direction of tidal flow.

In the study area, the interaction of the high tide with the shoaling region of the Laurentian Channel causes internal waves (up to 120 m in amplitude) to be propagated seaward from the channel head (Forrester 1974, Ingram 1985). During the full moon and the new moon tidal height and velocity are increased which may exaggerate the effect of the internal wave

(Mertz and Gratton 1990). One result is that nutrient-enriched intermediate-depth waters are pushed to the surface layer with the cresting internal waves (Therriault and Lacroix 1976). Lynas (1997) suggested that krill are either passively transported to the surface by the movement of the internal wave or actively swim to the surface waters in pursuit of prey which are being transported by the motion of the internal wave.

If minke whale movement is closely linked to fluctuations in prey availability, numbers sighted should have increased following the high tide and during the new or full moon when there was an increased amount of prey being brought to the surface waters. However, there was an insignificant change in minke whale presence with respect to the tide phase and lunar phase, probably a result of the high densities of prey within the study area. It is likely that prey are sufficiently abundant and predictable within the study area along the channel ridge that it is not energetically profitable for whales to leave in search of food even if there are slight fluctuations in prey abundance which correspond to the tidal and lunar cycles.

5.1.3 Temporal Patterns

Minke whales typically arrive at a feeding ground in spring, are most abundant during mid- to late summer when feeding conditions are good and begin to migrate to lower latitudes in the autumn for birthing (Sergeant 1963, Mitchell and Kozicki 1975, Kapel 1980). This study was conducted only during the summer months so it is unlikely that there would be variation in the numbers sighted as a result of migration.

There did not appear to be any fluctuation in the relative abundance of minke whales in the study area throughout the summer months (July -

September). There was no significant evidence that time of season was associated with whale presence. Murphy (1995) found a similar consistency of minke whale sightings through the summer months on Massachusetts and Cape Cod Bays; Edds and Macfarlane (1987) found only a slight variation in the monthly relative abundance of minke whales in the St. Lawrence Estuary between July and September.

The individual data shows that the number of "new" whales sighted in the study area was relatively constant during July and August but declined in September (Table 2). The appearance of "new" whales may be an indication that whales are entering and leaving the study area; however, it is likely that the study area is a part of a larger feeding ground which is used by minke whales during the summer months. It is also possible that whales were in the study area but not present in the area of observation. The decline in "new" whales sighted in September may be an indication that it takes time to get all of the observations of whales in the study area because of limitations in area covered and time on the water. Four of the minke whales which were sighted during the 1995 and 1996 seasons were observed during July, August and September suggesting that at least some minke whales remain in the study area throughout the summer months.

Table 2. Number of "new" whales sighted in the middle estuary of the St. Lawrence River from July - September 1995 and 1996.

	1995	1996
July	2	11
August	4	9
September	0	2

Intra-annual variation in minke whale abundance is typically linked to changes in the distribution and abundance of the principal prey species (Murphy 1995, Edds and Macfarlane 1987). The lack of any noticeable changes in minke whale abundance during 1996 in the St. Lawrence Estuary may be the result of stability in the abundance and distribution of prey from July to August. Capelin and euphausiid concentrations near the mouth of the Saguenay River in the St. Lawrence Estuary are typically high and consistent between July and September (Bailey et al. 1977).

5.2 Individual Habitat Utilization

Habitat utilization by individual minke whales was consistent with that observed in the general population within the study area. Individuals were most frequently sighted in areas along the ridge of the Laurentian Channel where prey abundance was probably highest and most predictable. Some individuals exhibited site tenacity in returning to a particular area not only throughout the feeding season, but also in consecutive years. Unfortunately, there were insufficient observations of individual whales to determine whether tide phase or lunar phase had any significant effect on their presence.

Previous studies of individual minke whales (Dorsey 1983, Hoelzel et al. 1989, Gill and Fairbains 1995) show habitat utilization patterns similar to those observed in the St. Lawrence Estuary. Eighty percent of all minke whale feeding observations off the coast of Washington were recorded over submarine slopes of moderate incline at a depth of 20 - 100m. Some minke whales off both Washington (Dorsey 1983) and Scotland (Gill and Fairbains 1995) also exhibited site tenacity in returning to a particular area both within a feeding season and in consecutive years. Hoelzel et al. (1989) reported individual feeding specialization according to geographic location, suggesting that individuals acquire skills for very localized marine conditions. The physical distinction most consistent with the specificity of a foraging strategy to a particular site was bottom topography. It is possible that whales in the St. Lawrence Estuary have a similar foraging strategy specialized for areas with steeply sloping bottom topography.

Habitat utilization by minke whales is unique from that of larger baleen whales, even from those observed on the same feeding grounds. Like minke whales, distribution and movement of larger baleen whales is strongly linked to prey distribution (Katona and Whitehead 1988, Piatt 1989, Piatt and Methven 1992). However, larger baleen whales do not seem to exhibit the site tenacity observed in minke whales. Environmental variables such as tide phase and time of season often result in the movement of larger whales. Edds and Macfarlane (1987) found that the relative abundance of Finback whales in the St. Lawrence Estuary was associated with temporal patterns such that the relative abundance increased from July to September. Gaskin (1982) observed finback whales off the southwest coast of Nova Scotia to disperse during ebb tides and gather along ledges to feed just after the tide turned.

Several explanations exist as to why minke whales may exhibit site tenacity while larger baleen whales do not. Site tenacity in minke whales may result from niche partitioning with the larger species. Four sympatric species observed in the Gulf of California exhibited niche partitioning such that smaller whales fed on higher quality, less concentrated and more spatially and temporally predictable patches of food than larger species (Tershey 1992). In the St. Lawrence Estuary, minke, finback and to a lesser degree blue whales overlap prey bases considerably; foraging on different densities of shared prey may allow these sympatric species to coexist (Steele 1974).

D. Wiley (Darling et al. 1995) believes that minke whales tend to stay in specific areas for a longer period of time than larger baleen whales because it is not energetically profitable for them to leave an area. Minke whales are able to take on fairly elusive prey in small patches because of their maneuverability; whereas larger whales, with less mobility, concentrate on less elusive prey in larger patches and are more exclusive in their diets. In Witless Bay, Newfoundland, Piatt and Methven (1992) found that the prey density threshold for minke whales foraging was significantly lower than those for the larger humpback and finback whales. Similarly, minke whales are not well adapted for long distance travel or for going long periods without feeding (Darling et al. 1995), thus it is more efficient for them to remain in an area if predictability of food in that area is high, than to travel in search of prey. Additionally, minke whales are generalist feeders and are able to shift among alternative food species; stomach contents of minke whales examined at the Newfoundland fishery included capelin, some cod, herring and euphasiids (Mitchell 1974). Even if there are slight fluctuations in prey availability, the fact that minke whales are able to shift among prey species may enable them to remain in an area and avoid searches with uncertain outcomes.

6. CONCLUSIONS

In the St. Lawrence Estuary, minke whale habitat appears to be primarily characterized by a steep slope in the bottom topography which causes predictable accumulations of euphausiids and capelin. Tide phase, lunar phase and time of season, all of which cause slight fluctuations in the prey abundance did not appear to have a significant influence on minke whale presence or movements.

Like minke whales off Washington (Dorsey 1983) and Scotland (Gill and Fairbains 1995), minke whales in the St. Lawrence Estuary exhibited site tenacity in returning to a localized area both within a season and in consecutive years. More extensive research is necessary to determine whether site tenacity in minke whales is a result of interspecific competition with larger baleen whales or just most profitable energetically.

It is possible that the study area may have been too small to observe significant changes in response to the variables examined. Alternative environmental variables (proximity of other whale species, salinity, water temperature, prey species and densities) also might have provided additional information about minke whale habitat use. However, it is likely that the results from this study are valid since previous studies of minke whales show habitat utilization patterns similar to those observed in the St. Lawrence Estuary (Dorsey 1983, Hoelzel et al. 1989, Gill and Fairbains 1995, Murphy 1995).

This study demonstrates the importance of examining prey species and the oceanographic features that influence the densities and distributions of prey in studies of baleen whales. Future research on habitat, feeding distribution and behavior of baleen whales on feeding grounds could profit by focusing more on prey species and the oceanographic conditions that influence the densities and distributions of prey. In order to better understand minke whale habitat use, future research should include direct or indirect measures of prey distributions and densities.

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