Regional distribution and abundance of blue and humpback whales in the Gulf of St. Lawrence

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ABSTRACT

Comtois, S., C. Savenkoff, M.-N. Bourassa, J.-C. Brêthes, and R. Sears. 2010. Regional distribution and abundance of blue and humpback whales in the Gulf of St. Lawrence. Can. Tech. Rep. Fish. Aquat. Sci. 2877: viii+38 pp.

Blue whale sightings have been monitored in the Gulf of St. Lawrence (GSL) by the Mingan Island Cetacean Study (MICS) since 1979. More than 400 individuals with a heterogeneous GSL distribution have been identified to date. This report aims to qualitatively describe the distribution, dispersal, and relative abundance of blue whales on temporal and spatial scales. Information gathered on humpback whales is also described. Results confirm the general nomadic behaviour of blue whales and suggest that the GSL represents only a portion of the broad summer feeding range. Results also indicate that individual behaviours on site fidelity vary considerably: occasional vs. regular visitors and cosmopolitan vs. exclusive animals. In addition, we were able to distinguish between several areas of significant blue whale sightings based on temporal trends in the site's frequentation. While the lower Estuary seems to be the area where blue whales are most often sighted, the Mingan region has seen its blue whale frequentation decrease to such an extent that observations are now rare. Conversely, an increasing number of humpback whales have been observed in the Mingan region each year. Because many questions on their general ecology remain unanswered, the aim of this study was to increase our knowledge on the habitat use and behaviour of these rorquals. Furthermore, since marine mammals have been proposed as ecosystem sentinels, long-term monitoring can detect spatial or temporal trends that could reflect changing processes in the environment.

RÉSUMÉ

Comtois, S., C. Savenkoff, M.-N. Bourassa, J.-C. Brêthes, and R. Sears. 2010. Regional distribution and abundance of blue and humpback whales in the Gulf of St. Lawrence. Can. Tech. Rep. Fish. Aquat. Sci. 2877: viii+38 pp.

La Station de Recherche des Îles Mingan (ou MICS) effectue le monitorage des rorquals bleus fréquentant le golfe du Saint-Laurent (GSL) depuis 1979. Jusqu'à présent, plus de 400 individus ont pu être photo-identifiés dans diverses régions du Golfe. Ce rapport vise à décrire qualitativement la distribution, l'abondance et le comportement des rorquals bleus à une échelle tant spatiale que temporelle. Les informations collectées sur les rorquals à bosse sont également décrites. Les résultats obtenus confirment le caractère généralement nomade du rorqual bleu et laissent présager que le GSL ne constitue qu'un fragment de l'aire d'alimentation estival de l'espèce. Les résultats révèlent également l'existence de divers comportements individuels par rapport à la fidélité au site : visiteurs occasionnels vs. réguliers et individus cosmopolites vs. exclusifs. Aussi, nous avons été capables d'effectuer une distinction entre les diverses zones de concentration des observations en se basant sur les tendances temporelles dans la fréquentation des sites. Alors que l'estuaire maritime semble être la région où les rorquals bleus sont le plus souvent observés, le nombre d'individus fréquentant la Minganie a décliné au cours du temps, au point où les observations sont maintenant un phénomène rare. Parallèlement, un nombre toujours croissant de rorquals à bosse a été observé chaque année dans cette même région. Comme plusieurs questions sur leur écologie générale restent sans réponse, le but de cette étude était d'augmenter l'état des connaissances sur le comportement et l'utilisation de l'habitat par ces rorquals. Les mammifères marins pourraient exercer le rôle de « sentinelle écosystémique ». Dans ce contexte, le monitorage à long terme permettrait de détecter toute tendance spatiale ou temporelle susceptible de refléter un changement dans l'environnement.

PREFACE

This study was carried out as a contribution to the Mingan Island Cetacean Study (MICS) research station. This report is based on one of the most extensive photo-identified blue whale data sets gathered by MICS.

This report is the first chapter of Sophie Comtois' M.Sc. thesis:

Comtois, S. Effets des changements de la structure trophique suivant l'effondrement des stocks de poissons de fond sur l'abondance et la distribution du rorqual bleu, de ses proies et compétiteurs dans le nord du golfe du Saint-Laurent. M.Sc. Thesis, ISMER, Université du Québec à Rimouski, Rimouski, QC, Canada, 143 pp.

INTRODUCTION

Described as nomadic and solitary, the blue whale (*Balaenoptera musculus*) is a cosmopolitan cetacean that typically undertakes long seasonal migrations (Jonsgård, 1966). As with most other baleen whales, this species exhibits a subtropical winter distribution (Sears and Calambokidis, 2002). In spring, they move poleward to reach the rich krill aggregations of the high-latitude seas in order to replenish their energy reserves (Sears and Calambokidis, 2002). In Canada, observations can be made off both the Pacific and Atlantic coasts. Two distinct populations seem to occur in the North Atlantic: one extending from New England and Canadian waters to the Labrador Sea and the other with more sightings west of Iceland (Sears and Calambokidis, 2002). In the Gulf of St. Lawrence, the first blue whales usually reach Cabot Strait by the end of March–beginning of April, when sea ice breaks up (Lien et al., 1987; Sears et al., 1990). Gradually, animals spread toward the northwestern shore of Quebec and the lower Estuary from June to August. By December, most individuals leave to undertake their southward migration, but in years of light ice cover, some whales may remain in the St. Lawrence for much of the winter (Sears and Calambokidis, 2002).

Global blue whale populations were greatly depleted by the time commercial hunting ended in the North Atlantic in 1955 and worldwide in 1966. The initial stock size for the western North Atlantic was roughly estimated at 1500 individuals (Sergeant, 1966), while the post-whaling population numbered in the low hundreds (Mitchell, 1974). With low calving and recruitment rates, this population still shows little sign of recovery. For all eastern Canadian and New England waters, fewer than 20 calves and few juvenile animals have been reported since 1979 (R. Sears, Mingan Island Cetacean Study [MICS], unpub. data). All this leads the Committee on the Status of Endangered Wildlife in Canada (COSEWIC) to designate the blue whale as "endangered" (any species facing imminent extirpation or extinction) in May 2002.

Since 1955, commercial hunting has been banned in Canadian waters and thus is not a threat to rorqual whale species. However, populations are jeopardized in other ways. Because of the small size of the northwest Atlantic blue whale population, even activities affecting only a limited number of individuals could be detrimental to the health of the population. Although further research is needed to better identify and understand the impacts of human activities on this population, some of the contemporary threats include 1) reductions in prey abundance, 2) noise, 3) contaminants, 4) disturbances caused by whale-watching vessels, 5) collisions with vessels, and 6) entanglement in fishing gears (reviewed by Sears and Calambokidis, 2002).

Since 1979, MICS has conducted annual surveys using photography to identify individuals of different whale species (blue, humpback [*Megaptera novaeangliae*], fin [*Balaenoptera physalus*], and minke [*Balaenoptera acutorostrata*] whales) in the Gulf of St. Lawrence. Using this long-term opportunistic sighting database, the present study attempts to spatially and temporally describe the distribution and abundance patterns of blue and humpback whales in different regions of the GSL for the first time. More specifically, the objectives are to characterize 1) the site attendance patterns of whales and 2) the relative importance of these regions to the species over time.

MATERIAL AND METHODS

Study area

The Gulf of St. Lawrence is a stratified semi-enclosed sea connected to the North Atlantic Ocean through Cabot Strait in the southeast and the Strait of Belle Isle in the northeast (Figure 1). The bathymetry of the Gulf is dominated by the Laurentian Channel, which divides the Gulf into two very distinct systems: the deep northern Gulf, characterized by a number of channels with depths greater than 200 m, and the southern Gulf, consisting of a shallow shelf, the Magdalen Shallows, with depths mostly less than 100 m (Koutitonsky and Bugden, 1991). The estuarine circulation, controlled by atmospheric, oceanic, and hydrologic forcings, induces strong heterogeneity in the productivity throughout the GSL (de Lafontaine et al., 1991; Koutitonsky and Bugden, 1991; Savenkoff et al., 2001; Saucier et al., 2003).

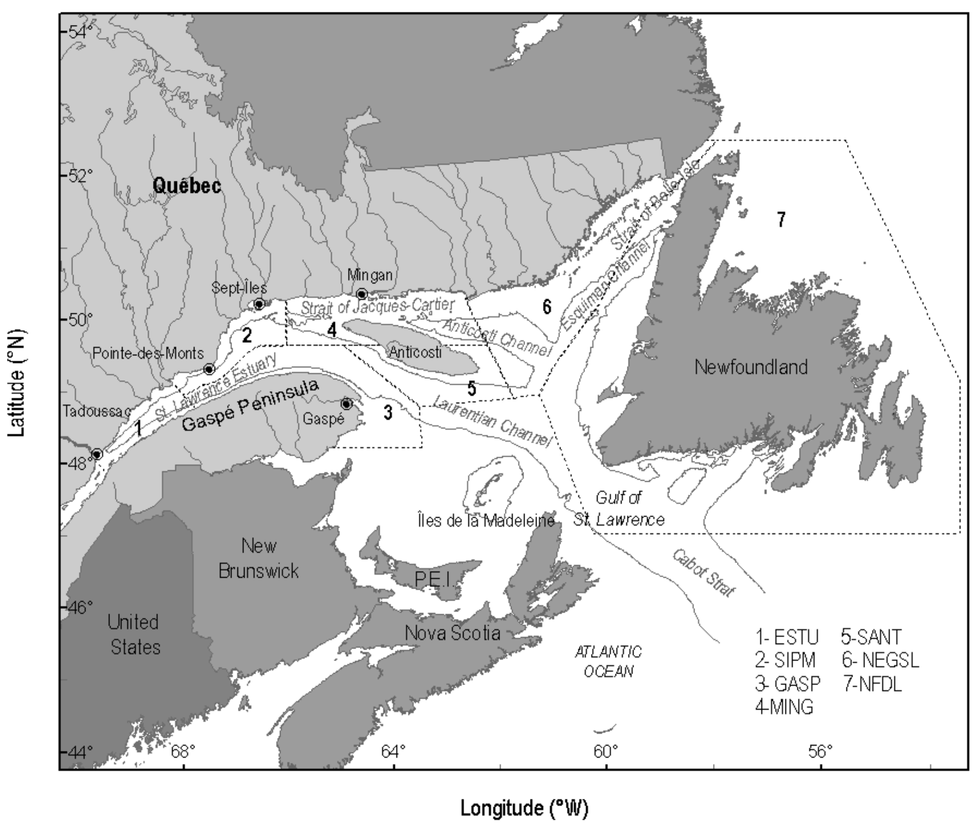

Figure 1. The Gulf of St. Lawrence, divided into seven zones related to rorqual sightings. ESTU: lower Estuary, SIPM: from Sept-Îles to Pointe-des-Monts, GASP: Gaspé Peninsula, MING: Mingan, SANT: southern Anticosti region, NEGSL: northeastern Gulf, and NFDL: Newfoundland.

Sampling protocol

The Mingan Island Cetacean Study (MICS) has collected blue whale sightings for the western North Atlantic since 1979. At the end of the 2008 season, the blue whale photo-identification catalogue included 430 individuals photographed predominantly within the GSL, but also from other areas such as the Scotian Shelf, the Gulf of Maine, and West Greenland. In this study, only individuals observed within the GSL were considered (i.e., 333 individuals).

Since 1987, the MICS sampling protocol and materials have been relatively stable. The sampling strategy is neither random nor systematic. Field work is conducted aboard rigid-hulled inflatable boats and is weather dependent. Sea state (wave height ≤ 2.5 m), wind speed (≤ 20 knots [≤ 5 on the Beaufort scale]), precipitation, and fog (visibility of at least 3 nautical miles) are the limiting factors for a survey to be conducted. The spatial effort is also weather dependent and is mainly constrained by wind direction and strength. Therefore the study area is not homogeneously covered. For each sampling day, research vessels attempt to cover the greatest possible area, passing more time where rorqual species (blue, humpback, or fin whale) are encountered (Doniol-Valcroze, 2001). Each observation is associated with a picture that allows individual identification based on the animal's pigmentation pattern (Katona and Whitehead, 1981; Agler et al., 1990; Sears et al., 1990). The time and date, footprint coordinates (where the animal dove), behaviour, and group composition, if any, complete the recorded information.

Since the whole GSL cannot be thoroughly studied, MICS conducts surveys in known whale aggregation areas. The principal study area, Mingan (hereafter referred as MING; see Figure 1), is along Québec's North Shore near the Mingan Islands; it includes Jacques Cartier Strait out to Anticosti Island and its western shelf waters. It is sampled every year from June to October inclusively, although some data were opportunistically collected during the rest of the year. The lower Estuary (ESTU) and the Gaspé Peninsula (GASP) are only covered during the peak of blue whale abundance, from the end of August to the beginning of September in ESTU and from the end of June to the beginning of July in GASP. It is important to mention that, due to logistic reasons, these areas were not systematically studied every year. Sites of secondary importance were sporadically sampled, when blue whales were known to be there, or opportunistically. These zones include Québec's North Shore, between Sept-Îles and Pointe-des-Monts (SIPM), and the northeast Gulf (NEGSL).

To increase the amount of information in areas where effort is limited, photo-identification data from non-MICS observers (other research stations, enterprises, or private persons) have been included under the category "opportunistic" (OPP). Each sighting typically consisted of the whale's picture with position and date, which enabled MICS staff to confirm the individual's identity. Because these sources did not follow any precise protocol, these sightings lacked information on spatial or temporal effort that made it difficult to standardize effort. For these sources of information, only the number of sighting days is available. The use of these OPP data adds information for two more regions of the GSL, Newfoundland (NFDL) and the southern Anticosti region (SANT), which have been poorly surveyed (Figure 1). For the SANT region, the rare sightings are impossible to identify on an individual basis. This zone has thus been removed from the general analysis. For the Estuary, a third source of information is available. In 2000 and 2001, a special MICS team (designated hereafter by the leader's initials, CLB) was present in this area to study blue whale acoustics using a protocol that diverges slightly from that used during regular MICS surveys. Consequently, the three sighting sources (MICS, OPP, and CLB) for the ESTU region cover June through October inclusively, with varying intensity depending on the amount of opportunistic data available each year and the duration of MICS surveys.

This study includes all observations on blue whales (MICS and non-MICS) for all zones from 1987 through 2007 (and 2008 for MING only). For the Mingan region only, humpback whale sightings were also included in the analyses. Because several data are not yet incorporated to the database, some analyses lack specific years or sighting sources (see in the analysis description and associated figures).

Effort analysis

Because a regular sampling protocol exists for the Mingan study area, an attempt was made to characterize the annual effort (e.g., whether the effort is constant between years) even though both the geographical and seasonal distributions of blue whales are biased due to the non-uniform observer efforts (see previous section). Temporal effort (1987 to 2006) was represented by 1) the total number of sampling days and 2) the total number of daily sighting hours per year (Figures 2A and B). Based on GPS positions, spatial effort (1987 to 2002) was estimated by 1) the tracks covered (in km) and 2) the area covered (in km^2) per year (Figures 2C and D).

All these analyses present different limitations. The temporal daily effort considered each daily survey equally, notwithstanding their duration, the area covered, or the number of boats used. The number of boats is taken into account in all other analyses because the total hours, tracks covered, and area covered for each boat are pooled on a daily basis. This suggests that the spatial and temporal efforts of each boat are completely independent, which is not exactly true since boats travel jointly for a great part of the day. In order to limit this bias, the total area covered per year was calculated. A two nautical-mile buffer was added to each side of the daily tracks. This buffer width is based on a subjective estimate, but it gives a more accurate picture of the spatial effort. Despite all these adjustments, none of the resulting analyses are rigorous enough to standardize the sampling effort because many other biases are simply impossible to normalize. For example, the amount of time spent surveying versus the time allocated for photo-identification or the weather conditions influencing visibility and field work effectiveness could both lead to missed observations. Consequently, the graphs in Figure 2 can only be regarded as best-guess estimates of effort representation.

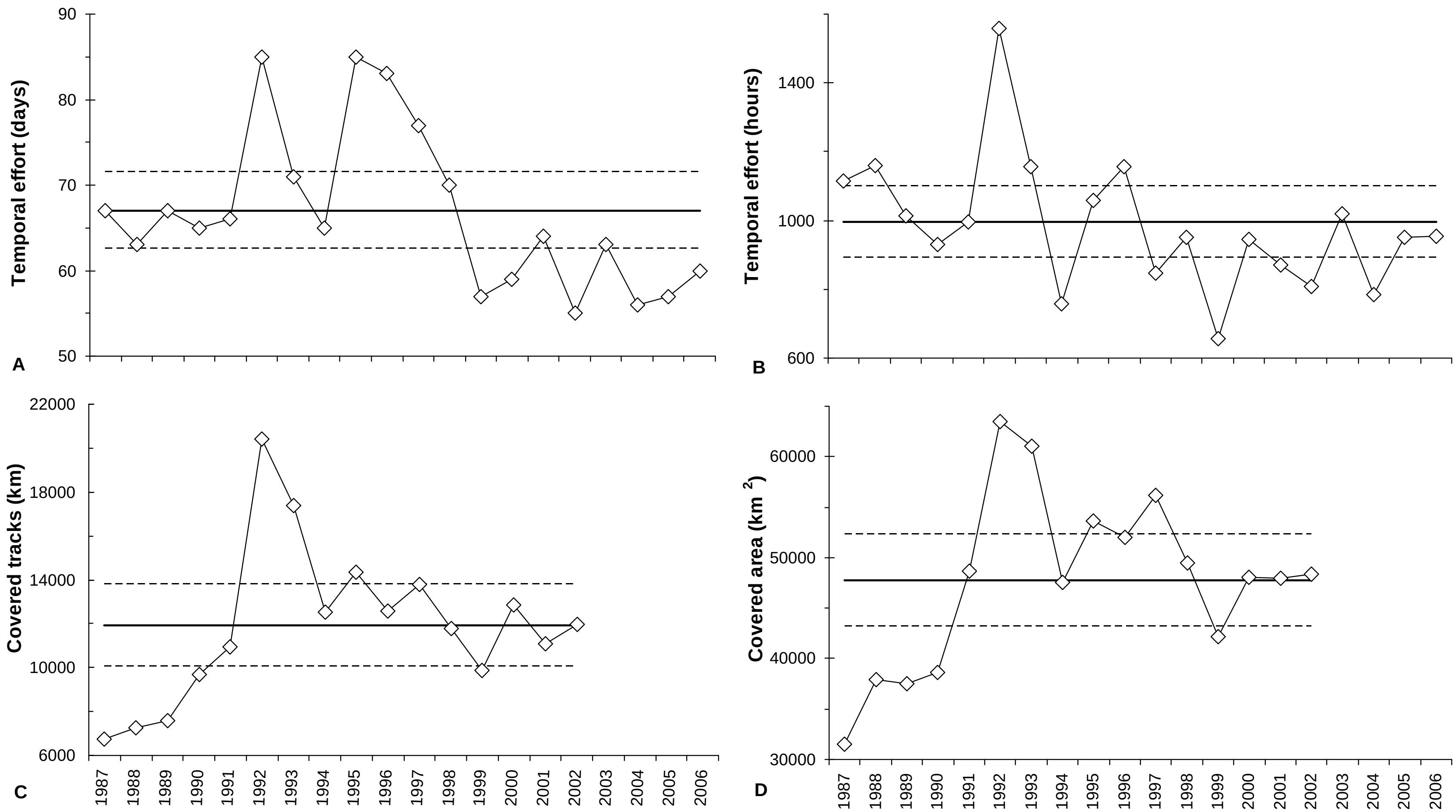

Figure 2. Annual sampling effort calculation for the Mingan area with mean values and 95% confidence intervals. Temporal effort in A) total number of days per year and B) total hours per year for the 1987–2006 period, and spatial effort in C) annual tracks (km) and D) annual covered area (km^2) for the 1987–2002 period.

All sampling effort estimates showed some variations. The total number of sighting days varies between 55 and 85 days (mean: 67 ± 4 days) while the total number of daily sighting hours ranges from about 700 to 1 600 hours (mean: 996 ± 103 hours) (Figures 2A and B). Spatial effort also fluctuates from year to year, ranging between a recorded annual minimum coverage of 7 000 km (mean: 11 928 ± 1 892 km) or 31 500 km^2 (mean: 47 756 ± 4 608 km^2) and a maximum coverage of 20 500 km or 63 550 km^2 (Figures 2C and D). Overall, there is no general trend in sampling effort (spatial or temporal) over time, and few annual fluctuations are observed for the 2000s.

RESULTS

Distribution of blue and humpback whales in the Gulf of St. Lawrence

The general distribution of the blue and humpback whales was based on all observations identified from the entire MICS database, which covers from the end of the 1970s until 2008 (Figures 3 and 4). For each individually identified whale, only the first sighting of the day was used. This ensures that the whale's position was not influenced by the approach of the boat. Because all daily sightings are plotted in these maps, a single whale can be represented by several dots (several observations of the same whale on different days). Furthermore, observations identified to the species only were plotted on the maps (but not used in the analyses) to give a better idea of the extent of these whales' distribution in the GSL (for more detailed maps of the temporal distribution of blue and humpback whales in the two main areas of research – the Estuary and Mingan region – refer to Appendices 1 to 3). Even though the two species can be sighted in most regions, most blue whales are found in the western part of the GSL (ESTU, MING, SIPM and GASP), while humpback whales were observed mainly in the MING and NEGSL areas.

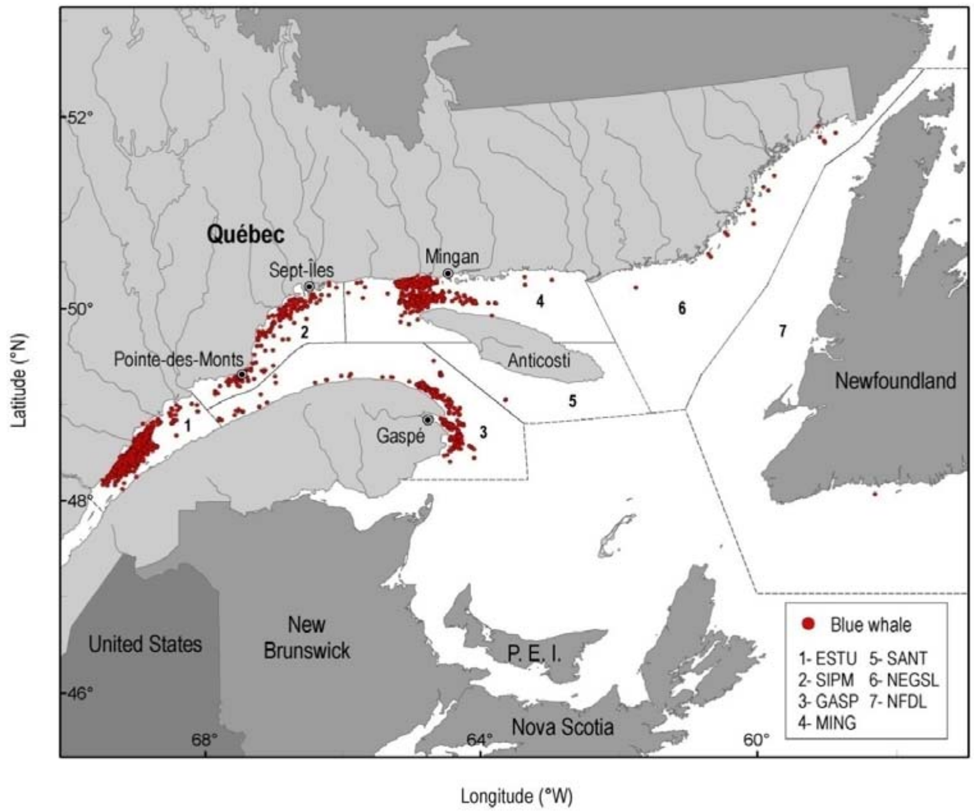

Figure 3. General distribution of blue whales in the Gulf of St. Lawrence (GSL) based on all identified whales from the entire Mingan Island Cetacean Study (MICS) database.

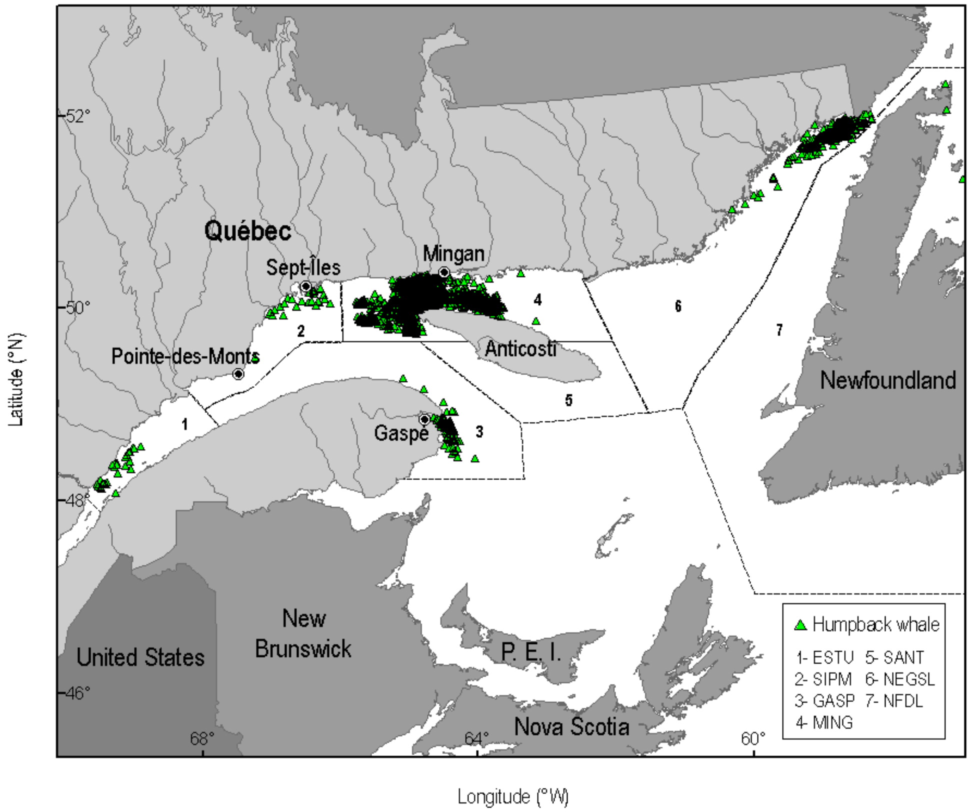

Figure 4. General distribution of humpback whales in the GSL based on all identified whales from the entire MICS database.

Abundance of blue and humpback whales in the Mingan region

Despite some inter-annual variations (1991 and 2001), there has been a sharp drop in the number of blue whale sightings over time in the Mingan area ($r = 0.69$, n = 22, $p < 0.05$). In fact, two time periods were distinguished (Figure 5A). The 1987–1993 period is characterized by high mean blue whale abundances (15 ± 8) while a mean of only three (± 3) whales were observed in the 1994–2008 period. In contrast, there has been a progressive increase in humpback whale abundance since the beginning of the study period (from 10 whales in 1987 to about 100 in 2008; $r = 0.73$, n = 22, $p < 0.05$) (Figure 5B). These trends are not related to bias in the spatio-temporal effort (see effort analysis section).

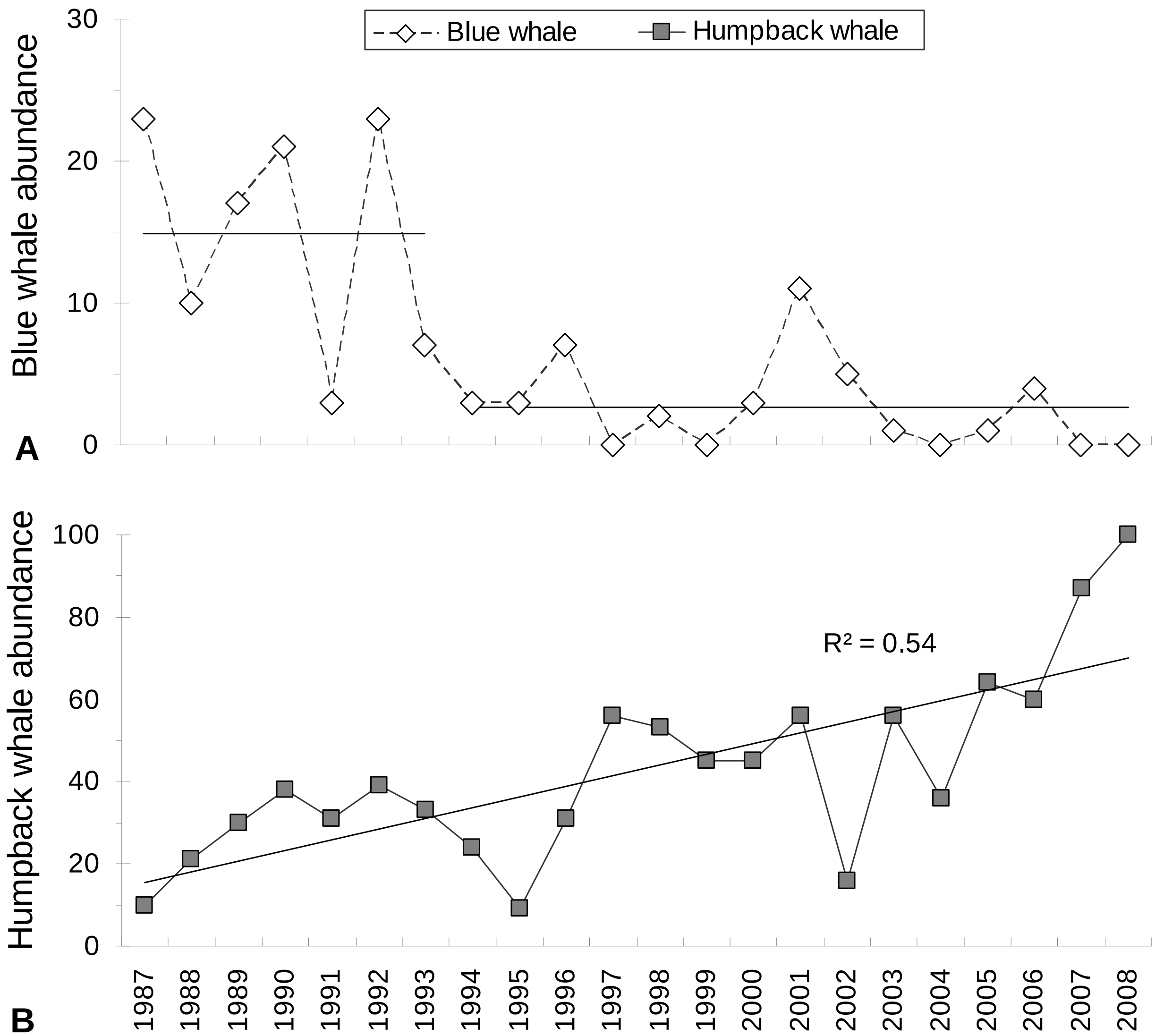

Figure 5. Annual abundance of blue A) and humpback B) whales in the Mingan region for the 1987–2008 period (blue: mean abundance for both periods; humpback: n = 22, r = 0.73, $p < 0.05$).

<u>Abundance of blue whales in the Estuary</u>

The number of sampling days per year (Figure 6) and the number of photo-identified blue whales per year (Figure 7) are represented for each of the three data sources available for the ESTU (MICS, OPP, and CLB). The total number of sampling days from these three sources combined varied greatly, with only four sighting days in 1989 to nearly 46 in 1994 and 2001 (Figure 6). A similar pattern is observed with the overall number of photo-identified individuals, when as few as five individuals were identified in 1989 compared to 72 in 1994 and 73 in 2001 (Figure 7). Hence, these two variables are highly correlated (r = 0.89, n = 21, $p < 0.05$) (Figure

8A). Note that there was no such relationship in the Mingan region ($r = 0.32$, n = 21, $p = 0.16$) (Figure 8B).

Despite a more extensive temporal coverage of the area, the OPP sources led to a lower identification rate compared to MICS. In 2000 for instance, MICS identified 34 different blue whales in 13 days whereas the OPP sources only reported 16 animals for 15 days out. Overall, and because of the highly heterogeneous effort, no general temporal trend of blue whale abundance can be estimated in the Estuary. However, the highest numbers of blue whales individually identified in the Mingan region (23 in 1987 and 1992; Figure 5) during this study period are among the lowest values recorded from the Estuary (Figure 7).

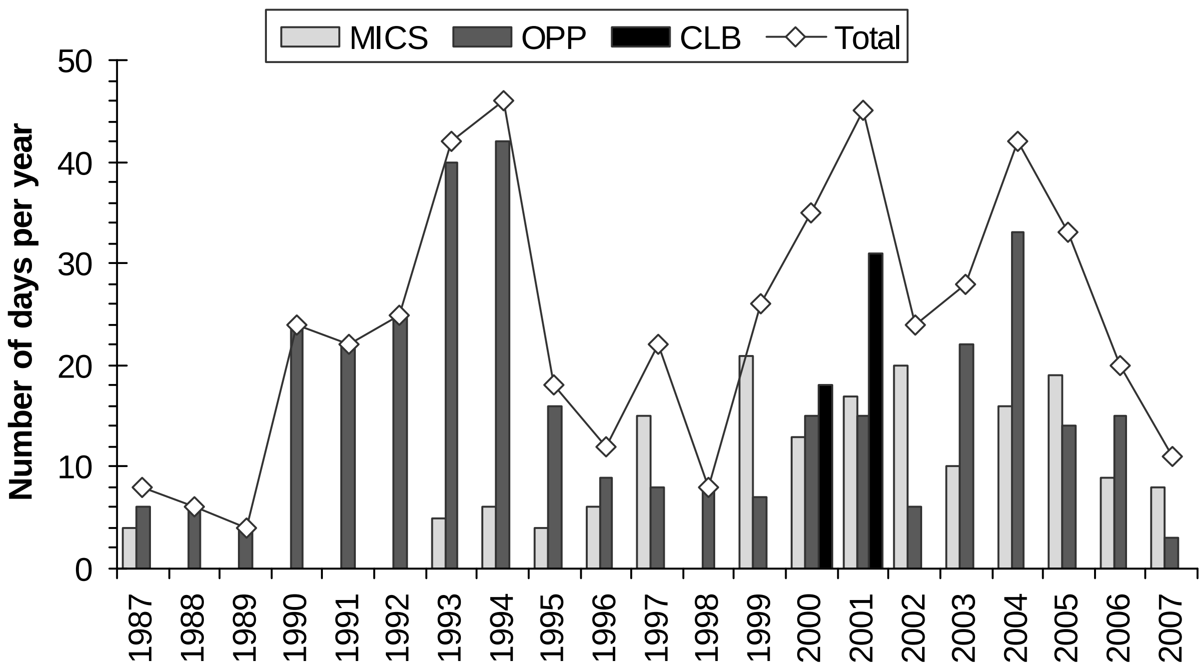

Figure 6. Number of days with sightings per year (opportunistic sources; OPP) or number of sampling days per year (MICS and CLB) in the Estuary for the 1987–2006 period. The 2007 data are only preliminary results.

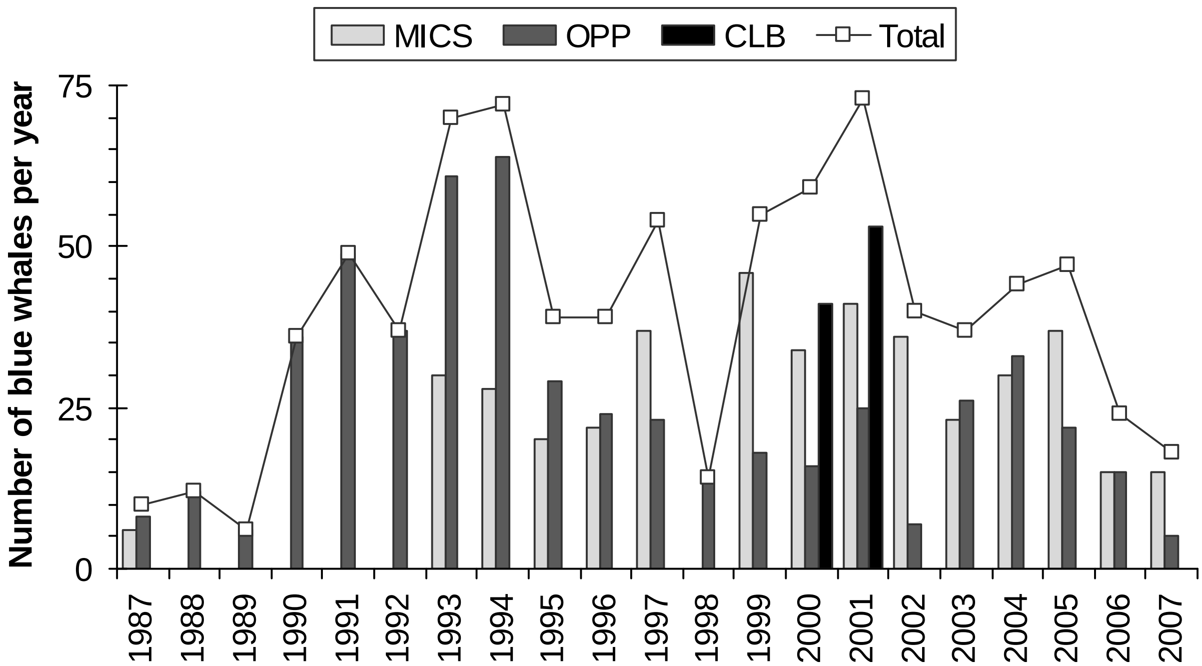

Figure 7. Number of blue whales identified per year by each different source in the Estuary for the 1987–2006 period. The 2007 data are only preliminary results.

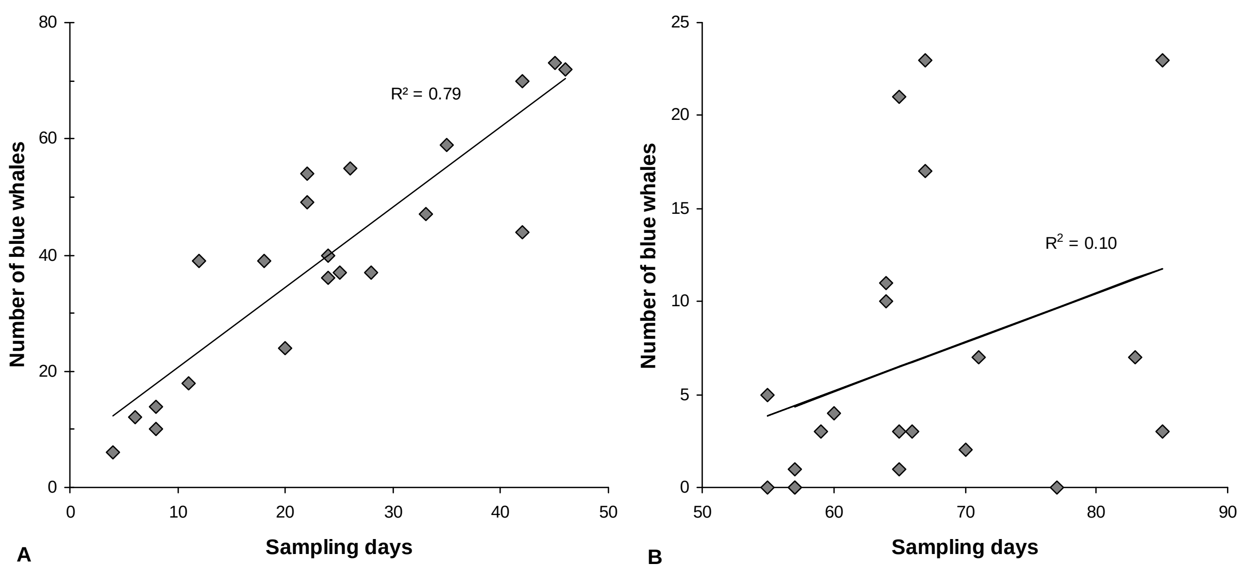

Figure 8. Relationships between the numbers of blue whales identified and the numbers of sampling days in A) the Estuary and B) the Mingan region.

Site attendance patterns of blue whales

From 1987 to 2007, 333 different blue whales were photo-identified throughout the Gulf. Table 1 summarizes the annual sightings of blue whales for all zones. The Estuary is the region where the highest number of blue whales has been observed (845) and individually photo-identified (220) from 1987 to 2007. Despite a smaller sampling effort, more whales were seen in GASP and SIPM (221 and 153 observations respectively) and individually photo-identified (134 and 114 individuals, respectively) compared to MING (144 observations for 94 different individuals). Maybe due to the low sampling coverage, only a few animals (five) were recorded for the NFDL and NEGSL regions. The yearly total of different blue whales identified for the entire GSL varies greatly between years, ranging between 23 and 96 whales. No temporal trend is observed, probably because of irregular spatial and temporal surveys. Note, however, that a high number of blue whales has still been observed throughout the GSL each year in recent years (Table 1).

A high proportion of blue whales that frequented the GSL appears to be non-exclusive to any specific site, meaning that they have been observed in more than one zone (Figure 9). Except for the NEGSL–NFDL area, most individuals were seen in at least two different zones of the GSL. Hence, 70% of the animals observed in MING (66 whales), 64% in ESTU (141 whales), 72% in GASP (97 whales), and 84% in SIPM (96 whales) are non-exclusive animals. Appendix 4 presents a detailed synthesis of the annual distribution of individual blue whales in the GSL. Data are subdivided to focus on the two main regions (MING and ESTU) as well as on the individuals' site attendance patterns. Globally, whales can be divided between individuals that are recurrently observed (more than three years over the study period; "regular visitors") in the GSL (all areas together) and those that are rarely encountered (three years or fewer; "occasional visitors," also referred as transient animals). In addition, some animals seem to prefer one specific area ("exclusive animals") while others explore many sectors ("cosmopolitan animals") of the GSL. The following paragraphs describe in detail the individual site attendance patterns of blue whales.

The first 29 individuals (Appendix 4.1) were occasionally seen over the studied period but exclusively in MING. Eight animals were regularly seen in MING (before 1993), but not exclusively in that area (Appendix 4.2). Appendix 4.3 presents 29 cosmopolitan whales sporadically observed in MING, but also elsewhere in the GSL. According to the information in these three appendices, several individuals visited the Mingan area every year (regular visitors as well as new transient animals), a phenomenon that has decreased since 1992–1993. Although one whale is known to be dead (B001 was found beached on the shore of Anticosti Island during the summer of 1992), most other animals seem to have vanished from the GSL.

Similar patterns are repeated for the individuals observed in the lower Estuary. Of the 79 blue whales observed solely in the Estuary (exclusives), 20 have been observed regularly (Appendix 4.4) and 59 occasionally (Appendix 4.5). In subsequent appendices, we catalogued another 120 individuals observed regularly (Appendix 4.6; 72 animals) or sporadically (Appendix 4.7; 48 animals) in the Estuary, but also in other regions (cosmopolitan individuals). Compared to MING, a bigger proportion of blue whales regularly frequented the Estuary (seen at least four different years). Many individuals observed in the late 1980s – early 1990s were still reported in the 2000s (e.g., B174, B235, and B191; see Appendices 4.4 and 4.6), and new individuals were inventoried each year. In 2001, for instance, around 15 blue whales were seen for the first time in the Estuary (Appendices 4.5 and 4.7).

Finally, 68 whales were reported exclusively in the areas that were surveyed at low coverage (GASP, SIPM, NEGSL, and NFDL) (Appendix 4.8). Hence, 20% of all blue whales identified for the whole GSL from 1987 to 2007 were never observed in the Mingan region or the Estuary.

Overall, no return pattern of blue whales in the GSL could be discerned from these results. Whales don’t seem to come back regularly (no specific temporal cycle).

Table 1. Summary of the distribution of blue whale sightings for the 333 individuals identified in the GSL from 1987 to 2007 (raw data, no standardization). For each area, the total number of observations of individuals (Total) per year are separated into animals seen on previous years (Known) and those observed in the area for the first time (New). Last row: Overall total observations per area. Last columns: Overall total observations per year, all area combined, and the number of distinct photo-identified animals per year in the GSL.

	ESTU			**MING**			**GASP**			**SIPM**			**NEGSL**			**NFDL**			Total annual observations in the GSL	Total annual individuals in the GSL
	New	Known	Total	New	Known	Total	New	Known	Total	New	Known	Total	New	Known	Total	New	Known	Total		
1987	10	0	10	23	0	23	0	0	0	1	0	1	1	0	1	0	0	0	35	33
1988	10	2	12	5	5	10	0	0	0	37	0	37	1	0	1	0	0	0	60	49
1989	5	1	6	8	9	17	1	0	1	5	1	6	0	0	0	0	0	0	30	29
1990	30	6	36	10	11	21	0	0	0	12	1	13	0	0	0	0	0	0	70	60
1991	32	16	48	2	1	3	1	0	1	6	2	8	0	0	0	0	0	0	60	58
1992	8	30	38	17	6	23	7	0	7	0	0	0	0	0	0	2	0	2	70	65
1993	17	54	71	5	2	7	21	0	21	0	0	0	0	0	0	0	0	0	99	94
1994	20	52	72	2	1	3	2	3	5	16	5	21	0	0	0	0	0	0	101	96
1995	9	32	41	1	2	3	4	1	5	0	0	0	0	0	0	0	0	0	49	48
1996	10	28	38	5	2	7	2	4	6	7	6	13	0	0	0	0	0	0	64	60
1997	8	48	56	0	0	0	10	6	16	3	5	9	0	0	0	0	0	0	81	73
1998	3	12	15	0	2	2	1	2	3	1	2	3	0	0	0	0	0	0	23	23
1999	8	47	55	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	55	55
2000	9	50	59	2	1	3	16	6	22	5	8	13	0	0	0	1	0	1	98	85
2001	16	58	74	10	1	11	1	0	1	2	1	3	0	0	0	0	0	0	89	87
2002	1	42	43	0	5	5	2	2	4	4	3	7	0	0	0	0	0	0	59	56
2003	3	33	36	0	1	1	6	2	8	3	1	4	0	0	0	0	0	0	49	43
2004	3	42	45	0	0	0	5	5	10	0	0	0	0	0	0	0	0	0	55	50
2005	4	42	46	1	0	1	15	8	23	0	0	0	0	0	0	0	0	0	70	64
2006	3	23	26	3	1	4	29	29	58	8	4	12	0	0	0	0	0	0	100	88
2007	0	18	18	0	0	0	12	18	30	2	1	3	0	0	0	0	0	0	51	46
Total observations per area			845			144			221			153			2			3	1368	n

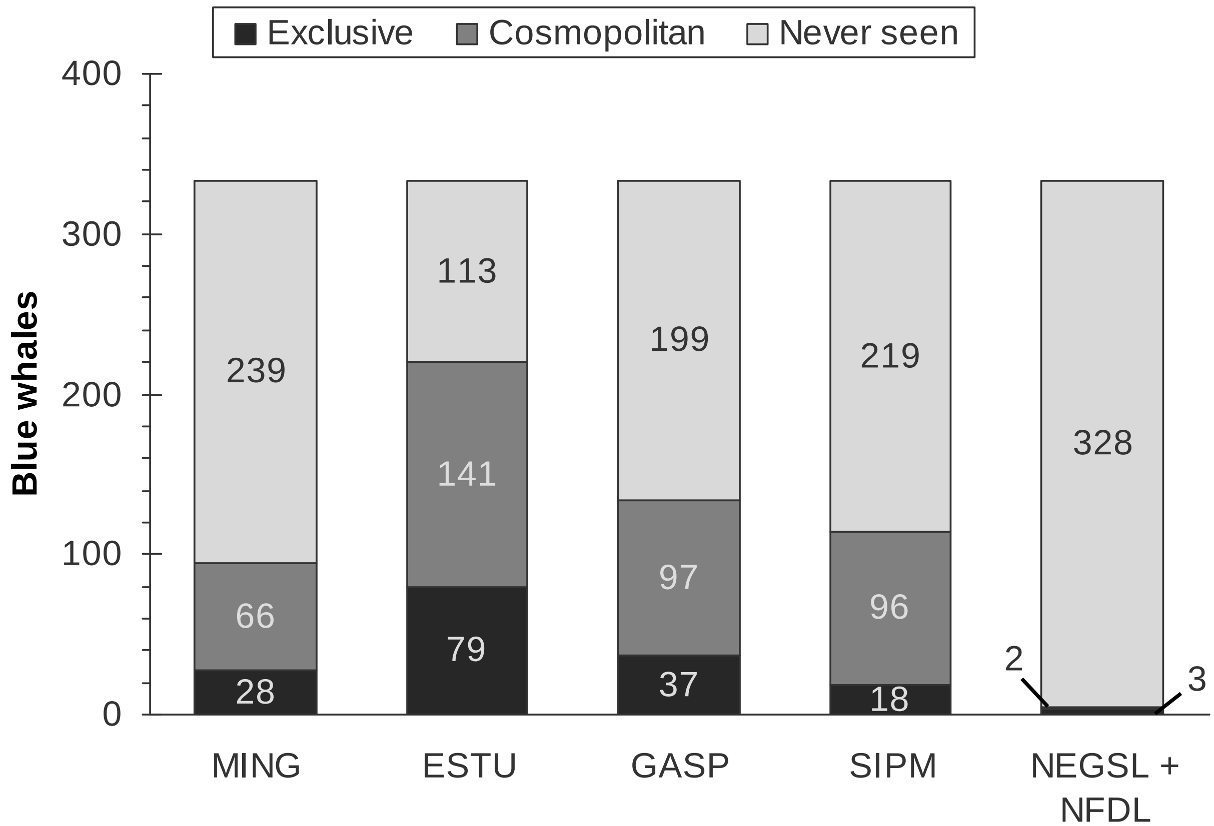

Figure 9. Distribution of the 333 blue whales photo-identified in the five zones for the 1987–2007 period. MING: Mingan, ESTU: lower Estuary, GASP: Gaspé Peninsula, SIPM: from Sept-Îles to Pointe-des-Monts, NEGSL+NFDL: northeastern Gulf and Newfoundland. "Never seen": blue whales never observed in the indicated area but seen in the other zones of the GSL.

Site frequentation patterns of blue whales

Individual whales visit the GSL on a more or less regular basis, depending on the species and the area. In this section, details on their presence at the main studied sites, Mingan and Estuary, are presented. For Mingan, the whole time period is used (i.e., 1987 to 2008). Because MICS did not conduct regular field surveys in the Estuary before 1993 nor in 1998, and since 2007 data are not yet available, these years were not included in the present analysis, which focuses on the 1993–2006 period (1998 excluded).

The total frequentation (number of years an animal visited the GSL over the studied period) and mean occurrence (number of days an animal was seen in a specific year) of blue whales in Mingan (Figures 10A and B) or in the Estuary (Figures 11A and B) were compared. The total frequentation consists of the percentage of whales seen a definite number of years over the whole study period (e.g., 74% of the blue whales observed in MING were seen a single year). For specific individuals, each sighting year was given equal weight, notwithstanding the individuals' site attendance patterns (regular or occasional visitor). Hence, the whale coded B200 was observed for at least three different years in MING (1987, 1989, and 1993) (see Appendix 4.2). This individual is included in the 3% of whales observed over three years in this area (Figure 10A). Some animals were seen in both sectors and were thus included in both total frequentation calculations. As an example, B019 was identified four different years in MING (1987 to 1990) and three in the Estuary (1993, 1994, and 2000) (Appendix 4.2). Hence this whale is one of the 4% that visited MING for four years (Figure 10A) and is also part of the 11% observed over three different years in the ESTU (Figure 11A).

To determine the mean occurrence (following the definition by Clapham et al. 1993), individuals were classified each year according to their specific number of sighting days, which was then divided by the total number of whales identified that year. For example, in 2000, 59 blue whales were observed in the Estuary. Out of this number, 18 individuals were seen one day, 13 on two different days (not always consecutive days), and 28 on at least three different days. Then, from all identified whales of the Estuary in 2000, 31% were seen one day and 22% two days. Finally, the resulting percentages were averaged for the entire study period. Note that these estimates are only the number of survey days when each whale was identified (no real duration of visit).

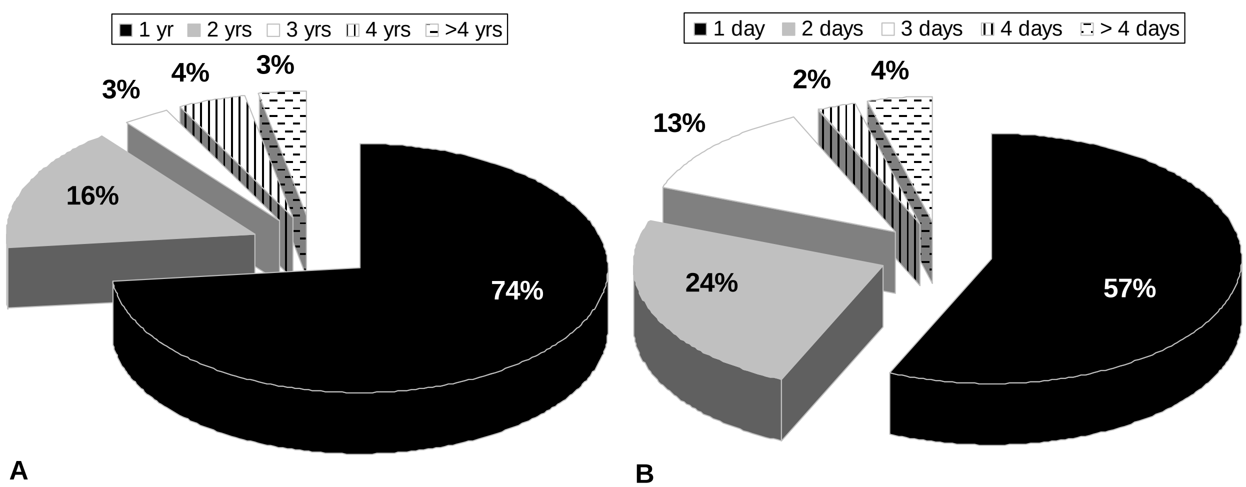

Figure 10. Blue whale A) total frequentation and B) mean occurence in the Mingan region for the whole 1987–2008 period.

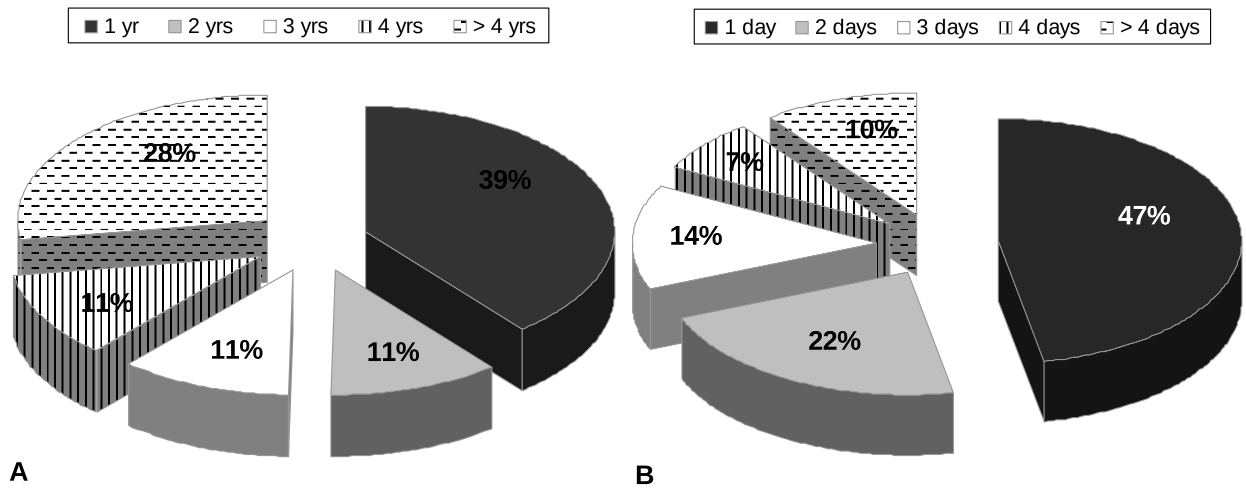

Figure 11. Blue whale A) total frequentation and B) mean occurrence in the Estuary for the 1993–2006 period (1998 not included).

Most blue whales don't seem to be regular visitors of the Mingan region (74% were only observed one year; Figure 10A) and are rarely observed for more than a few days (57% for only one day; Figure 10B). However, there was a change in these patterns over time. During a period of higher frequentation (1987–1990), animals showed a prolonged mean occurrence in Mingan (40% of individuals were observed three different days or more), while during a period of low frequentation (2000–2003), this number dropped to 19% (Figure 12A and B). The picture is slightly different in the Estuary, where the percentage of animals observed one year is lower (39% only, Figure 11A) compared to Mingan (74%; Figure 10A). Nevertheless, blue whales do not stay much longer there (47% of the individuals are observed only one day compared to 57% in MING) (Figure 11B). Their total frequentation was enhanced, however, because 61% were seen at least two years in the Estuary compared with 26% of the whales in MING. Although comparison between these sites might be biased by the different time series used and the heterogeneous sampling efforts, blue whale frequentation at those two sites seems to be different.

Site frequentation patterns of humpback whales in MING were also estimated (Figure 13). A large number of humpback whales (56%) was also seen a single year. This species generally stays longer when present in the area (31% were observed for one day only; Figure 13B).

Globally, blue whales have a lower mean occurrence compared to humpback whales. On the other hand, blue whales seem to have a higher total frequentation in the Estuary (61% observed at least two years) compared to both these species in the Mingan area (26% and 44% for blue and humpback whales, respectively).

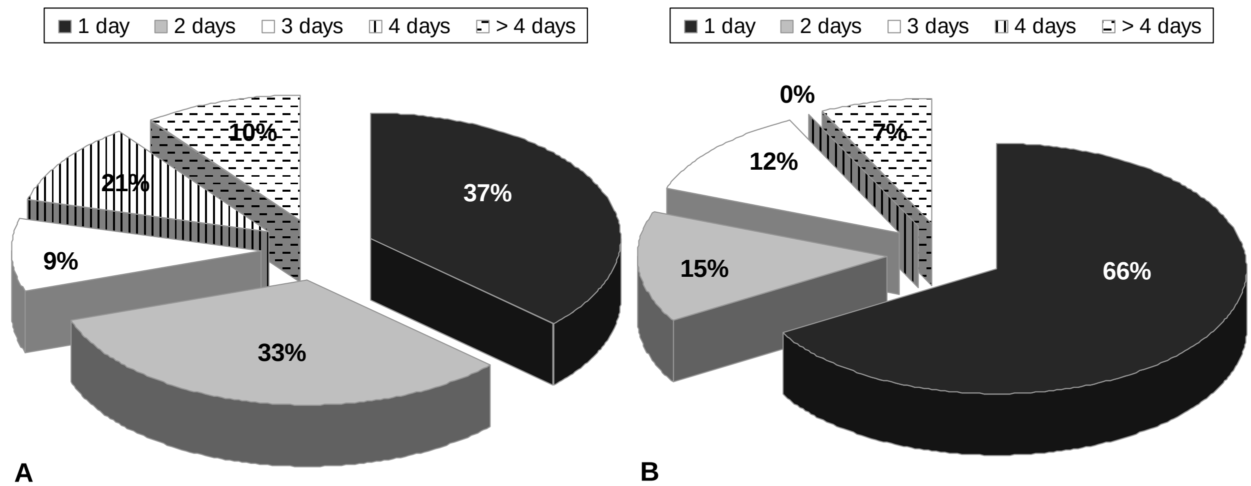

Figure 12. Mean occurence of blue whales observed in the Mingan region during a period of A) high frequentation (1987–1990) and B) low frequentation (2000–2003).

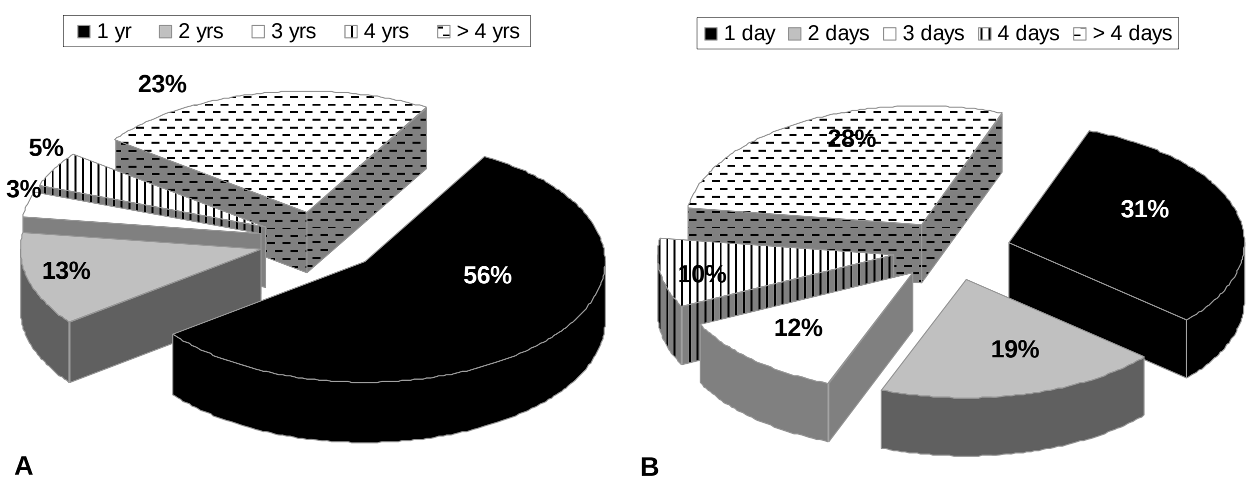

Figure 13. Humpback whale A) total frequentation and B) mean occurrence in the Mingan region for the 1987–2006 period.

DISCUSSION

This work is based on the longest photo-identified blue whale data sets collected by the Mingan Island Cetacean Study (MICS). Although it is not perfect and does present some limitations, it contains valuable information on a poorly known endangered species. This work aims to qualitatively describe this database and highlight any trends on the abundance and distribution of blue and humpback whales in the Gulf of St. Lawrence during the 1987–2008 time period.

The MICS protocol strategy is to identify a maximum number of blue whale individuals rather than to do a stratified random sampling. However, only Mingan was systematically sampled from spring to fall on an annual basis since the beginning of this study period. All other zones were covered opportunistically or during periods of blue whale peak abundance (see material and methods section). Thus, the absence of blue whales from a region might be the result of a lack of observers; this is one of the major limitations of this database and the associated analyses.

Variation of abundance and distribution over time

The Gulf of St. Lawrence is a known summer feeding ground for blue whales and other rorqual whale species (Sears et al., 1981, 1990; Kingsley and Reeves, 1998; Sears and Calambokidis, 2002). Based on three aerial surveys (1995 and 1996 [published previously by Kingsley and Reeves, 1998] and 2002), two satellite-telemetry studies, and information from the literature, Lesage et al. (2007) reviewed areas of concentration of marine mammals in the Estuary and the Gulf of St. Lawrence. These authors estimated that blue whales are likely to occur at least seasonally 1) in the Strait of Belle Isle/Mecatina plateau, 2) from Pointe-des-Monts to Sept-Îles, 3) west of Anticosti, 4) at the entrance of St. Georges Bay Newfoundland, 5) offshore of Gaspé, and 6) on the western shelf of Newfoundland including the head of the Esquiman Channel. However, areas known to be used regularly by blue whales were not surveyed (St. Lawrence Estuary) or were surveyed at a low coverage. Since 1979, the MICS research station has catalogued more than 430 different individual blue whales for the western North Atlantic, with the large majority of the identifications (400 out of 430) made inside the Gulf of St. Lawrence. The present work shows that sightings were mainly reported from the western part of the GSL (ESTU, SIPM, MING, and GASP), in agreement with Lesage et al. (2007). Many individual blue whales were still observed in recent years (Table 1), and the GSL remains an area of significant blue whale sightings. During the same time period (from 1979 until 2008), 741 humpback whales were observed primarily in the eastern GSL (MING, GASP, and NEGSL) (208 individuals in MING only from 1987 to 2006). Humpback whales usually arrive in the GSL near the Gaspé Peninsula by June and move toward Jacques Cartier Strait and along the Québec's North Shore later in summer (Ramp, 2008). Other individuals probably pass through the Strait of Belle Isle to reach the NEGSL. Only rare observations come from the Estuary. This is consistent with previous studies that depict the Estuary as being of minor importance for this species (Edds and Macfarlane, 1987; Ramp, 2008).

Changes in whale abundance have been observed over time in the Mingan area, where an obvious collapse in blue whale frequentation occurred by 1993. Fluctuation in the abundance and distribution of marine mammals on an annual time scale is expected and usually matches patterns of food availability, which are directly affected by oceanographic conditions (Forney and Barlow, 1998; Benson et al., 2002; Friedlaender et al., 2006). Could the Mingan pattern result from a reduction in krill density? Blue whales have a high-energy feeding behaviour and high metabolic demands. Like other rorquals, they exhibit a threshold foraging behaviour, meaning that below a certain prey density, foraging becomes unprofitable and whale aggregations do not occur (Piatt and Methven, 1992; Acevedo-Gutiérrez et al., 2002; Friedlaender et al., 2006). Blue whales must then seek out areas of dense prey aggregations. Several long-term studies conducted in the GSL have suggested a general decrease in euphausiid biomass (Hanson and Chouinard, 2002; Harvey and Devine, 2008). In the southern Gulf, Hanson and Chouinard (2002) suggested that this decline might be related to unusually cold bottom water temperature (Gilbert and Pettigrew, 1997), a situation also reported from the Barents Sea (Seigel, 2000). If this decline in krill abundance results in prey densities below the optimal foraging level, it could account for the departure of blue whales from the Mingan region. A similar phenomenon occurred off western North America, where a dramatic drop in the overall zooplankton abundance since the 1970s resulted in a 90% decline in sooty shearwater abundance, a euphausiid-feeding seabird (Veit et al., 1997).

Recently, Moore (2008) proposed marine mammals as prime sentinels of marine ecosystem changes because they integrate and reflect ecological variations across large spatial and long temporal scales. Strong changes were observed in the trophic structure of the northern Gulf of St. Lawrence ecosystem following the groundfish stock collapse (Savenkoff et al., 2007). This could also explain the observed variations in whale distribution and abundance from MING. The community structure shifted from one previously dominated by demersal (cod, redfish) and small-bodied forage (capelin, herring, mackerel, shrimp) species in the 1980s to one dominated by small-bodied forage species in the early 2000s (Savenkoff et al., 2007), all of which feed largely on krill (Vesin et al., 1981; Darbyson et al., 2003; Savenkoff et al., 2009). The possible increase in fish – blue whale competition for the same food source might result in the whale's departure from the area (Comtois et al., 2008). This hypothesis is further supported by the concomitant increasing number of humpback whales visiting the same region: the humpback whale is a more generalist species that feeds both on zooplankton and small schooling species of fish (Mitchell, 1975; Borobia et al., 1995; Pauly et al., 1998).

Site attendance patterns of whales

Blue whales are highly dispersed nomadic animals that rarely spend much time in any specific area even during the feeding season. Mate et al. (1999) studied blue whale movements in southern California during the summer feeding season and fall migration using satellite tracking tags. On the feeding ground, tagged whales showed a mean occupancy time of 4.2 days (± 2.9 days), during which they travelled distances from a few hundred kilometres to more than 2 000 km. Previous studies within the GSL also suggested nomadic behaviour, supported by generally low local resident time and re-sighting rates (Sears et al., 1990; Ramp et al., 2006). Results from the present study are consistent with these findings, with low mean occurrence and total frequentation recorded for the animals seen in Mingan or in the Estuary. In addition, most individuals seen in the GSL moved between many different areas during a single year or over the study period (cosmopolitan animals). Acevedo-Guiérrez et al. (2002) estimated that foraging dives are about two times more energetically expensive than non-foraging ones. Since blue whales in the St. Lawrence Estuary can feed for extensive periods of time with few interruptions (up to 22 hours per day; V. Lesage, DFO, Maurice-Lamontagne Institute, unpub. data), it is possible that travelling between food patches or between different feeding areas also serves as recovery time.

The GSL is probably only a small portion of a much larger summer feeding ground that might encompass the whole northwest Atlantic. This is suggested by the low total frequentation of most whales over the study period, the high number of animals rarely observed (transient individuals), and the absence of systematic returns for the great majority of the observed individuals. Hammond et al. (1990) stated that blue whales frequenting the GSL could be a variable component of a larger population, an assumption further supported by Ramp (2001).

Although blue whales are globally nomadic animals, some individuals show different site attendance patterns and can be distinguished: whales seen only in a single area (exclusive) vs. cosmopolitan individuals, and whales regularly observed in the GSL vs. occasional visitors (also referred as transients). Even though about 50% of the encountered blue whales proved to be non-exclusive to a specific site and travel between the sampled zones, still about 10% (33) of the identified whales seem to prefer a single area, since they have been regularly observed (on three different years or more) in one precise sector (the other 40% are exclusives, but also transient animals). These results could be misestimated because of the incomplete monitoring of the GSL. However, many of the cosmopolitan animals also show a clear preference for one particular zone. As an example, a lot of non-exclusive individuals frequented the Estuary for eight years or more while rarely seen in other areas. In addition, several individuals were sighted regularly (between three and four years) in the Mingan area during the late 1980s and early 1990s. According to these observations, some individuals (cosmopolitans and exclusives) do show site fidelity characteristics. Furthermore, half of the catalogued whales were regularly observed in the GSL whereas the other half were seldom identified (one third [110 animals] were seen one year only). Again, the high percentage of animals rarely observed could result from the incomplete coverage of the GSL. It would be very surprising, however, to have missed many individuals in all monitored zones for 20 consecutive years.

Interspecific and interregional differences

Blue whale sightings are clearly more abundant and more regular in the Estuary than in Mingan as evidenced by the higher abundances and longer frequentation patterns in the Estuary. Of the 333 individually identified whales, 220 visited the Estuary during the study period compared to only 94 in MING. From 1987 to 2007, an average of 40 individuals were identified per year in this area (all three sources combined), with a maximum of 73 identifications in 2001. Moreover, the strong relationship between the number of survey days and the total number of individual identifications found in the Estuary (Figure 8A) implies that the abundance of blue whales might be underestimated. By comparison, the maximum in Mingan was 23 blue whales identified in both 1987 and 1992, while the mean sighting was seven individuals per year for the 1987–2008 period. From these results, blue whales appear to make a more extensive use of the lower Estuary area. However, there was a decrease in the mean occurrence between periods of higher (before 1993) and lower (after 1993) blue whale frequentation in Mingan. Hence, when present in the area, blue whales were observed for a longer period of time before 1993. Furthermore, blue whale abundance in the 1980s was at least as high but most likely higher than what was documented for the end of the 1980 – beginning of the 1990s in this study (R. Sears, MICS, unpub. data). The Mingan area could have been a much more significant zone for the species than what our analyses of the data time series of this study reveals.

Blue whale distribution patterns have been strongly correlated with the location of dense euphausiid patches, particularly adult stages (Reilly and Thayer, 1990; Croll et al., 1998; Fiedler et al., 1998; Croll et al., 2005). The lower Estuary was suggested as being one of the richest persistent krill aggregation site documented in the GSL (Simard and Lavoie, 1999; Sourisseau et al., 2006). A combination of local currents, topography, and the negative phototactism behaviour of euphausiids leads to the advection, concentration, and retention of adult krill species in the lower Estuary, a process known as the "estuarine pumping system" (Lavoie et al., 2000; Cotté and Simard, 2005; Sourisseau et al., 2006). This could explain the strong presence of blue whales in the area (higher annual abundance and longer site frequentation patterns). Because blue whales are designated as endangered on the COSEWIC species' list and on the International Union for Conservation of Nature (IUCN) Red List of Threatened Species, data on blue whale abundance in the Estuary should continue to be collected and should be extended to the complete feeding season. If the krill pump remains vital and keeps attracting blue whales to this area, any downward trend in the abundance of blue whales could be an indication of some significant environmental or biological changes occurring in the system.

Although a small spatial scale study is not the most effective manner to determine population trends, it clearly presents some advantages. One can evaluate the importance of different areas for species. For example, probably because the "krill pump" in the Estuary helps to maintain regular and more abundant prey patches, blue whale sightings in this region are much higher compared to the MING region. Furthermore, the small spatial scale study enables us to perceive variations in site frequentation that could suggest ecosystem changes. For instance, the departure of the small regular blue whale cohort from the Mingan area in 1992–1993 and the subsequent general desertion of blue whales from this region indicate possible ecosystem changes starting in the early 1990s.

In contrast to blue whales, humpback whales are known to have a strong matrilineal site fidelity behaviour (Katona and Beard, 1990). Results obtained show mean occurrences that exceed those of blue whales in both regions (MING and ESTU). However, the total frequentation over the study period is not as high as expected and even inferior to that of blue whales in the Estuary (with 56% of humpback whales seen only one year in MING compared to 39% for the blue whales observed in ESTU). The inclusion in the statistical analysis of numerous individuals identified for the first time in recent years (from 2003 to 2008) could have overestimated the signal of whales seen only a limited number of years. However, this bias would be marginal for blue whales because only four new animals were reported in MING and 13 in the Estuary over the last five years (2003–2007). In comparison, 50 new humpback whales were recorded from 2003 to 2006 in MING. Removing these animals from the analysis would raise the number of humpback whales seen more than one year in MING from 44% to 52%. Since 2005, sighting rates of humpback whale calves and juveniles rose considerably in MING (R. Sears, MICS, unpub. data). Ramp (2008) reported that juveniles appeared to emigrate more often than adults from the GSL, which could partly explain the resulting low total frequentation obtained for humpback whales in the present study. This possibility seems improbable for blue whales: fewer than 20 blue whale calves have been reported for the whole Gulf compared to more than 100 humpback whale calves since 1980 in the same region.

Many other sectors of the GSL are important foraging areas for rorqual species. A large number of blue whale identifications (almost 20%; 68 individuals) came from the secondary zones (SIPM, GASP, NEGSL, NFDL). Despite the lower sampling effort in these areas, two regions (GASP and SIPM) have a higher total individual identification number compared to MING (134, 114, and 94 animals, respectively), suggesting the fundamental importance of these zones to blue whales. Also, during September 2006, 11 additional individuals were identified off the Gaspé area. These findings illustrate the need for further work at both the spatial scale (e.g., at least to the entire GSL) and seasonal scale in several areas (e.g., Estuary, Gaspé) in order to have a better picture of the general distribution and abundance of blue whales in the Gulf of St. Lawrence.

CONCLUSION

Based on a long-term opportunistic sighting database, the present study describes for the first time the temporal variations in the distribution and abundance of blue whales in different regions of the GSL. The general nomadic behaviour of blue whales is confirmed by the high percentage of whales with low total frequentation and the reduced overall occurrence. This also strengthens the assumption that the GSL makes up only a portion of a much larger feeding ground that might encompass the whole northwest Atlantic (east coast of North America, including the Scotian Shelf, Newfoundland and Labrador shelf waters, the Grand Banks and Flemish Cap, and north to western Greenland). A closer look at individual site attendance patterns can highlight differences in the significance of diverse areas to blue whales, showing a clear preference for the Estuary compared to the Mingan region. The study also illustrates the striking abandonment of the Mingan area by blue whales, a situation that may result from the reduced availability or access to adequate food resources (suggesting changes in the ecosystem). However, the more opportunistic humpback whales, which target both zooplankton and fish, might be favoured by this situation, thus explaining their increased abundance in the Mingan region. Because blue whales are listed as endangered by COSEWIC and IUCN, investigation of the abundance and distribution as well as site attendance and frequentation patterns of blue whales in the Gulf of St. Lawrence has to be continued in order to learn more about the basic ecology of these species. This knowledge could help adapt management strategies to the current stock situation and to ensure adequate protection under the Species At Risk Act.

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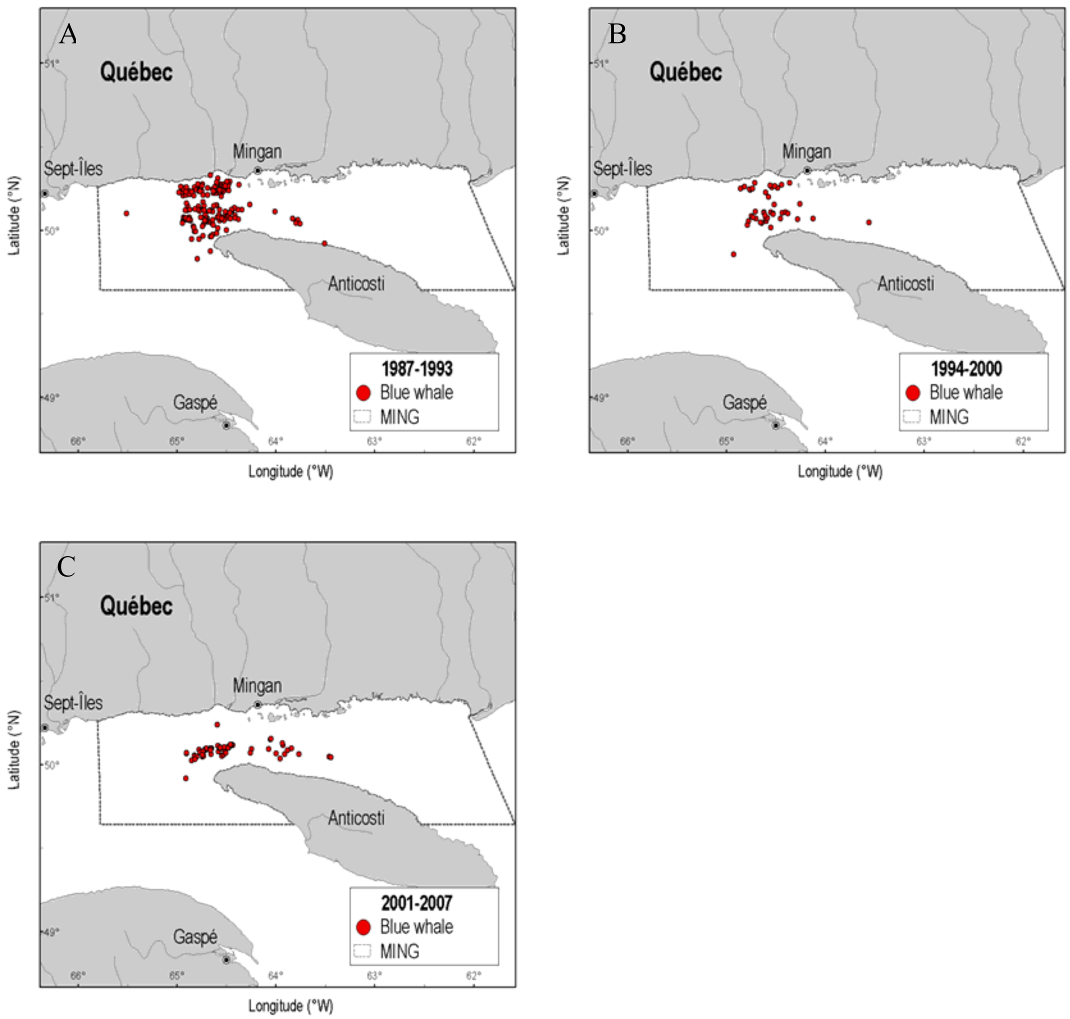
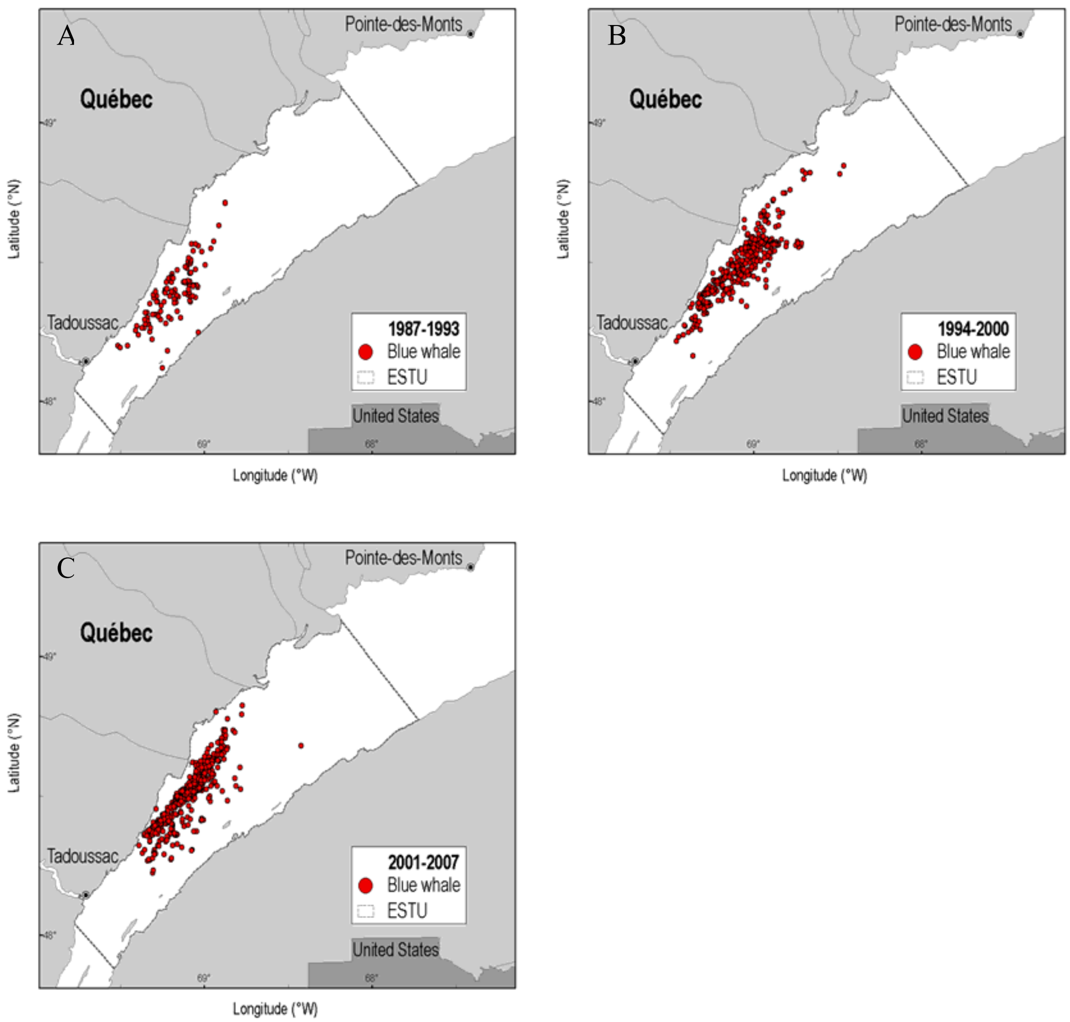
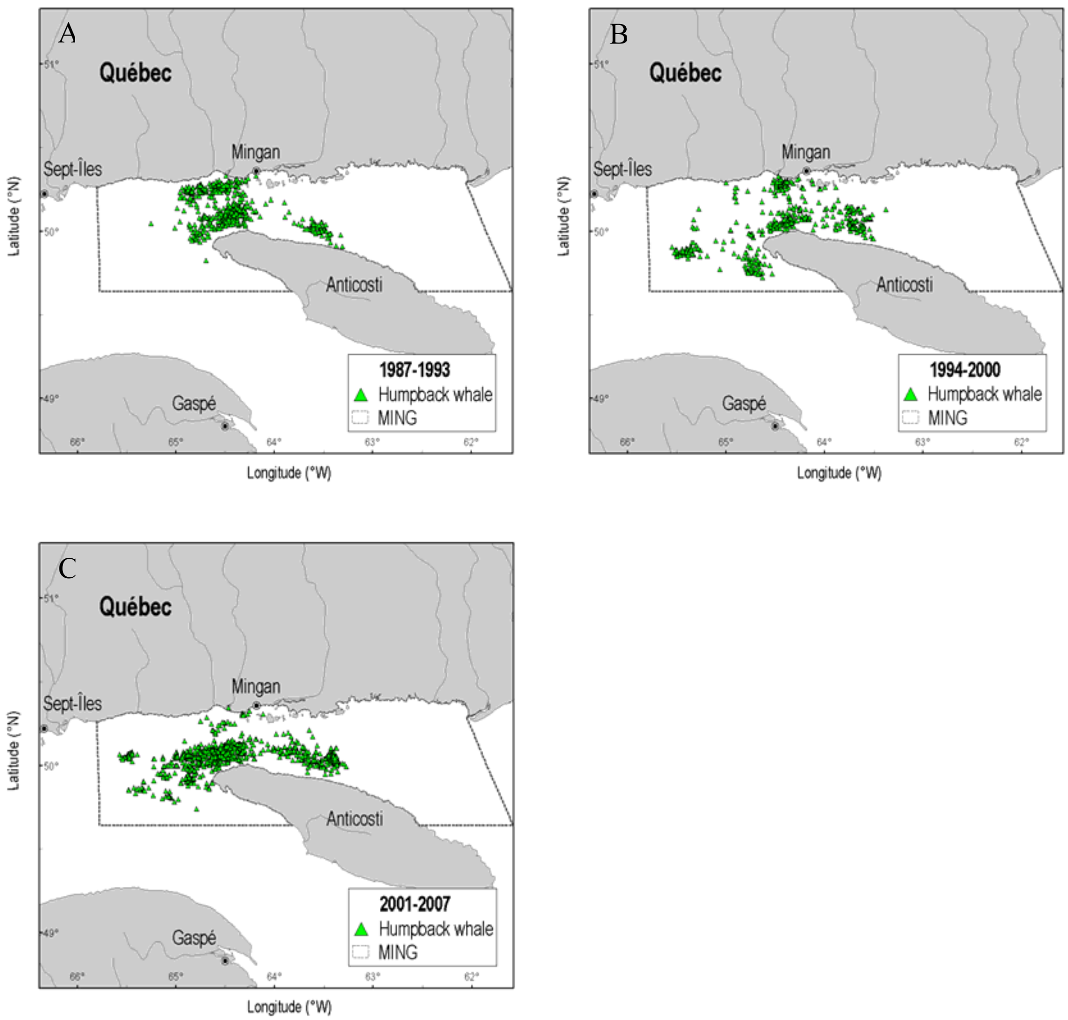
Appendix 1. Temporal distribution of blue whales in the Mingan region for three time periods: (A) before the collapse of groundfish stocks (1987–1993), (B) intermediate period (1994–2000), and (C) recent years (2001–2007). Each circle is the first daily sighting of one photo-identified animal during the studied time period. Thus, several circles can be the same roqual observed many times over the time period.



Appendix 2. Temporal distribution of blue whales in the lower Estuary for three time periods: (A) before the collapse of groundfish stocks (1987–1993), (B) intermediate period (1994–2000), and (C) recent years (2001–2007). Each circle is the first daily sighting of one photo-identified animal during the studied time period. Thus, several circles can be the same roqual observed many times over the time period.



Appendix 3. Temporal distribution of humpback whales in the Mingan region for three time periods: (A) before the collapse of groundfish stocks (1987–1993), (B) intermediate period (1994–2000), and (C) recent years (2001–2007). Each triangle is the first daily sighting of one photo-identified animal during the studied time period. Thus, several triangles can be the same roqual observed many times over the time period.



Appendix 4. Details of the individual blue whale sightings by year.

Legend:

1	ESTU	2	MING	3	GASP	4	SIPM	5	NEGSL	6	NFDL	X	Several areas

Appendix 4.1. Blue whales occasionally observed in the Mingan region only.

Ind.	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007
B065	2		2	2																	
B021	2		2																		
B004	2																				
B023	2																				
B069	2																				
B205	2																				
B183		2	2																		
B029		2		2																	
B051		2																			
B135		2																			
B102			2			2															
B199			2																		
B222				2			2														
B225				2																	
B229				2																	
B263					2																
B180						2															
B277						2															
B279						2															
B280						2															
B282						2															
B292							2														
B294							2														
B066									2												
B186										2											
B376															2	2					
B377															2	2					
B374															2						
B151																				2	

Appendix 4.2. Cosmopolitan blue whales mainly observed in the Mingan region.

Ind	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007
B001	2	2	2,4	2	2	2															
B059	2,4,5	2	2	2																	
B052	2,4	2		1,2		2	1														
B204	2	1,4	2	2		2	1	1			1										
B019	2	2,4	2	1,2			1	1		3,4				1							
B005	2		2	2	1	2	1	1	1	2		2		2							
B200	2		2				2	1					1					1			1,4
B161			2	2	1		1		2	2		2	1	4	2	2	1,3		1	3,4	3

Appendix 4.3. Cosmopolitan blue whales occasionally observed in the Mingan regon (3 years or less).

Ind.	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007
B150	2	4		2																	
B143	2	4				2		1													
B100	2	4					3	4													
B073	2	4																			
B141	2	1,4																			
B133	2							1													
B095			2	1																	
B214			2		4				1	4									3	3	
B192			2					2,4	1						1						
B061			2									4		4						4	4
B228				2				4													
B241					2	3															
B224				4		2															
B146		4				2				1											
B064		4				2															
B270						2		4	3												
B254						2				4											
B295							2			3	3			3			4			3	3
B002				4			2				1,3						4			3,4	
B310								2	3		4										
B309							1			2											
B339										2							4				
B094		4									4			2,4							
B084		4						4			1				2	2				2	
B349											4				1,2	2					
B326									1					3	2						
B373															2		2			3	3
B372														1	2						
B353														1					2		

Appendix 4.4. Blue whales regularly observed in the Estuary only.

Ind.	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007
B177	1		1	1	1	1	1														
B174			1	1	1	1	1	1			1		1	1		1					
B235				1	1		1	1		1					1	1	1	1	1	1	
B242				1	1		1	1		1											
B191				1		1	1				1	1	1	1	1				1		
B131				1		1		1	1	1				1	1		1	1			
B233				1												1		1		1	
B046					1	1	1	1			1		1								
B249					1	1	1	1					1	1	1				1		
B178					1		1	1	1				1								
B257					1			1					1	1		1					
B231						1		1	1	1											
B053							1							1		1			1		
B285								1	1						1		1				
B216								1					1	1		1		1	1		
B352									1		1		1			1		1	1		
B324									1	1	1		1		1				1		
B120										1					1	1	1		1		
B362													1	1	1		1	1	1		1
B356														1	1				1	1	

Appendix 4.5. Blue whales occasionally observed in the Estuary only.

Ind.	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007
B003	1									1											
B022	1																				
B087			1																		
B213			1																		
B217				1		1	1														
B230				1		1		1													
B101				1			1	1											1		
B232				1										1							
B025				1																	
B070				1																	
B237				1																	
B238				1																	
B039					1	1	1														
B099					1		1														
B251					1					1											
B009					1						1										
B121					1																
B140					1																
B258							1	1	1												
B048							1	1		1											
B308							1				1										
B297							1														
B299							1														
B055								1	1												
B078								1		1	1										
B111								1							1						
B329								1									1				
B045								1													
B056								1													
B118								1													
B259								1													
B327									1		1										
B323									1												

Appendix 4.5. Cont.

Ind.	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007
B336										1					1						
B346										1											
B288											1										
B304											1										
B351											1										
B363												1						1			
B008												1									
B334													1					1			
B357													1								
B359														1	1					1	
B210														1	1						
B358														1							
B366														1							
B298															1	1					
B375															1			1			
B067															1						
B153															1						
B278															1						
B365															1						
B380															1						
B049																1					
B390																	1				
B395																	1				
B027																		1			
B399																			1		
B408																				1	

Appendix 4.6. Cosmopolitan blue whales mainly observed in the Estuary.

Ind.	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007
B129	1	1,4		1	1		1	1					1		1						
B124	1	4		1	1,4	1,3	1	1,3	1	3	1		1	1	1	1			1,3		3
B195	1	4		4		1	1			1		4		1			1,3				
B126	1	4				1	1		1				1								
B035	1						1	1			1	1		1,3		1		1,3	1	2	
B244		1		1	1	1	1		1		1,3	3				1,4	1	1		3	
B197		1		1	1	3	1	1,3		1	1			1	1	1	1	1,3	1		1
B190		1,4			1	1	1	4													
B201		1,4					1	1					1	1	1					1,3	
B202		1,4									4			3						3	
B082		4	1				1	1			1			1	1	1	1,3	1			
B147				1	1	1		1	1		1	1		3	1		1,3	1			
B093				1	1	3	1	1		1	1			1,2	1		1	3	1	3	3
B171				1	1	1,2		1	1	1	1			1	1	1,4			1	4	
B166				1	1						1			4	1	1	1		1		1,3
B236				1		1	1				1	1		1	1			1	1	3	
B036				1		1	1									1	1	1	1	3	3
B104				1		1	1,3	1,2			1	1	1	1	1			1			
B159				1				1,4	1				1								
B240				1							1			1	1			1		1	3
B137				1,2	1			1						3		1	1		3		
B047				1,4	1		1	1		1	1		1								
B160				1,2			1	1	1,2	1				1	1	3			1		
B188	2			1,2,4			1,3	1	3	3											
B221				2,4			1,3			1	1,3		1								
B116		4			1		1			1	1		1								
B103					1	1	1	1	1	1	1	1	1	1,3	1	1	1	1	1		
B250					1	1	1	1	1		1			1,3						1	3
B243					1	1	1	1		1	1		1		1	1	1		1,3	1	
B261					1	1	1	1					1		1				3	3	
B248					1	1	1		1	2		1	1								
B260					1	1		1		1	1		1		1					3	

Appendix 4.6. Cont.

Ind.	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007
B245					1	1,2	1	1	1		1			1						1,3	1
B119		2			1	1			1		1		1	1	1	1	1	1			
B227				2	1	1								1	1		3		1	1,3	
B246					1		1	1	1	1	1	1	1		1,3	1	1	1	1	1	1
B017	2	2			1		1			1	1,3		1	1	1	1	1,3	1		1,3,4	
B108					1			1	1	1,2	1		1	1	1			1			
B107	2				1			1		1					1					1	
B169			4			1		4			1		1	1	1			3			3
B268						1	1	1	1		1		1	1,3	1	1	1	1	1	1	1
B185						1	1	1	1		1			1	2	1	1	1	1		1
B218						1	1	1			1		1							1,3	
B274						1	1	1					1	1,4	1		1	1	1	1,3	1
B271						1	1	3		1	3			1						3	3
B275						1	3	1	1		1			1			1	1	1	3	1
B112				4			1	1						1	1			1	1,3	1,3	
B145		4					1	1			1							1			
B301							1	1			1	1	1	1		1	1		1	1	1,3
B043		4					1		1							1					
B168		4					1			4	1	1	1	1,4		1	1	1	1	1	
B207		4					1,3		1				1	1,4	1		1	1	1	1	1
B122						3	1	1	1	1	1		1		1	1				3	
B139							1	1	3	1,4	3			1	2	1				3	
B307							1	4					1			1		1,3		1	
B316							1	4				1	1	1	1	1	1	1	1	3	
B318								1				1	1	1	1	1	1	1	1,3		1
B058	2							1					1					1	1		
B255								1						1				1		3	
B328									1	1			1	1	1	1	4				
B215			2						1		1		1	1	1	1					
B081									1	4	1			1,4	1		1		1		
B057									1		1		1		1				1		1,3
B284						2		4	1				1			1,4	3		1,3	3	
B113		4								1	4,3			4		1		1			
B335										1					1	1			1	4	1
B338										1,4	1			1,3		4					
B090		4								4	1		1	1				1			
B184							3				1			1	1	1		3		3	3
B361													1	1	1					1,4	
B311								4					1		1	1		1,3	1,3		1,3
B041		5											1				1,3	3	1		

Appendix 4.7. Cosmopolitan blue whales occasionally observed in the Estuary (3 years or less).

Ind.	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007
B128	1	1,4																			
B132	1												1						3	3	
B075		1,4																			
B148		1,4																			
B193		1,4													1					3	
B196		4	1																		
B060				1,2,4	1																
B253					1	1,2															
B256					1	1,2															
B302					1		1,2														
B156					1	2		1													
B033				4	1																
B089		4	4		1,4																
B226				2			1	1													
B283						2	1	4							1						
B176			4				1			4				3							
B287							1				3,4			3							
B315								1			1				4						3
B117								1			3						1				
B173								1												3	
B290						3		1													
B325									1					3					3	3	
B092									1											4	
B264					4					1											
B234							3			1											
B333										1										4	
B273											1,3				1				3	3	
B300							3					1				3				3	
B194						3				3	3		1		1				3		3
B322							3						1								
B262					4			4			4	4		1							
B350											4			1.4	1						
B208			4					4				3		3	1	1				3	
B276							3								1	1		1			
B378				4											1			1,3		3	3
B203															1					2	1
B181							3							4	1						
B136								4							1						
B179										4					1						
B337										4					1						
B394																	1			3	
B397																		1		3	1
B401																		1	3		
B344																			1	1	3
B389																			1		3
B354														3					1		
B392																			3	1	
B405																				1	3

Appendix 4.8. Blue whales never observed in the Mingan region or Estuary.

Ind.	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007
B098		4								4											
B158		4																3			
B091		4																			
B097		4																			
B206		4																			
B239			3																		
B212			4																		
B383				4												4				3	
B220				4																	
B223				4																	
B079					4									3,4						3	3
B266					4										4						
B144					3																
B265					4																
B272						6															
B289						6															
B286							3	3		3	3	3		3					3	3	
B252							3														
B293							3														
B296							3														
B303							3														
B305							3														
B306							3														
B319							3														
B321							3													4	
B187								3													
B110								4													
B312								4													
B313								4													
B314								4													
B317								4													
B320									3												
B340										4											
B347											3			3					3	3,4	
B348											3			3						3	
B247											3										
B364														3		3					
B332														3					3	3	
B355														3							
B331														4							3
B209														6							
B381															4						
B281																4			3		
B360																3					
B384																4					

Appendix 4.8. Cont.

Ind.	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007
B369																			3	3	4
B371																			3	3	3
B400																			3		3
B403																			3		
B050																				3	
B404																				3	
B410																				3	
B411																				3	
B412																				3	
B413																				3	
B414																				3	
B415																				3	
B416																				3	
B417																				3	
B418																				3	
B419																				3	
B420																				3	
B409																				4	
B391																					3
B422																					3
B423																					3
B428																					3
B430																					3