Aerial surveys of cetaceans in the Gulf of St. Lawrence in 1995 and 1996

M.C.S. Kingsley and R.R. Reeves

Abstract: Aerial line-transect surveys of cetaceans were flown in the Gulf of St. Lawrence in late August and early September of 1995 and in late July and early August of 1996. Systematic north–south transects were spaced 15′ of longitude apart. In 1995, the study area comprised the entire Gulf, divided into three strata for analysis; 69% was flown. In 1996, a single stratum covered only the north shore shelf; 75% of the design was flown. The survey platform was a light high-winged aircraft with bubble windows flown at 213 m (700 ft). Ten species were seen. Minke whales (*Balaenoptera acutorostrata*), Atlantic white-sided dolphins (*Lagenorhynchus acutus*), and harbour porpoises (*Phocoena phocoena*) yielded enough sightings to support good estimates, while fin whales (*Balaenoptera physalus*), humpback whales (*Megaptera novaeangliae*), white-beaked dolphins (*Lagenorhynchus albirostris*), and long-finned pilot whales (*Globicephala melas*) yielded few sightings and unreliable estimates. Blue whales (*Balaenoptera musculus*) and belugas (*Delphinapterus leucas*) were seen too rarely to support any analysis. The tenth species was a small delphinid, not positively identified. Minke whales were ubiquitous, but more common in the northern strata. We estimated about 1000 in the whole Gulf in 1995 and about 600 in the northernmost stratum in 1996 (these numbers, and those following, are uncorrected for visibility bias). We estimated about 12 000 Atlantic white-sided dolphins in the Gulf in 1995, but in 1996 saw hardly any, perhaps because we flew the survey earlier. Harbour porpoises (12 000 in 1995 and 21 000 in 1996) were most numerous in the northern stratum, but were also widely distributed at lower densities in the central and southern Gulf. White-beaked dolphins (2500 in 1995 and 2500 in 1996) occurred only in the Strait of Belle Isle and the extreme northeastern Gulf. We estimated a few hundred fin whales in the northern and central strata and about 100 humpbacks, mostly in the northeast. Long-finned pilot whales were only seen in the southeastern Gulf, surveyed only in 1995 (about 1500).

Résumé : Des inventaires aériens le long de transects ont été effectués au-dessus du golfe du Saint-Laurent à la fin d'août et au début de septembre en 1995 et à la fin de juillet et au début d'août en 1996. Les transects nord-sud étaient systématiquement espacés par 15 minutes de longitude. En 1995, tout le golfe a été inventorié, divisé en 3 strates pour fins d'analyse; 69% a été survolé. En 1996, une seule strate ne couvrait que la plate-forme le long de la rive nord; 75% a été survolé. Le véhicule utilisé était un petit avion léger à ailes hautes et à fenêtres en bulles volant à 213,4 m (700 pieds) d'altitude. Dix espèces ont été repérées. Nous avons vu suffisamment de Petits Rorquals (*Balaenoptera acutorostrata*), de Dauphins à flancs blancs (*Lagenorhynchus acutus*) et de Marsouins communs (*Phocoena phocoena*) pour faire une bonne estimation des populations, mais le nombre restreint de Rorquals communs (*Balaenoptera physalus*), de Rorquals à bosse (*Megaptera novaeangliae*), de Dauphins à nez blanc (*L. albirostris*) et de Globicéphales noirs (*Globicephala melas*) observés ne permettait de faire que des estimations approximatives des populations. Les Rorquals bleus (*Balaenoptera musculus*) et les Bélugas (*Delphinapterus leucas*) ont également été vus trop rarement pour permettre toute analyse. La dixième espèce était un petit delphinidé qu'il a été impossible d'identifier. Les Petits Rorquals ont été vus partout, mais ils abondaient surtout dans la strate nord. Nous avons estimé leur nombre à environ 1 000 dans tout le golfe en 1995 et à environ 600 dans la strate nord en 1996 (ces nombres et ceux qui suivent n'ont pas été corrigés en fonction de la visibilité). Nous avons estimé à environ 12 000 le nombre de Dauphins à flancs blancs dans tout le golfe en 1995, mais n'en avons vu que très peu en 1996, peut-être parce que l'inventaire a été fait plus tôt en saison. Les Marsouins communs (12 000 en 1995 et 21 000 en 1996) étaient nombreux surtout dans la strate nord, mais ils étaient également bien répartis quoique en densités moindres, dans le centre et le sud du golfe. Les Dauphins à nez blanc (2500 en 1995 et 2500 en 1996) n'ont été aperçus que dans le détroit de Belle-Isle et dans la partie de l'extrême nord-est du golfe. Nous avons estimé quelques centaines de Rorquals communs dans les strates nord et centre et environ 100 Rorquals à bosse, surtout dans le nord-est. Les Globicéphales noirs n'ont été vus que dans le sud-est du golfe, inventorié seulement en 1995 (environ 1 500 individus).

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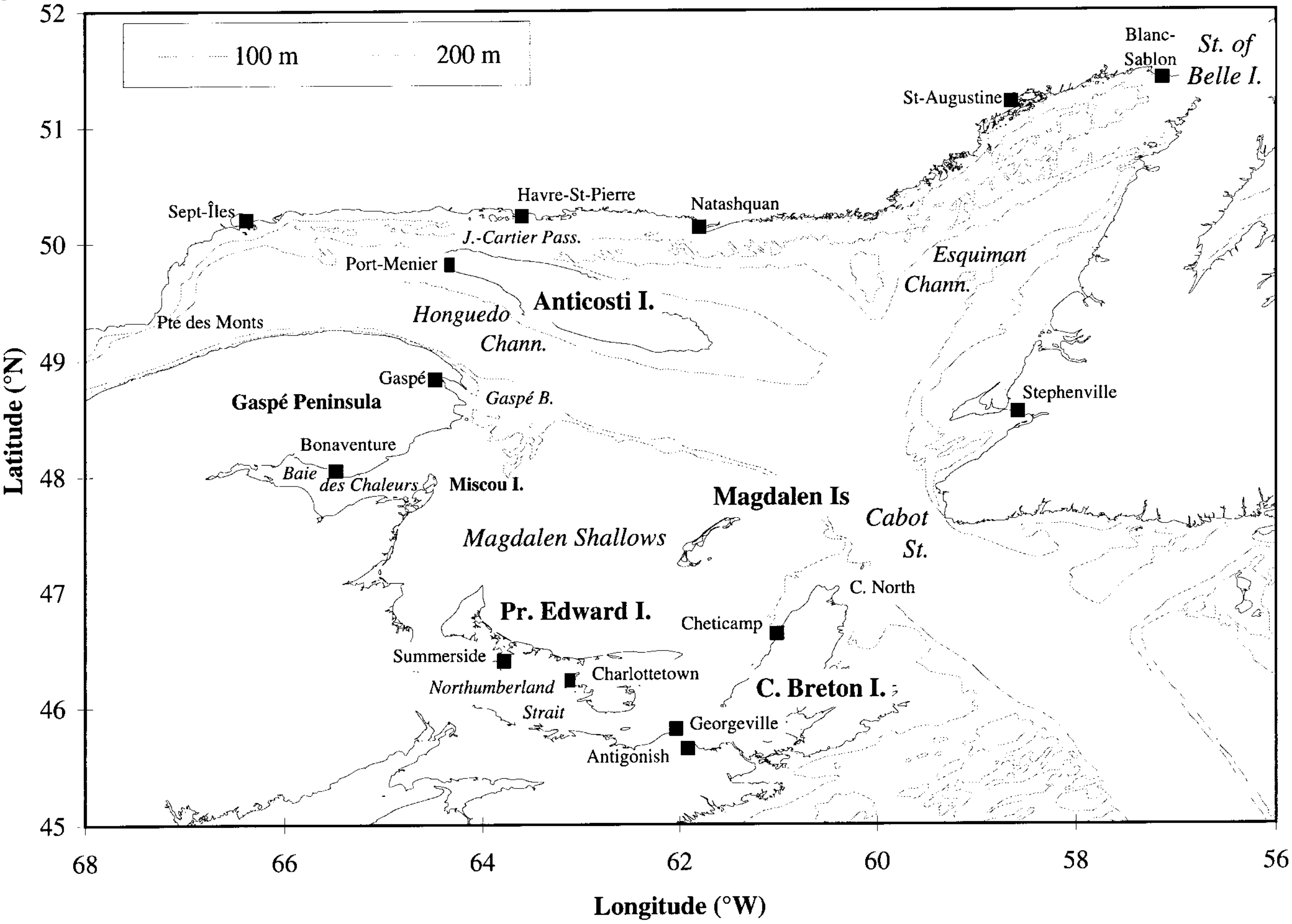
Fig. 1. Gulf of St. Lawrence.



Introduction

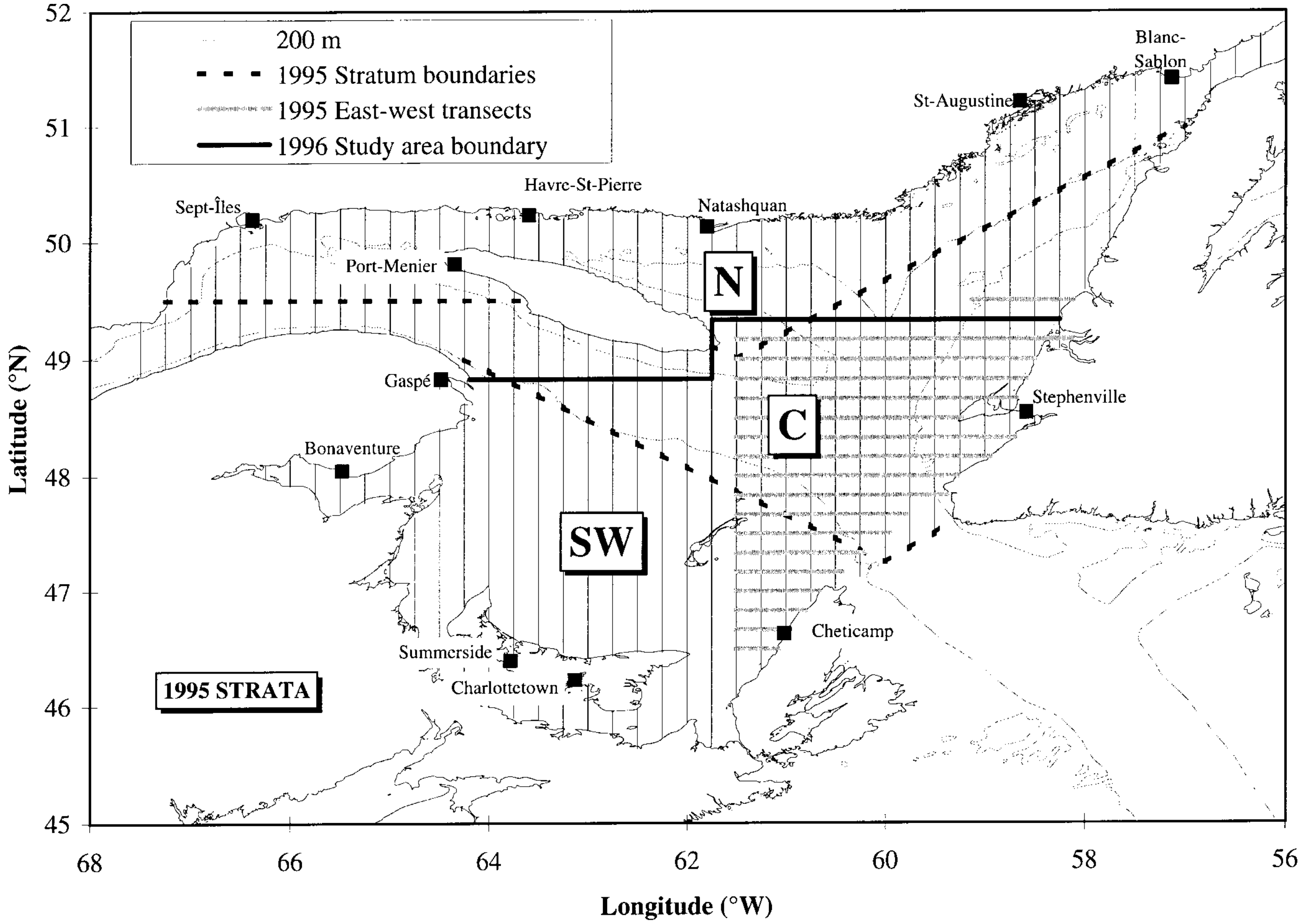
The Gulf of St. Lawrence is a marginal sea in the northwestern Atlantic Ocean, with a total surface area of some 195 000 km^2. Its main connections with the Atlantic Ocean are Cabot Strait in the south (104 km wide, 480 m deep) and the Strait of Belle Isle in the north (16–29 km wide, 60 m deep) (Fig. 1). Relatively warm "Slope" water enters the Gulf at depth through Cabot Strait (Lauzier and Trites 1958), while cold "Labrador" water enters along the north shore of the Strait of Belle Isle (Huntsman et al. 1954). Approximately two-thirds of the annual freshwater discharge into the Gulf comes from the St. Lawrence River (Trites 1971). During summer, the main body of the Gulf is a three-layered system comprising a warm mixed surface layer, a cold intermediate layer, and a warm deep layer with maximal temperatures at depths of 200–300 m (Trites 1971).

The Gulf can be broadly divided into three main regions on the basis of physical characteristics. (1) The shallow shelf along the north shore, with a rocky uneven bottom, is strongly influenced by upwelling of the cold nutrient-rich water of the Labrador Current flowing in through the Strait of Belle Isle. (2) The Laurentian Channel, a trench 500 m deep in places, cuts diagonally through the central Gulf from Cabot Strait and northwestward, extending upstream to the confluence of the Saguenay River. The Esquiman Channel, which branches to the northeast, connects the Laurentian Channel with the Strait of Belle Isle. These channels have an average depth of 420 m and, together, account for about half the total surface area of the Gulf. (3) The southern and western Gulf, relatively shallow (average depth 50 m) and temperate with an even, sandy bottom, is broadly called the Magdalen Shallows (Lauzier et al. 1957; de Lafontaine et al. 1991).

The cetacean fauna of the Gulf reflects the transitional nature of its water regime. A standard array of North Atlantic boreal species dominates the cetacean fauna in the St. Lawrence system today. These range from large and medium-sized mysticetes (blue (*Balaenoptera musculus*), fin (*Balaenoptera physalus*), humpback (*Megaptera novaeangliae*), right (*Eubalaena glacialis*), and minke whales (*Balaenoptera acutorostrata*)) and odontocetes (sperm (*Physeter macrocephalus*), killer (*Orcinus orca*), long-finned pilot (*Globicephala melas*), and northern bottlenose whales (*Hyperoodon ampullatus*)) to small odontocetes including harbour porpoises (*Phocoena phocoena*), white-beaked dolphins (*Lagenorhynchus albirostris*), and Atlantic white-sided dolphins (*Lagenorhynchus acutus*). Arctic species are represented by a relict population of belugas (*Delphinapterus leucas*) that inhabits the lower St. Lawrence River and estuary in summer (Vladykov 1944). Bowhead whales (*Balaena mysticetus*) occurred in the Strait of Belle Isle within historic times (Cumbaa 1986).

Whaling records (Mitchell 1974; Mitchell and Reeves 1983) and field studies (Williamson 1985; Edds and Macfarlane 1987; Sears et al. 1990; Borobia et al. 1995) in-

Fig. 2. Systematic designs for aerial surveys flown in the Gulf of St. Lawrence in 1995 and 1996.



dicated that portions of the Gulf were important summer feeding grounds for blue, fin, humpback, and minke whales, the right whale having been essentially extirpated by premodern whaling. Although Sears and Williamson (1982), in the only previous survey of the entire Gulf, obtained some information on areas of concentrated occurrence and on seasonal changes in the overall pattern of cetacean distribution, little quantitative information has been available on the Gulf's cetacean fauna. In particular, the abundance and distribution of odontocetes have been poorly known, except for the intensively studied population of belugas in the St. Lawrence River (Lesage and Kingsley 1998; Kingsley 1998).

A bycatch of close to 2000 harbour porpoises per year, mainly in bottom-set gill nets, was estimated for portions of the Gulf of St. Lawrence in the late 1980s (Fontaine et al. 1994*a*). This reinforced concern as to whether the porpoise population in the Gulf was large enough to sustain recent levels of human-caused mortality without becoming depleted (cf. Gaskin 1992*a*; International Whaling Commission 1996). Therefore, one objective of the present study was to obtain an abundance estimate for harbour porpoises.

Interest on the part of Heritage Canada in identifying marine areas of particular significance (Mercier and Mondor 1995; Meltzer Research and Consulting[2,3]) provided the impetus for an additional objective: to obtain a quantitative assessment of the cetacean fauna of the Gulf in summer. We therefore conducted systematic visual aerial surveys between 17 August and 3 September 1995 and between 27 July and 5 August 1996.

Methods

Survey design

The timing of the surveys was intended to sample the peak season of cetacean residence in the Gulf, from the perspectives of species diversity, numerical abundance, and aggregate biomass. It was assumed that the migratory populations that enter the Gulf in summer would have largely arrived by the end of July (Sears and Williamson 1982, pp. 40–56) and that their departure would not have begun until after mid-September. The interval of 25 July to 15 September was selected for the surveys.

A grid was mapped over the entire Gulf to as far west as Pointe des Monts (67°30′W), where the Gulf narrows dramatically into the maritime estuary of the St. Lawrence River (Fig. 2). North–south transects were spaced at intervals of 15′ of longitude (17.9 km at the northern limit of the study area and 19.3 km at the southern limit). After experiencing problems with sun glare during

[2] Meltzer Research and Consulting. 1996*a*. Identification of representative marine areas in the Laurentian Channel marine region. Unpublished, unnumbered report prepared for Parks Canada, Department of Canadian Heritage, Ottawa, Ont.
[3] Meltzer Research and Consulting. 1996*b*. Identification of representative marine areas in the North Gulf Shelf marine region. Unpublished, unnumbered report prepared for Parks Canada, Department of Canadian Heritage, Ottawa, Ont.

Table 1. Unidentified sightings[a] of cetaceans in aerial surveys of the Gulf of St. Lawrence in the summers of 1995 and 1996.

	Total		Group size		
	Sightings	Individuals	Mean	SD	CHM[b]
Lagenorhynchus sp.	3	36	12	7.2	14.9
Dolphin species ("not *Lagenorhynchus*, possibly *Delphinus* or *Stenella*")	3[c]	179	59.7	78.9	129.3
Dolphin species (other notes)	9	51	4.2	5.7	8.4
"Small whales" (usually, but not invariably, "not minke," "*P. phocoena* or *Lagenorhynchus* sp.")	11	30	2.7	2.1	4.2
"Whales"	14	15	1.07	0.27	1.13
"Large whales" (often "larger than minke," "fin or blue," "probably blue")	11	16	1.45	0.82	1.88

[a]One sighting of three "large whales" was secondary; all others were primary, often under poor conditions or at great distance.
[b]Contraharmonic mean.
[c]Same day, same place.

the early days of the first year's survey, we designed a series of east–west transects in the eastern portion of the Gulf. These were spaced 10′ of latitude (18.6 km) apart and so provided coverage equivalent to that of the north–south transects.

The survey design in 1995 was unstratified, i.e., coverage of all areas was equally intense. For analysing the data, the effort and sightings were stratified into the north shore shelf (stratum N), the deep Laurentian and Esquiman channels (stratum C), and the Magdalen Shallows (stratum SW) (Fig. 2). These strata, although crudely constructed and not conforming exactly to previously published subdivisions based on fishing, biological production, biogeography, general topography, or physical oceanographic regimes (e.g., see de Lafontaine et al. 1991), provided a simple means of comparing generalized habitat zones. Foreseen funding limitations in 1996 limited the effort that year, which was concentrated in stratum N and portions of stratum C; in flying the survey, priority was given to areas that had been missed in 1995 because of bad weather.

Effort allocation in both years was affected by the availability of landing and refuelling sites (few in the northeast) and by having to fly only in good weather. In 1995, we experienced not only the usual effects of weather such as high winds associated with frontal movements, low clouds, and precipitation resulting from stationary low pressure, but also periods of fog and haze due to major forest fires in Quebec and northern New Brunswick.

Survey equipment and procedures

The surveys were flown in a high-winged Cessna 337 "Skymaster," with endurance of 7 h, normal cruising speed of 155 kn (287 km/h), minimal continuous operating speed of 100–110 kn (185–204 km/h), and stall speed of 60 kn (111 km/h). Bubble windows had been installed at the two rear seating positions to improve the ability of observers to see animals near the transect line.

Standard line-transect methods were used for collecting data. Two observers, one sitting on each side of the aircraft immediately behind the pilot, maintained a continuous watch and spoke into independent tape recorders. When a cetacean or group of cetaceans was sighted, the angle perpendicular to the flight track was estimated with a hand-held inclinometer. As a backup, the wing struts had been marked with black tape at 10° intervals.

On the few occasions when the observer was unable to take an inclinometer reading, the sighting position relative to these wing strut markers was noted. For each sighting, the species, number of individuals, declination angle, and stopwatch time (usually to the nearest minute) were recorded. Each observer also recorded the sea state (Beaufort scale), visibility, cloud cover, and sun glare at the beginning of each transect and as they changed. Serious visibility problems were recorded as "fog" and subsequently dropped from the data, and small visibility deteriorations were recorded as 10° sighting angle intervals lost at the outer edge of the transect. Glare was described while flying and coded during data reduction: "none" included cloud cover and sun on the other side of or generally towards the back of the aircraft, "moderate" included sun directly abeam or dead ahead, with enough wind to spread the reflections, and "severe" generally included sun ahead of the beam on the observer's side. Positions (latitudes and longitudes) of sightings and changes in conditions were interpolated along the transect assuming a constant flying speed. The pilot navigated from a Global Positioning System receiver and attempted to maintain a standard ground speed of 110 kn (204 km/h) and a flight altitude of 700 ft (213 m).

For the most part, the surveys were conducted in passing mode. However, the survey leader exercised judgment with regard to the usefulness of closing on sightings to verify species identifications, count individuals, or investigate unusual observations. Whenever closing mode was used, the times and positions of departure from and return to the trackline were noted, and the on-transect effort was adjusted accordingly.

It was assumed that sea states greater than Beaufort 3 were unacceptable for detecting minke whales and small odontocetes and suboptimal generally for aerial survey, so we did not start, or soon stopped, flying when the sea state was Beaufort 4 or greater.

Data management

Survey effort was calculated as distance flown on transect in searching mode ("on-effort") by stratum. The effort for each observer was initially calculated separately in order to account for differences in visibility between the two sides of the aircraft due to sun angle. Each transect, subdivided by stratum when the transect crossed a stratum boundary, was treated as a survey unit, and each kilometre flown was assigned to a sea state class between 0 and 5 and a glare class of 0 (none), 1 (moderate), or 2 (severe). In this way, the total survey effort for each transect or transect segment and each stratum could be assigned to quality categories according to sea state and glare conditions: very good, good, or unacceptable (see later). In the initial treatment of the data, we decided for groups of species what constituted "acceptable" conditions based on their overall mean sighting rate and analysed only data from acceptable transect segments.

Sightings were classified as primary (on transect) and secondary (off transect, or first seen in closing mode). All sightings were plotted to show overall distributions, but only primary sightings were used for quantitative analyses. Because the aircraft was pass-

Table 2. Stratum areas and transect lengths designed and flown in aerial surveys of the Gulf of St. Lawrence in the summers of 1995 and 1996.

	1995				
	Stratum N	Stratum C	Stratum SW	Total	1996
Estimated area (km^2)	59 989	84 479	77 482	221 949	94 665
Design transect length (km)	3 371	4 628	4 110	12 108	5 293
Percentage of design flown in "very good" conditions	36.9	31.8	38.8	35.6	32.8
Percentage of design flown in "good" or "very good" conditions	52.3	49.4	60.5	54.0	61.4

Note: "Very good" conditions were sea state Beaufort 2 or less, sun glare none or some; "good" conditions were sea state Beaufort 3 or less, sun glare none or some.

ing at high speed and we had only limited time to circle on sightings, positive species identifications and precise counts were not always achieved. Sometimes, counts of small odontocetes were given as ranges or rounded estimates. When a count was imprecise, the midpoint of the stated range was used. When the species was not positively identified, an attempt was made to at least narrow the range of possibilities (Table 1). We attempted to use all available information on each sighting, but we refrained from guessing and assigned few posterior identifications.

Analytical methods

Densities were estimated by line-transect analysis of distance data (Burnham et al. 1980; Buckland et al. 1993). Primary sightings made under appropriate conditions were used to estimate species encounter rates (animals per unit distance) by year and stratum. All such sightings, regardless of year, observer, or stratum, were pooled to estimate a single detection curve for each species. Errors in abundance estimates are therefore positively correlated between years and strata. Detection curves were fitted by maximum likelihood, using standard spreadsheet software, to the perpendicular distances of individual animals (see Hiby and Hammond 1989); all members of a group were assigned to the same distance.

Line transect data analysis was limited to distance ranges that included most, but not necessarily all, of the sightings with distances recorded, i.e., 762 m (2500 ft) for harbour porpoises, 1219 m (4000 ft) for dolphins, and 1524 m (5000 ft) for minke whales. For larger whales, the limit was set at 1829 m (6000 ft) because sightings farther off were few and their distances probably inaccurate. The drop-off curve used to model the decrease of detection at distance was a three-parameter version of a hazard-rate curve (Buckland 1985). From examining the detection curves, and from experience while flying, it was evident that animals close to the trackline were missed, so on the inboard side of the survey strip, an increase in detection probability with distance from the trackline was modelled by a simple sinusoid. The usual assumption that detection is greatest at distance zero was thus replaced by an assumption that it was greatest at some distance indicated by the data. The visibility bias normally expressed by $g(0) < 1$ would be replaced by $g(\max) < 1$.

Line-transect methods fit sighting curves closely to observed sample data and may therefore underestimate the effective strip width (ESW) and overestimate densities. To counter this possibility, Quenouille's jackknife bias reduction procedure (Efron 1982, eq. 2.8) was applied to the "survey expansion factor," defined as the reciprocal of ESW:

$$\tilde{k} = n\hat{k} - (n-1)\hat{k}_{(\cdot)}$$

where $\tilde{k}$ is the bias-reduced estimate and $\hat{k}_{(\cdot)}$ is the mean of n different estimates of $\hat{k}$, each calculated omitting one sighting. Numbers in strata were estimated as the product of stratum area, mean encounter rate (animals per unit distance), and survey expansion factor (per unit distance). Sightings outside distance limits were rejected both from sighting curves and from abundance estimation. Sightings with no angle recorded in the field (i.e., for which no estimate of perpendicular distance was possible) had to be left out of ESW calculations, but it was assumed that they were within distance limits (because this was true of most identified sightings) and they were included in density and abundance estimations.

Standard errors had two components, one due to uncertainty in estimating mean encounter rate (i.e., the transects were a sample of the study area) and another due to uncertainty in the survey expansion factor (i.e., the distance data were a sample of possible sighting distances). The basic survey design was systematic, but in every stratum, and in both years, blocks of consecutive transects either were not flown or if flown did not yield usable data because of weather or glare problems. Therefore, we estimated standard errors as though sampling had been random (Cochran 1963, p. 153, eq. 6.2):

$$\operatorname{var}(\hat{D}_L) = \frac{\sum y_i^2 - 2\hat{D}_L \sum x_i y_i + \hat{D}_L^2 \sum x_i^2}{n(n-1)\bar{x}^2}$$

where D_L is the encounter rate (individuals per unit distance) and x_i is the length of transect i, while y_i is the number of animals on it. It was assumed that transects unsurveyed because of weather occurred randomly with respect to the distribution of cetaceans. Jackknife output was used to calculate the uncertainty of the survey expansion factor (Efron 1982, eq. 3.2):

$$\operatorname{var}(\tilde{k}) = \frac{n-1}{n} \sum (\hat{k}_{(i)} - \hat{k}_{(\cdot)})^2$$

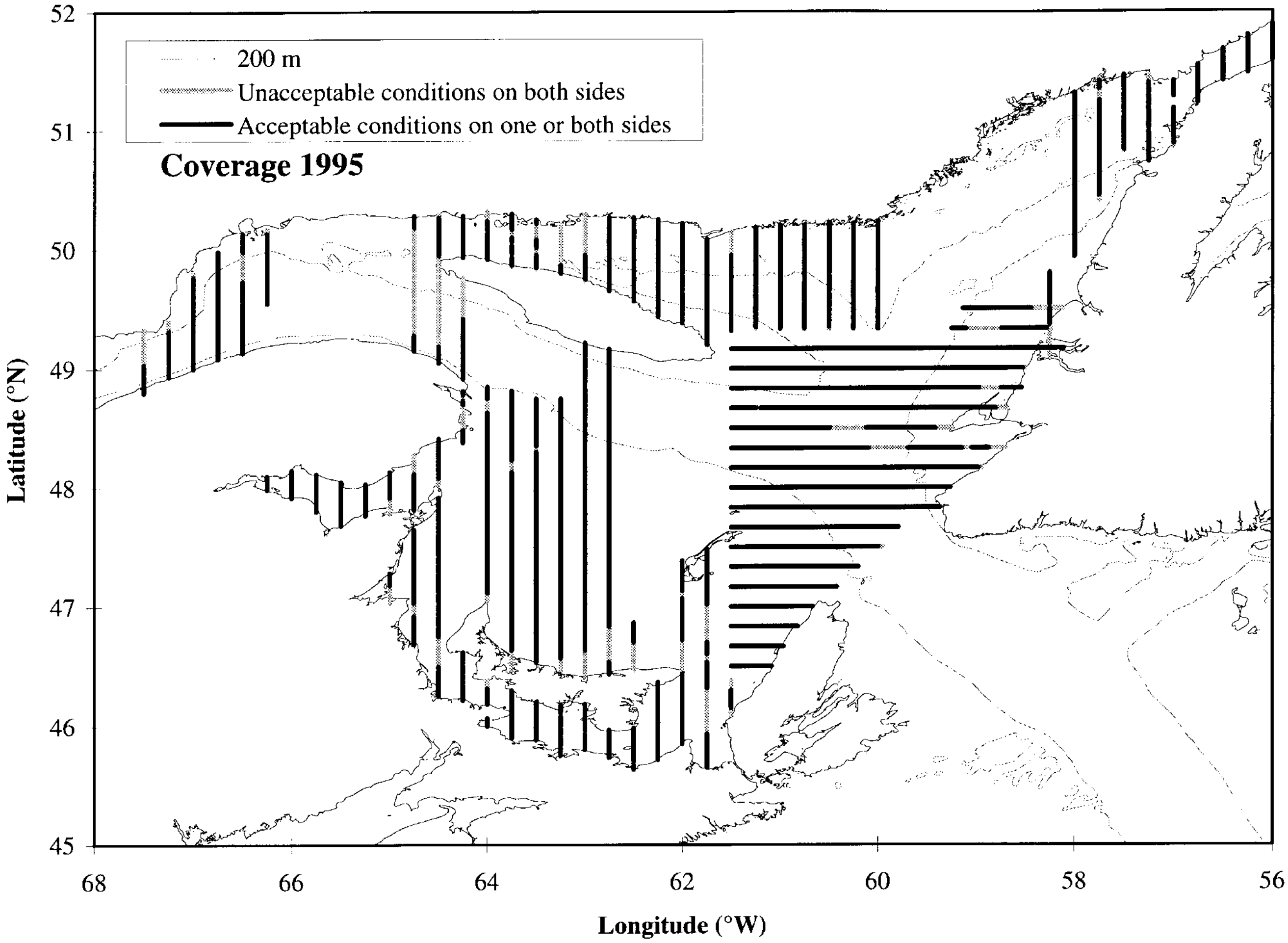
Density and abundance estimates were calculated for each species in each stratum in 1995 and summed to give estimates for the study area as a whole; the 1996 survey area was treated as a single stratum. "Uncorrected" estimates include the jackknife bias reduction; they are not corrected for availability or detection biases, although for some species, we have discussed how big such corrections might be.

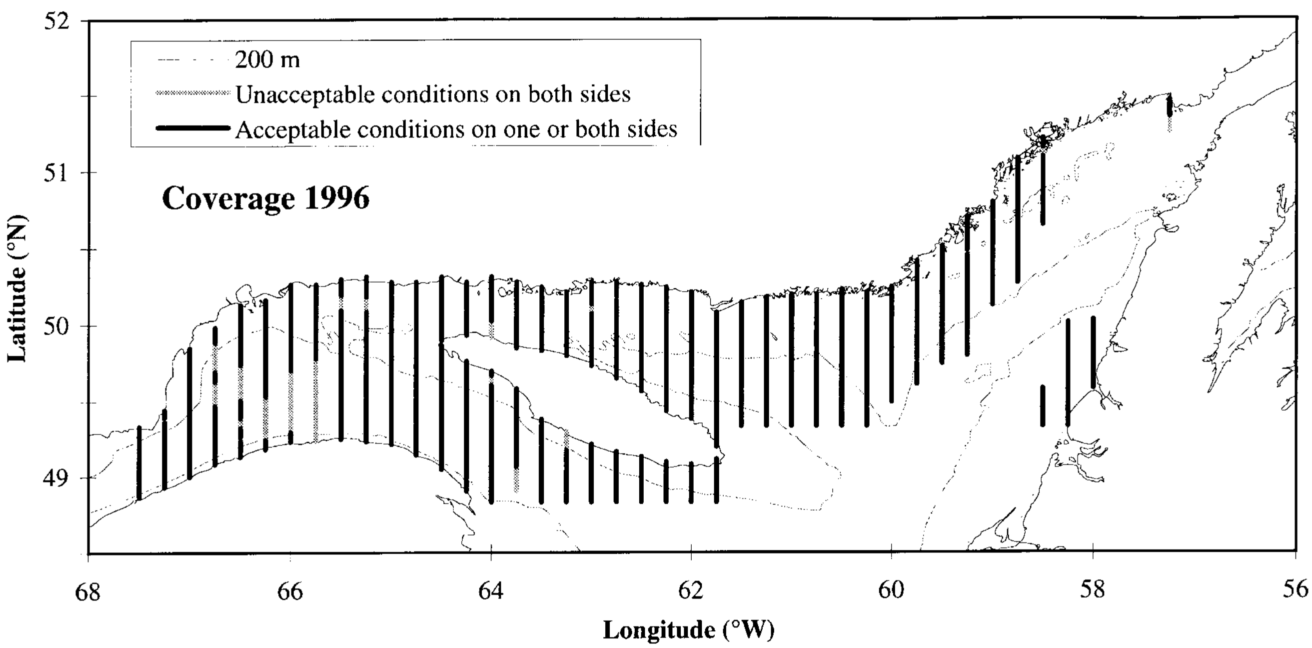
Results and discussion

Effort and sightings

In 1995, we flew 8427 of a designed 12 108 km (Table 2), with 91 km off-effort, owing to fog, haze, or islands. Of the remaining 8336 km, 83 (1%) were in sea state 5 or worse and 887 (10.6%) in sea state 4. Of the designed transect grid, we flew in Beaufort 3 or better 58.8% of stratum N (1983/3371 km), 52.2% of stratum C (2415/4628), and 72.2% (2967/4110) of stratum SW. Sizeable gaps in coverage occurred in all three strata (Fig. 3). The transects were

Fig. 3. Aerial survey coverage in the Gulf of St. Lawrence in summer 1995 and 1996.





flown in a generally anticlockwise sequence, starting in the northwest and following the coast of the Gulf. One thousand and fifty-nine individuals were observed in 216 primary sightings and 116 in 15 secondary sightings.

In 1996, the design comprised 5293 km of transect, of which 3993 (76%) were surveyed on-effort (Table 2). Only 26 km was in sea state 5 and 289 in sea state 4, so 3676 km, or 69.5% of the design, was surveyed in Beaufort 3 or better.

Table 3. Sightings and effort by sea state, Gulf aerial survey, 1995 and 1996.

	Sea state (Beaufort scale)							
	1995				1996			
	0 and 1	2	3	4+	0 and 1	2	3	4+
Minke whales	9	16	2	1	7	7	1	
Identified large whales (fin, blue, and humpback)	6	10	7		6	3	4	
Pilot whales (1995) and belugas (1996)	6	12				2	1	
Identified *Lagenorhynchus*	19	31	1		2	7		
Harbour porpoises	22	40	3	2	44	84	11	
Unidentified small cetaceans	6	13	5	1		1		
Unidentified medium and large cetaceans	1	10	4	2	1	1	5	
Nautical miles flown	724	1846	1407	524	275	761	950	170
Kilometres flown	1341	3419	2606	970	509	1409	1759	315
%	16.1	41.0	31.3	11.6	12.8	35.3	44.1	7.9

Note: Some transect segments that were off-effort for other reasons (e.g., fog) had no sea state recorded.

Table 4. Primary sightings and effort by severity of sun glare, Gulf aerial survey, 1995 and 1996.

	Glare level					
	1995			1996		
	0	1	2	0	1	2
Minke whales	23	4	1	10	3	2
Identified large whales (fin, blue, and humpback)	19	5		10	3	
Pilot whales (1995) and belugas (1996)	14	4		1	0	2
Identified *Lagenorhynchus*	38	13		8	2	
Harbour porpoises	53	8	3	114	19	8
Unidentified small cetaceans	20	4	1	1		
Unidentified medium and large cetaceans	12	4	1	3	1	3
Nautical miles flown	2962	738	515	1371	529	247
Kilometres flown	5486	1367	954	2539	980	457
Percentage	70.3	17.5	12.2	63.8	24.6	11.5

Note: Distances are for left and right glare conditions summed and divided by 2. In 1995, glare condition was not recorded for 578 km and in 1996 for 30 km. Glare was not recorded for most secondary sightings, which were usually made while circling.

Table 5. Parameters of line-transect analysis of sighting distances for selected cetacean species in aerial surveys of the Gulf of St. Lawrence in the summers of 1995 and 1996.

	Number included in line-transect analysis[a]			One-sided effective strip width (m)		Two-sided survey expansion factor (/km)		
	Individuals	Sightings	Effective sightings[b]	Sightings	Individuals	Initial	Bias reduced[c]	Error CV (%)[c]
Fin whales	31	16	9.2	572.7	656.3	0.762	0.720	54.1
Humpback whales	14	11	9.2	1403.7	1467.7	0.341	0.316	9.7[d]
Minke whales	35	33	31.4	535.3	549.3	0.910	0.869	13.8
Long-finned pilot whales	95	14	6.6	785.7	1579.0	0.316	0.304	3.9[d]
Atlantic white-sided dolphins	267	39	20.9	403.7	521.0	0.960	0.862	17.1
White-beaked dolphins	135	16	8.6	351.7	383.3	1.305	0.853	54.8
Harbour porpoises	395	166	88.2	245.3	277.3	1.801	1.574	13.1

[a]Included are primary sightings made under satisfactory weather conditions and within the distance limit imposed for each species.
[b]Calculated as the number of individuals divided by the contraharmonic mean of group size (e.g., see Kingsley 1989, p. 109, eq. 4).
[c]Bias was reduced and SE values were estimated by simple jackknife using sightings as independent observations.
[d]For these species, the jackknife is thought to have seriously underestimated the uncertainty attached to the survey expansion factor.

Weather conditions forced us to begin this survey in the middle of the study area and work eastward, and then back-track to complete the westernmost section at the end of the field period. One hundred and eighty-nine primary sightings comprised 438 individuals, and there was one secondary sighting of 3.

Sightings, recording, and line-transect analysis

Scott and Gilbert (1982) had difficulty making sense of the effects of glare and sea state on sightability in their much larger multispecies aerial survey program off the east coast of the United States. Most authors, however, have found that harbour porpoises cannot be reliably detected in sea states

Table 6. Identified sightings, both primary and secondary, of the principal cetacean species in aerial surveys of the Gulf of St. Lawrence in the summers of 1995 and 1996.

	Total		Group size		
	Sightings	Individuals	Mean	SD	CHM[a]
Minke whales	43	46	1.07	0.26	1.13
Fin whales	18	34	1.89	1.64	3.24
Blue whales	5	5	1.00	0.00	1.00
Humpback whales	14	21	1.50	0.85	1.95
Long-finned pilot whales	18	166	9.22	12.15	24.35
Belugas	3	6	2.00	1.00	2.33
Atlantic white-sided dolphins	44	363	8.25	8.73	17.28
White-beaked dolphins	17	147	8.65	7.84	15.34
Harbour porpoises	208	501	2.42	2.24	4.48

[a]Contraharmonic mean.

Fig. 4. Cumulative sightings, plotted against distance from the trackline, of 395 individual harbour porpoises and 35 minke whales, with fitted visibility curves both simple and cumulative.

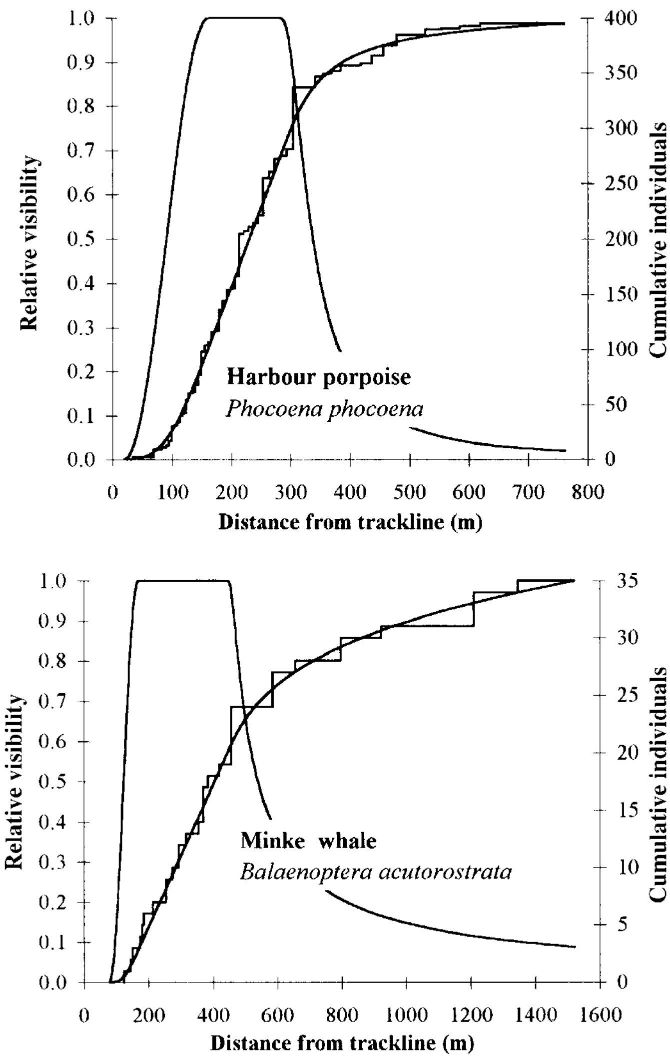
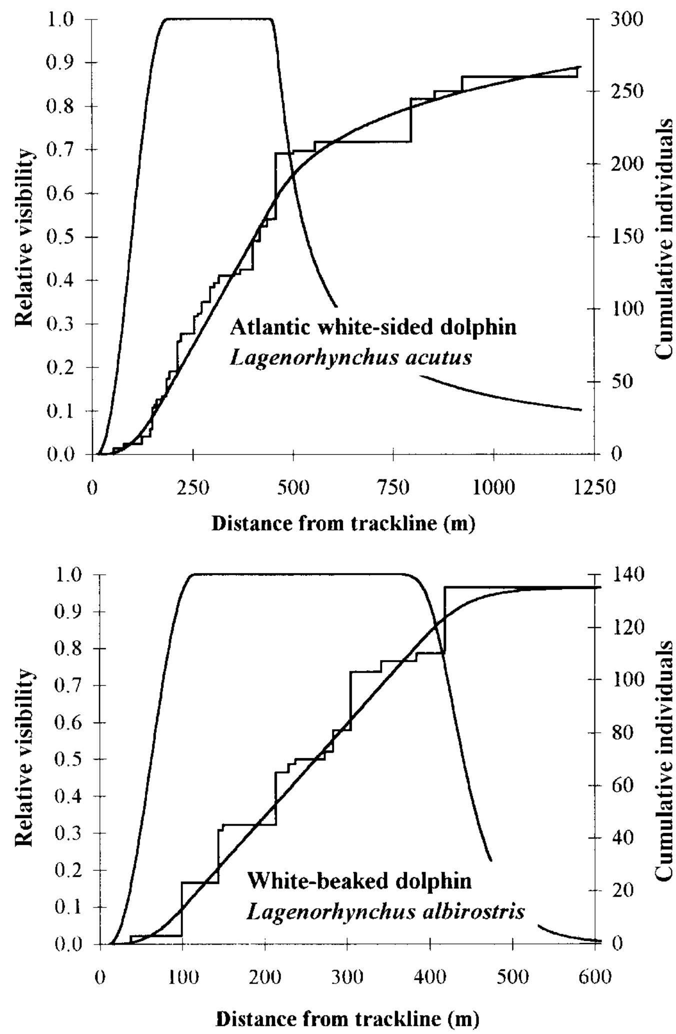


Fig. 5. Cumulative sightings, plotted against distance from the trackline, of 267 individual Atlantic white-sided dolphins and 135 white-beaked dolphins, with fitted visibility curves both simple and cumulative.



greater than Beaufort 2 (Gunnlaugsson et al. 1988; Forney et al. 1991; Heide-Jørgensen et al. 1992, 1993), and this is consistent with our observations, in which 7.8% of the harbour porpoise sightings, but 45.5% of effort, were in sea states of Beaufort 3 or 4. We also found, like Gunnlaugsson et al. (1988), that sea state was correlated with the detection of other species up to at least the size of minke whales (Table 3). Even when animals were detected in Beaufort 3 and

Fig. 6. Cumulative sightings, plotted against distance from the trackline, of 31 individual fin whales, with the fitted visibility curve both simple and cumulative.

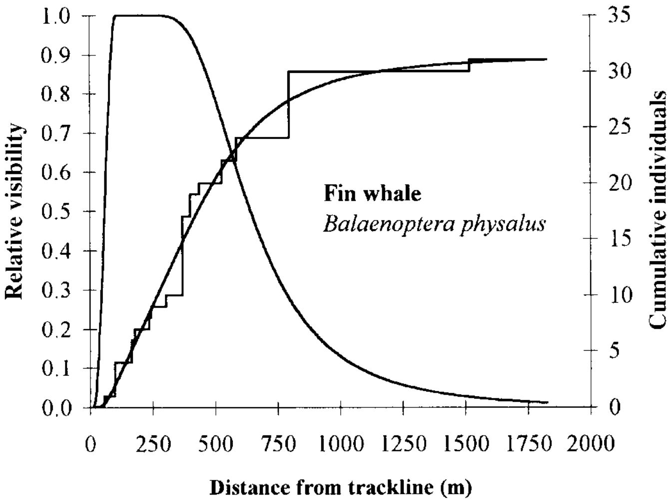
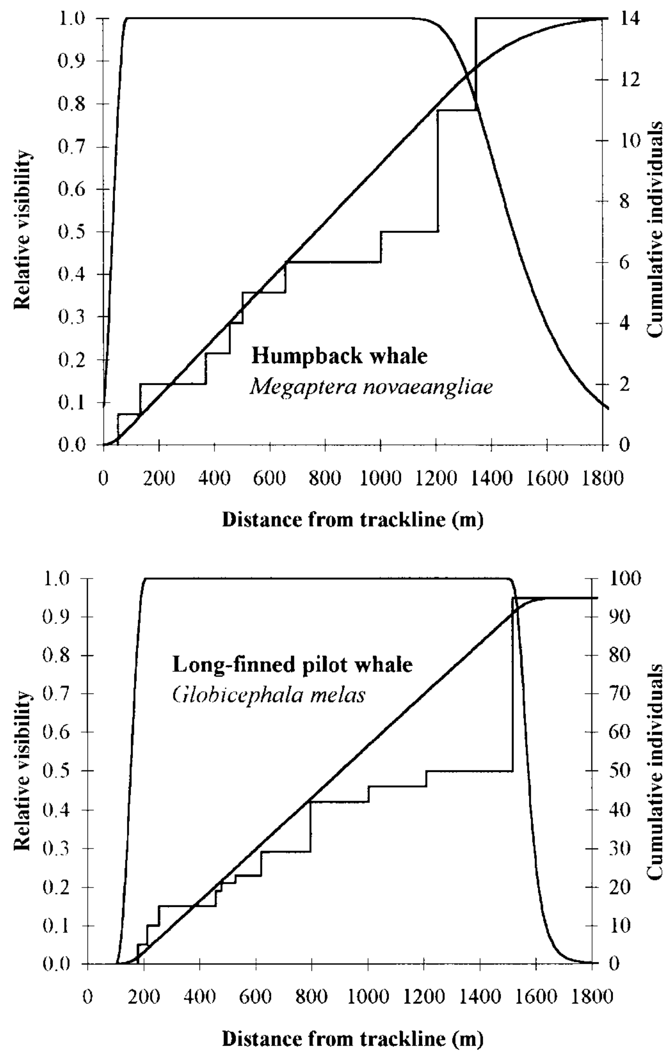


Fig. 7. Cumulative sightings, plotted against distance from the trackline, of 14 individual humpback whales and 135 long-finned pilot whales, with fitted visibility curves both simple and cumulative.



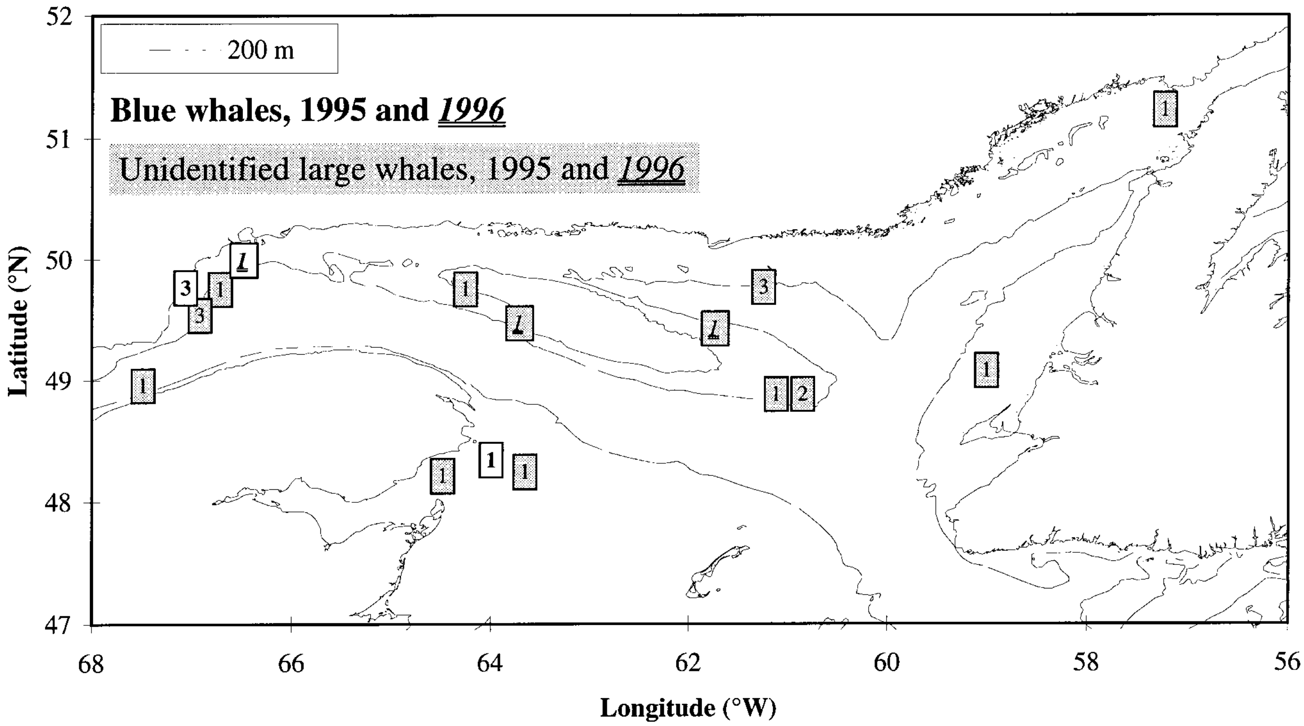
4, the observers were often unable to identify them to species (Table 3). Severe sun glare dramatically reduces sighting efficiency for all species, as others have found (see above) and as demonstrated by our data (Table 4). Therefore, we used only the effort and sightings in sea state 0–2 and glare 0–1 conditions ("very good") for all odontocetes and the minke whale and only those in sea state 0–3 and glare 0–1 conditions ("good") for the larger species (blue, fin, and humpback whales). It is possible that small species such as the harbour porpoise prefer sheltered waters, where waves are *usually* more moderate, and if so, applying density estimates made in such areas to other, more exposed, parts of the study area would overestimate numbers. However, quantitative evaluation of this hypothesis has not been undertaken and is outside the scope of this study.

The hazard-rate curve used was easily fitted to the distance data. On average, for the common species, maximum sighting rates were not achieved until about 150 m from the trackline, but most species then had a range of distances, varying with species, where sighting rates were constant. For all species, recorded group size was positively correlated with distance from the trackline, and the ESW fitted to sightings was less than that fitted to individuals (Table 5). This could be because either (*i*) single animals or small groups are missed at distance or (*ii*) single animals or small groups are distinguished when close in, but are recorded as aggregated when farther away. Such effects could vary by species. Minke whales, porpoises, and white-sided dolphins, all having relatively large sample sizes, showed decreases in recorded density of individuals at distance, lending credibility to the first possible explanation. Humpback whales, pilot whales, and white-beaked dolphins showed constant or increasing density of individuals with distance, but all had small numbers of observations.

There were 370 identified sightings comprising 1289 individuals between the two years of survey (Table 6). Three species had enough sightings for line-transect analysis to work well. These were the minke whale, the Atlantic white-sided dolphin, and the harbour porpoise. Detection curves for these species showed well-defined plateaux, indicating that the decline in detection due to distance did not overlap that due to proximity (Figs. 4 and 5) and that the estimate of density was not biased by the loss of sightings close in. The drop-off at distance was sudden and marked for all these species and occurred at 286 m for harbour porpoises and 456 m for white-sided dolphins and minke whales. The detection curves for the white-sided dolphin and the minke whale had tails that continued to greater distances, but for the harbour porpoise the decline in detection was rapid and nearly total (Fig. 4). The estimated error coefficients of variation for the survey expansion factors for these species were all near 15% (Table 5).

Four other species had between 10 and 20 usable sightings but such variable group sizes that the effective number of sightings was in each case less than 10. Line-transect procedures were used, but the results were unconvincing. The sighting distribution for white-beaked dolphins showed a nearly constant density out to a limit at about 430 m

Fig. 8. Sighting positions of blue whales and unidentified large whales in aerial surveys of the Gulf of St. Lawrence in 1995 and 1996.



(Fig. 5), which was near the visibility drop-off for the white-sided dolphin, and jackknife procedures worked well. But the effective number of sightings was so low that the estimated error was large, as it was for fin whales (Fig. 6).

For humpback whales and long-finned pilot whales, line-transect methods worked less well. Two groups of each of these species, larger than those seen close in, were recorded at the outer limit of vision. These distant sightings dominated the calculation of ESW. Jackknife estimation of uncertainty uses subsamples obtained by deleting observations singly, and when the most distant observation was deleted, the calculated ESW changed little because the second most distant was close to it. We therefore think that jackknifing underestimated the true uncertainties in ESW for these two species (Table 5, Fig. 7).

This study was limited by its attempt to target a wide range of species (see Scott and Gilbert 1982). Visual searches by single observers travelling at high speed can be relatively efficient at detecting harbour porpoises only when the search pattern is confined to a narrow strip along the trackline. While the observers in this study did regard the harbour porpoise as a high priority and therefore concentrated much of their attention on the area within 1000 m of the trackline, they also scanned for whales and dolphins at greater distances. The multispecies nature of these surveys compromised our efficiency at detecting any particular species or species group.

The density and abundance estimates represent only the number of animals present at the surface during overflight (availability bias) and seen by the observers (detection bias) (Marsh and Sinclair 1989). These biases are negative and contribute to underestimation of true abundance. Failure to identify sightings also, overall, creates a negative bias, although the effect of *wrong* identifications, if any, is unpredictable.

Table 7. Recorded distances to (primary) sightings of identified large whales and to unidentified "whale species" and "large whale species."

	Number of sightings at:		
	<305 m (1000 ft)	305–1830 m	>1830 m (6000 ft)
Fin whales	8 (10)	8 (21)	1 (1)
Humpback whales	2 (2)	9 (12)	0 (0)
"Whale species"	2 (2)	6 (6)	1 (1)
"Large whale species"	0 (0)	3 (3)	3 (6)

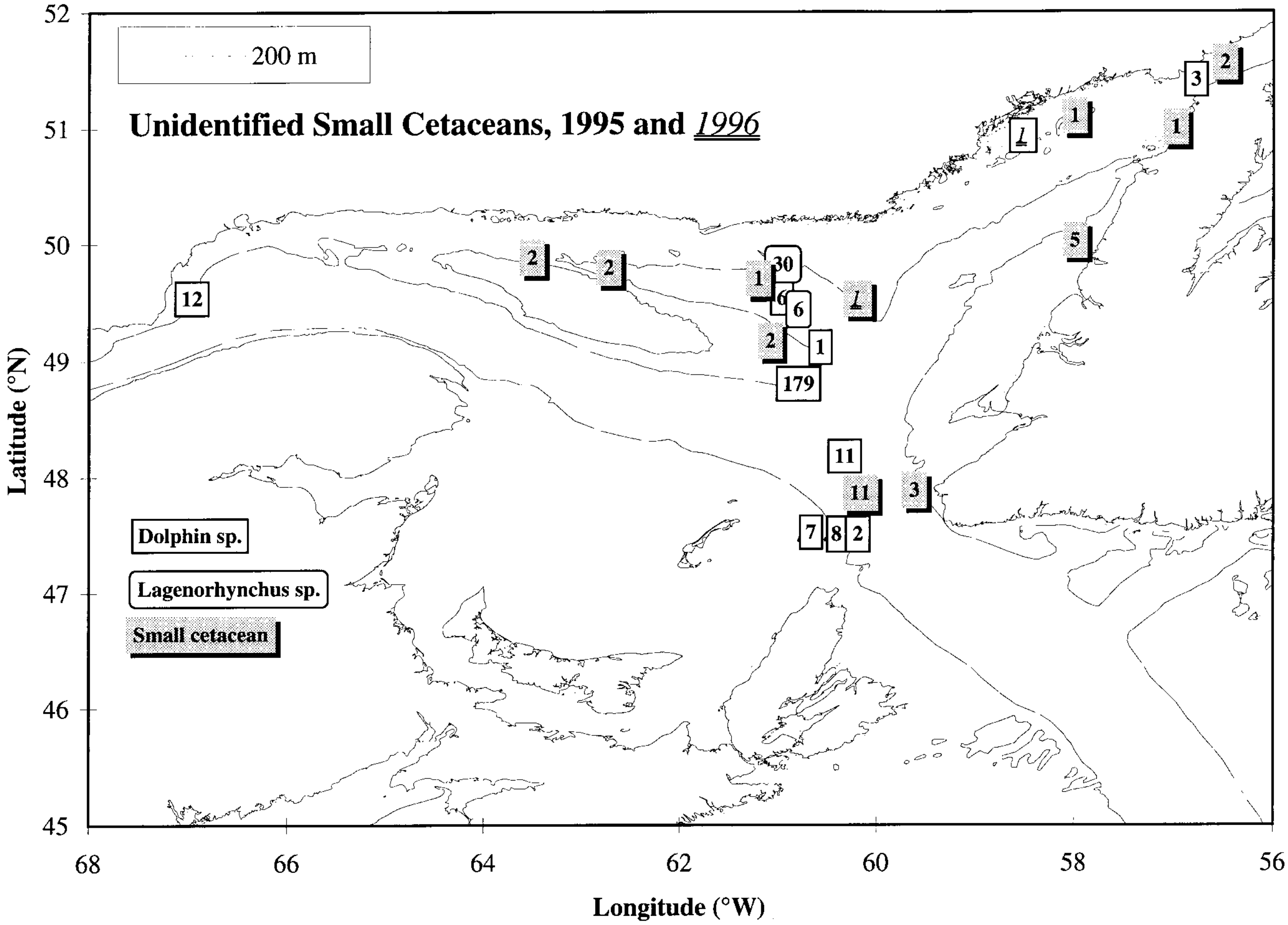
Note: Numbers in parentheses show the number of individuals.

Recorded observations of unidentified species

Twelve percent of sightings, comprising 20% of individuals, were unidentified to species, but all except three or four sightings were probably common species that were not well enough seen to be identified. Unidentified sightings were classified on the basis of comments in the field notes (see Table 1). Group-size statistics gave some clues as to what they might have been. "Small whales" were often marked "not minke" or "smaller than minke," and the groups are too large to be minke whales, but on the other hand are too small to be typical of dolphins. The group-size statistics for "whale species," which were almost all singleton, are consistent with their being mostly minke whales, but the sighting distances or conditions would in any case have disqualified most of these sightings for estimating densities.

Ten primary sightings (13 individuals) and 1 secondary sighting (3 individuals) were logged as unidentified "large

Fig. 9. Sighting positions of unidentified small cetaceans in aerial surveys of the Gulf of St. Lawrence in 1995 and 1996.



whales" (Fig. 8; Table 1). "Large whales" were often marked "fin or blue" or "larger than minke" on the record sheets; however, the group size statistics, showing mostly singletons, are more consistent with blue whales than fin whales. The high number of unidentified sightings obviously confounds interpretation of survey results for large mysticetes, but these sightings, like those of smaller species, were mostly at greater distances (Table 7). Most of the time, whales that were well seen at close range were unambiguously identifiable. None of the unidentified whales were sperm or right whales, and we are confident that they were all rorquals.

Unidentified cetaceans were not allocated to species and therefore are not accounted for in the density and abundance estimates. Most such sightings were either outside the full-visibility strip, so they would have had little effect on density estimates anyway, or they were made under conditions that would disqualify them. However, three sightings of unidentified *Lagenorhynchus* dolphins, comprising 36 individuals, were all in acceptable sighting conditions and within the full-visibility window.

One group of unidentified sightings was of particular interest. A school of about 150 dolphins was seen approximately 90 km southeast of Anticosti Island on 28 August 1995 (Fig. 9), and two smaller groups (25 and 4 individuals) of the same species were seen nearby. The dolphins were staying in the same area, swimming very actively at the surface (although not jumping) and changing direction frequently and suddenly. Large numbers of seabirds were circling and diving. At least six large mysticetes (some, possibly all of them, fin whales) were present in the area at the same time (see below). These dolphins were not *Lagenorhynchus* and were tentatively identified in the field as either striped dolphins (*Stenella coeruleoalba*) or short-beaked common dolphins (*Delphinus delphis*). Both have been reported occasionally from shelf and slope waters off Nova Scotia and southern Newfoundland (Gaskin 1992*b*; Baird et al. 1993), but nothing in the published record would have led us to expect such a large aggregation of either species inside the Gulf.

Distribution, density, and numbers by species

Estimates, uncorrected for visibility bias, obtained from line-transect analysis are given in Table 8 by species (both years) and stratum (1995 only). These estimates are probably reasonable for minke whales, Atlantic white-sided dolphins, and harbour porpoises but less reliable for white-beaked dolphins, fin whales, humpback whales, and long-finned pilot whales, all of which had few sightings.

Harbour porpoise

Sixty-four primary and 3 secondary sightings of harbour porpoises were made, totalling 193 and 6 individuals, respectively, in 1995. One hundred and forty-one primary

Table 8. Estimated numbers, uncorrected for visibility bias, of the principal species of cetacean in the Gulf of St. Lawrence from line-transect aerial survey in the summers of 1995 and 1996.

	Estimated number				
	Stratum N				
	1995	1996	Stratum C, 1995	Stratum SW, 1995	Total, 1995
Fin whales	180 (200)	340 (240)	220 (180)	0	380 (300)
Humpback whales	120 (50)	40 (30)	0	0	120 (50)
Minke whales	760 (220)	620 (320)	100 (100)	160 (90)	1020 (280)
Long-finned pilot whales	0	0	1220 (1000)	360 (280)	1 600 (1040)
Atlantic white-sided dolphins	5400 (2340)	560 (500)	1640 (1080)	4700 (4540)	11 740 (5460)
White-beaked dolphins	2640 (2080)	2 380 (2540)	0	0	2 640 (2080)
Harbour porpoises	7220 (2340)	21 720 (8360)	1440 (880)	3440 (1640)	12 100 (3200)

Note: Values up to 100 have been rounded to the nearest 10 and greater values to the nearest 20. Values in parentheses show the estimated standard error.

sightings and no secondary sightings were logged in 1996, with a total of 302 individual porpoises counted. The mean group size for all 208 sightings was 2.42 (SD = 2.24), but in some areas, sightings were aggregated. This species could be equally well seen out to about 285 m, but the probability of detection then decreased rapidly (cf. Calambokidis et al. 1992, who found this probability to be almost nil beyond 400 m). The uncorrected abundance estimate in 1995 was about 12 000, but in 1996 was 21 000 in the northern part of the Gulf alone, to which we may add about 5000 for the central and southern strata, assuming them to have remained the same as in 1995.

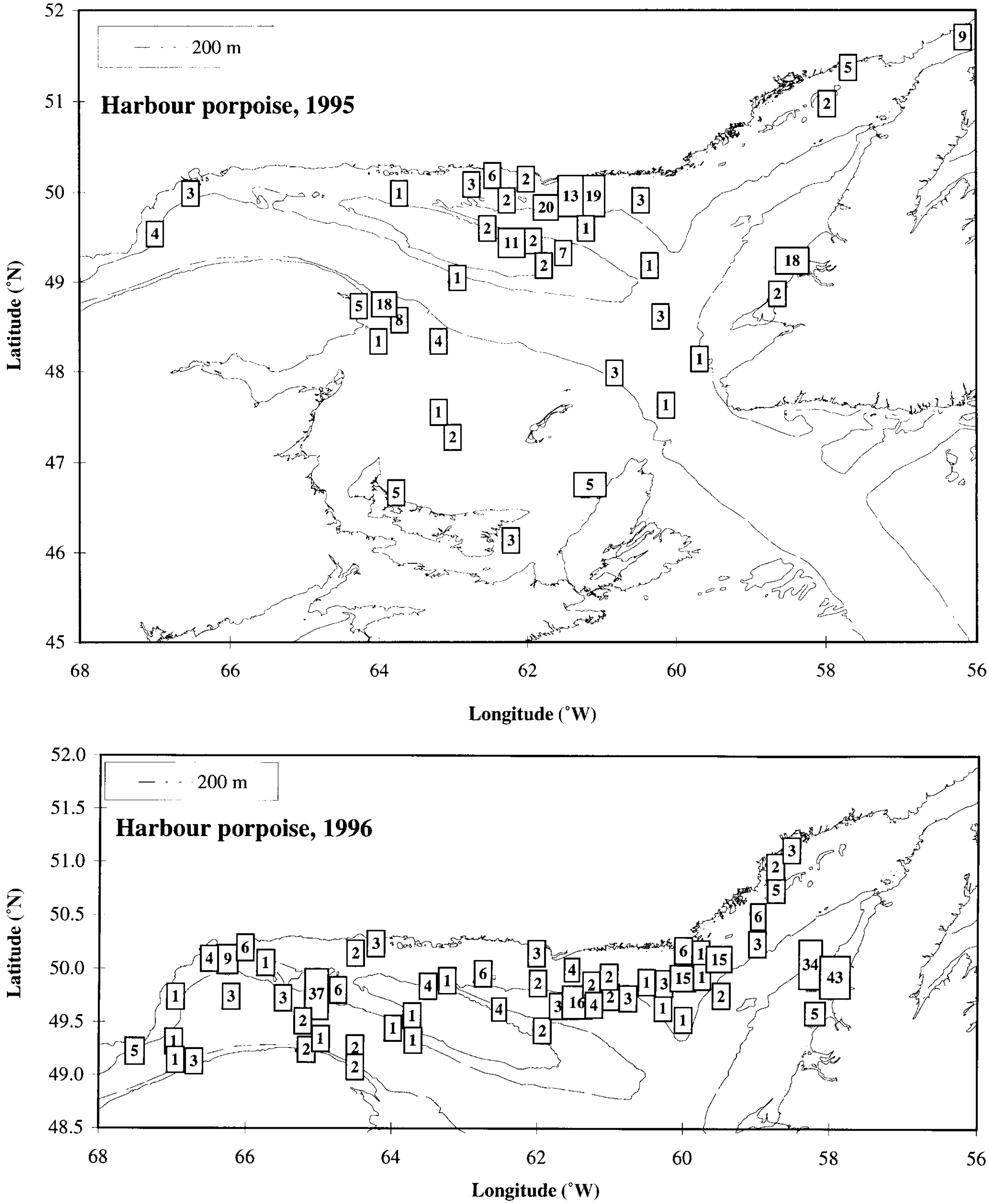
Porpoises were widely distributed but, judging mainly from the 1995 survey, are most abundant in late summer in stratum N and moderately abundant in the other two strata. Apparent differences in distribution between the two years are confounded by effort considerations and the difference in timing of the surveys. Four areas of exceptionally high density were evident from the geographical distribution of sightings in this data set: centred on Banc Parent in the entrance of the St. Lawrence estuary, from the centre of Jacques Cartier Passage and eastward on the north shore shelf, on the Newfoundland shelf from Bay of Islands northward, and immediately outside the entrance of Gaspé Bay (Fig. 10). However, 2 years of data are not enough to say whether these highly used areas are stable over time. Palka (1995), in extended surveys of the Bay of Fundy and the Gulf of Maine, also found a heterogeneous distribution. Frequentation of the Jacques Cartier Passage is supported by Hoek's (1992) observation of a large aggregation in those waters and by Gaskin's (1992*a*) description of Jacques Cartier Passage as a summer concentration area. Gaskin also referred to "frequent" sightings near the Magdalen Islands during the 1950s, which we could not confirm.

Some 1500–2000 harbour porpoises were taken annually as a fishery bycatch, mainly in the northern Gulf of St. Lawrence and off the Gaspé Peninsula, during the late 1980s (Fontaine et al. 1994*a*). Unknown, but possibly large, numbers have also been taken in inshore fishing gear along the Newfoundland and Labrador coasts (Gaskin 1984). Some directed hunting of harbour porpoises (which are locally esteemed as food) has occurred, and may still occur, in parts of the St. Lawrence system, especially along the lower north shore and on the west coast of Newfoundland (Gaskin 1984). The four areas of exceptional porpoise density (identified above) correspond in a general way to regions of high incidental catch mapped by Fontaine et al. (1994*a*). Bycatch in 1992 in bottom-set gill nets was concentrated in areas of the Gulf where fishing effort was heavy, i.e., in the northeast, near the western end of Anticosti Island, east of the Gaspé Peninsula, and on the Miscou Bank in the southwest Gulf (M.-L. Larrivée, personal communication).

It has been suggested that the harbour porpoise has too small reserves of energy to feed seasonally and must therefore be closely linked year-round to a reliable food base (Brodie 1995). Capelin (*Mallotus villosus*), Atlantic herring (*Clupea harengus*), and redfish (*Sebastes* spp.) are its principal prey in the estuary and northern Gulf of St. Lawrence (Fontaine et al. 1994*b*). In the Bay of Fundy, porpoises appear to favour interisland passages, perhaps because currents there trap or concentrate juvenile herring (Watts and Gaskin 1985). Capelin and herring spawn in the St. Lawrence estuary in spring, and herring probably also spawn there in autumn (de Lafontaine 1990; Gagné and Sinclair 1990). The downstream dispersion of larvae, juvenile fish, and spent adults during the summer may create good feeding conditions for harbour porpoises in the lower estuary and northwestern Gulf. Redfish are also abundant and spawn in the north-central Gulf (Runge and de Lafontaine 1996).

Gaskin (1984) proposed that the harbour porpoises in the St. Lawrence system were 1 of 14 subpopulations in the North Atlantic, possibly further divided into 2 smaller population units by the deep Laurentian Channel. Later, Gaskin (1992*a*) made a very crude abundance estimate of 11 900 to 28 800 porpoises in the Gulf, based on a series of tenuous assumptions about catch and yield. Our results, although not definitive, provide a starting point for assessing the ability of the Gulf population to withstand bycatch. In the late summer of 1995, we estimated about 7000 harbour porpoises visible from the air in stratum N and about 5000 in the other two strata combined; in 1996, we estimated about 21 000 in the sampled portion of the study area. These values are too low by substantial, but unquantifiable, factors of both availability and detection. Experienced observers have been estimated to record from the air only 33.8% of porpoises present on the trackline and inexperienced observers only 7.9% (Laake et al. 1997), and this from an aircraft with a belly window and bubble side windows. A suitable adjust-

Fig. 10. Sighting positions of harbour porpoises in aerial surveys of the Gulf of St. Lawrence in 1995 and 1996.



ment for availability and detection bias would be to multiply counts by experienced observers by 3. If the observers in our study were approximately midway between "experienced" and "inexperienced" (by the criteria of Laake et al. (1997) for dedicated harbour porpoise surveys), which was probably true at least in 1995, our abundance estimates would be too low by a factor of approximately 5. In addition, the observers in our surveys were not always focusing their attention on the area close to the trackline where harbour porpoises are most likely to be detected, but were searching a wider swath along the flight path for cetaceans of any size. It appears from these results that there might be of the order of 36 000 (i.e., 12 000 × 3) to 125 000 (i.e., 25 000 × 5) porpoises in the Gulf in summer.

Atlantic white-sided dolphin

This species was the most difficult to count of those seen, and for many of the sightings we used rounded estimates or midpoints of the ranges recorded by the observers. In 1995, these dolphins often occurred in loose groups of associated pods, each pod consisting of 5–25 individuals. Because of this, the observers were not entirely consistent in the way they recorded sightings: usually, small groups in the same general area were entered as separate sightings, but a few times they were lumped into a single sighting, so the calculated mean group size is positively biased. Thirty-nine primary and 2 secondary sightings, totalling 321 and 30 individuals, were made in 1995; only 3 sightings of a total of 12 animals were made in 1996. The mean group size (all sightings combined, $N = 44$) was 8.25 (SD = 8.73). The uncorrected estimate for 1995 for the Gulf was about 12 000, of which about 5400 were in the northern stratum; however, in 1996 our estimate was only 500.

In both years, sightings were scattered round the margins of the Gulf, mainly along areas with steep bottom relief (Fig. 11), a pattern consistent with that found for this species in the Gulf of Maine and south along the U.S. coast (Selzer and Payne 1988). Three 1995 sightings (totalling 36 animals) identified in the field only to genus (Fig. 9) were probably this species, judging by the distributions of identified sightings of the two *Lagenorhynchus* species (see below).

The Atlantic white-sided dolphin is abundant in cool temperate waters of the North Atlantic (Reeves et al. 1998*a*). It was widely distributed in all three strata in 1995, and from our data was the second most abundant species in the Gulf at the time of that survey, but in 1996, we hardly saw any. White-sided dolphins occur in the St. Lawrence system as far west as the confluence of the Saguenay River (Sergeant et al. 1980; Katona et al. 1983; Gaskin 1992*c*), but there is no evidence that they congregate regularly in any area. Sightings have been made in the estuary: off Baie-Comeau in summer 1990, and in 1991, by a party conducting a ship survey for porpoises, in the Honguedo Channel (12 July 1991 on 65°15′W at 49°12′–49°13′N and on 13 July 1991 on 64°25′W at 49°17′–49°21′N) (M.C.S. Kingsley, unpublished data). In fall of 1990, a group of white-sided dolphins seems to have gotten into Northumberland Strait and lost its way out: there were repeated live strandings, entrapments, and other sightings between September and December of that year in Bedeque Bay near Summerside, P.E.I., in Charlottetown Harbour and its tributary rivers, and on other parts of the south coast of Prince Edward Island (Department of Fisheries and Oceans, unpublished records).

Our results show a large difference between years, which we are uncertain how to interpret. The 1996 survey may have taken place ahead of the peak season for these dolphins in the northern Gulf, or, more likely, if this is a gregarious, roving species, the numbers of Atlantic white-sided dolphins visiting the Gulf may vary greatly from year to year. Since they also occur in late summer in the Gulf of Maine and Bay of Fundy and on the Scotian Shelf, the estimate presented here represents only a part of the western North Atlantic population; there may be more than 100 000 in the entire North Atlantic (Reeves et al. 1998*a*).

White-beaked dolphin

There were 17 sightings of this species, totalling 147 individuals (both years, combined), giving a mean group size of 8.65 (SD = 7.84). White-beaked dolphins were easier to count than white-sided dolphins, as they occurred in single, compact pods. With few sightings, our estimates were imprecise but in each year were near 2500. The 1995 and 1996 surveys covered distinct areas of the northeastern Gulf: in 1995 the Strait of Belle Isle was surveyed, but only as far west as 58°, while in 1996 the eastern limit on the north shore was at 58°30′. If we are correct in concluding that white-beaked dolphins are mostly found in the extreme northeast, total numbers might be better estimated by the sum of the 1995 and 1996 estimates than by their average.

Alling and Whitehead (1987) surveyed the Atlantic (outer) coasts of Labrador and northeastern Newfoundland, inside the 200-m contour, by ship for white-beaked dolphins in August 1982. Their study area abutted, but did not overlap, the eastern limit of ours. They estimated a mean density of 0.065 dolphin/km^2 in that survey (total estimated abundance 3486); we estimated about 0.044/km^2 in 1995 and 0.025/km^2 in 1996 in the northern part of the Gulf, but in both years our density estimates were averaged over much larger areas than are frequented by this species.

The white-beaked dolphin is another North Atlantic endemic, generally more northerly, cool-water, and coastal than the Atlantic white-sided dolphin (Reeves et al. 1998*b*). We saw white-beaked dolphins only in the Strait of Belle Isle or on the north side of the Esquiman Channel (Fig. 12). Although this species is seen as far west as the Mingan Islands at about 64°W (I. Gauthier, personal communication), our westernmost observations were at about 58°W in 1995 and 59°30′W in 1996, and all but one of our sightings were in water less than 100 m deep. This restricted distribution, all in shallow waters of the Strait of Belle Isle or the northeast corner of the Gulf, is consistent with previous reports (e.g., Sears and Williamson 1982).

The observation that the two *Lagenorhynchus* species are locally parapatric in the Gulf is consistent with observations on their distributions elsewhere in the North Atlantic (Reeves et al. 1998*a*, 1998*b*). As these two odontocetes are similar in size and configuration, competitive exclusion may be the cause.

Long-finned pilot whale

The 16 primary and two secondary sightings (totalling 110 and 56 individuals, respectively) were all made in 1995 in the southeastern part of the Gulf (Fig. 13), in deep water with steep bottom relief. The concentration of sightings off northwestern Cape Breton Island was located over the Cape Breton Trough, which terminates off Cheticamp, N.S., and northeast of there descends abruptly to about 300 m.

Like Atlantic white-sided dolphins, long-finned pilot whales often occurred in small, tight pods travelling in loose

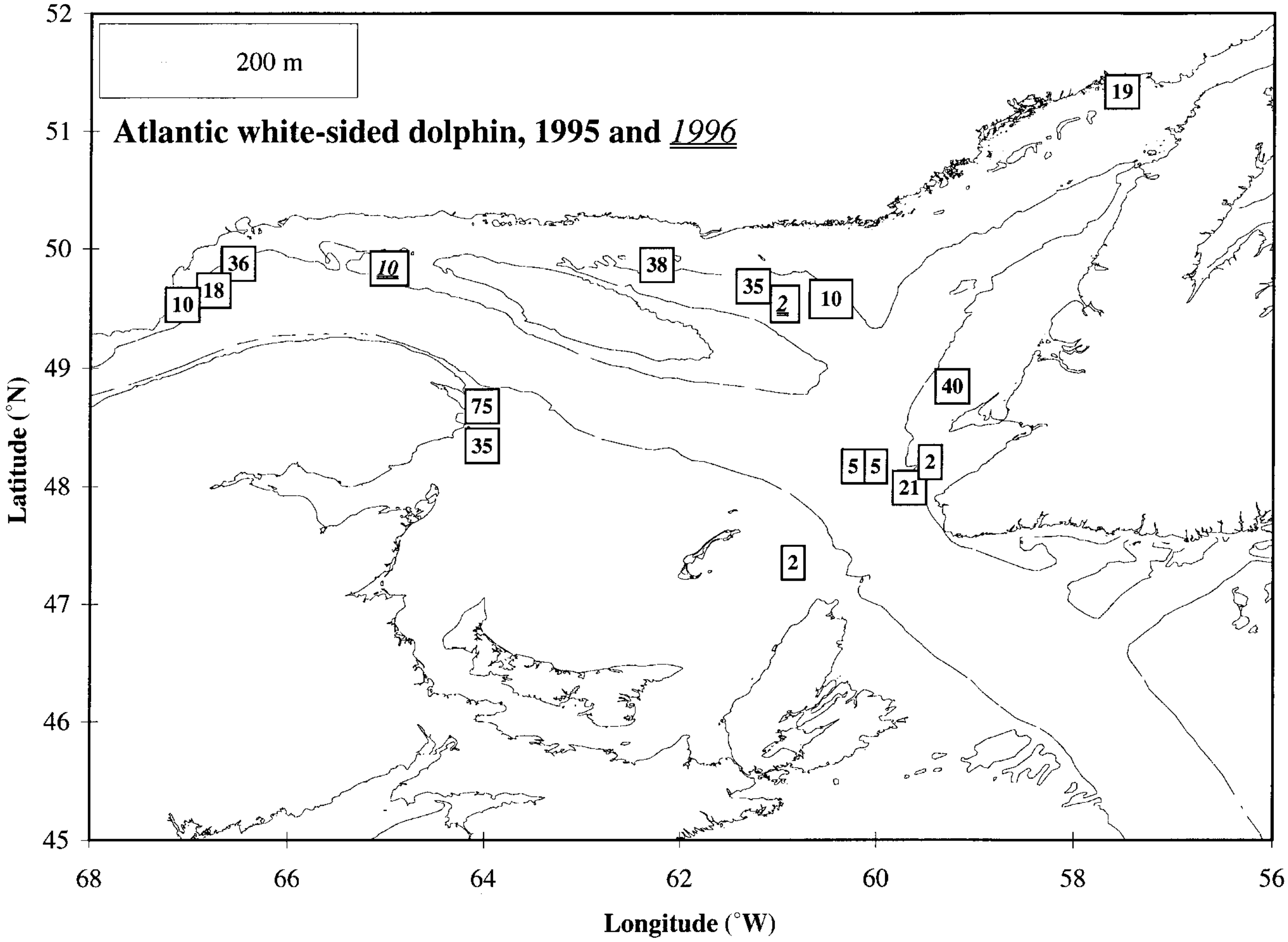


Fig. 11. Sighting positions of Atlantic white-sided dolphins in aerial surveys of the Gulf of St. Lawrence in 1995 and 1996.

association with one another. The mean group size was 9.22 (SD = 12.15), not including a secondary sighting of at least 50 whales very near the Cape Breton coast. On this and at least one other occasion, the whales were milling and seabirds were circling and diving nearby, all suggestive of feeding.

Long-finned pilot whales have been reported regularly from the southeastern part of the Gulf. For example, schools of more than 100 stranded alive in August 1990 and again in November 1995 near Cheticamp (Department of Fisheries and Oceans, unpublished journals). "Large numbers" of pilot whales were reported by fishermen and fishery officers off Georgeville, N.S., in mid-September 1991, and a group was seen in the harbour at Pugwash, N.S., from 6 to 20 September 1993 (Department of Fisheries and Oceans, unpublished reports). Between August and December 1997, there were reports of strandings of single dead adult pilot whales all along the northwest coast of Cape Breton Island, totalling some 20–30 whales (Department of Fisheries and Oceans, unpublished journals). In the present survey, the occurrence of pilot whales was strikingly limited to the southeastern Gulf, which is also the only area where this species was seen by Sears and Williamson (1982), and it would appear that their distribution within the Gulf, as perhaps elsewhere (Sergeant 1982, p. 4), is associated with an appropriate combination of depth and temperature. Sightings are relatively infrequent elsewhere in the St. Lawrence system, but 40, apparently feeding, were seen in a single group near Les Escoumins (48°24.33′N, 69°10.75′W) in mid-August 1995 (unpublished observations), and Sergeant (1982, Fig. 3) plotted six occurrences distributed on all coasts of the Gulf except the north.

Pilot whales in the Gulf are probably part of a much larger population centred on the continental shelf and along the shelf edge from Newfoundland to the southern Gulf of Maine (Hay 1982; Payne and Heinemann 1993). Sergeant (1962) and Mercer (1975) found them to be closely associated with mass inshore occurrences of short-finned squid (*Illex illecebrosus*) along eastern Newfoundland. In U.S. waters, their seasonal movements and distribution seem to be correlated with concentrations of two additional species, the long-finned squid (*Loligo pealei*) and the Atlantic mackerel (*Scomber scombrus*) (Payne and Heinemann 1993).

Beluga

No belugas were seen in 1995; three sightings totalling six animals were made in 1996, all in an area off Sept-Îles on the north side of the estuary (Fig. 13). These sightings are outside the accepted summer range of the St. Lawrence population, which has been surveyed regularly to monitor population trends (Kingsley 1998).

Minke whale

Forty-three sightings, all but one of them primary, totalled 46 individuals. They were widely scattered throughout the

Fig. 12. Sighting positions of white-beaked dolphins in aerial surveys of the Gulf of St. Lawrence in 1995 and 1996.

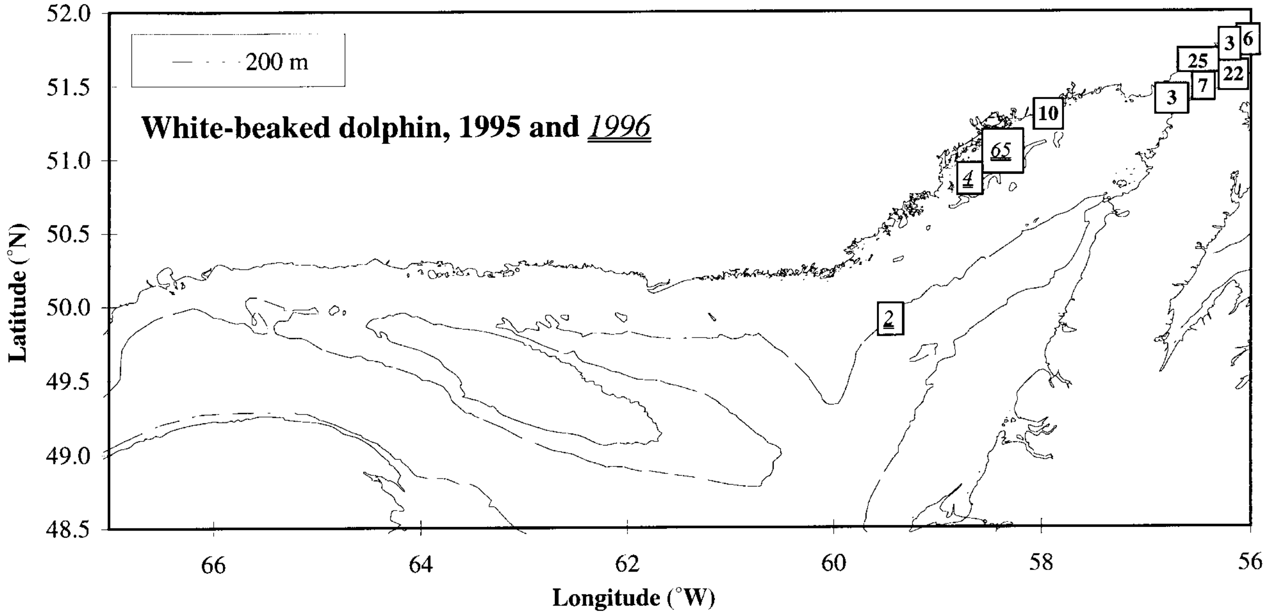
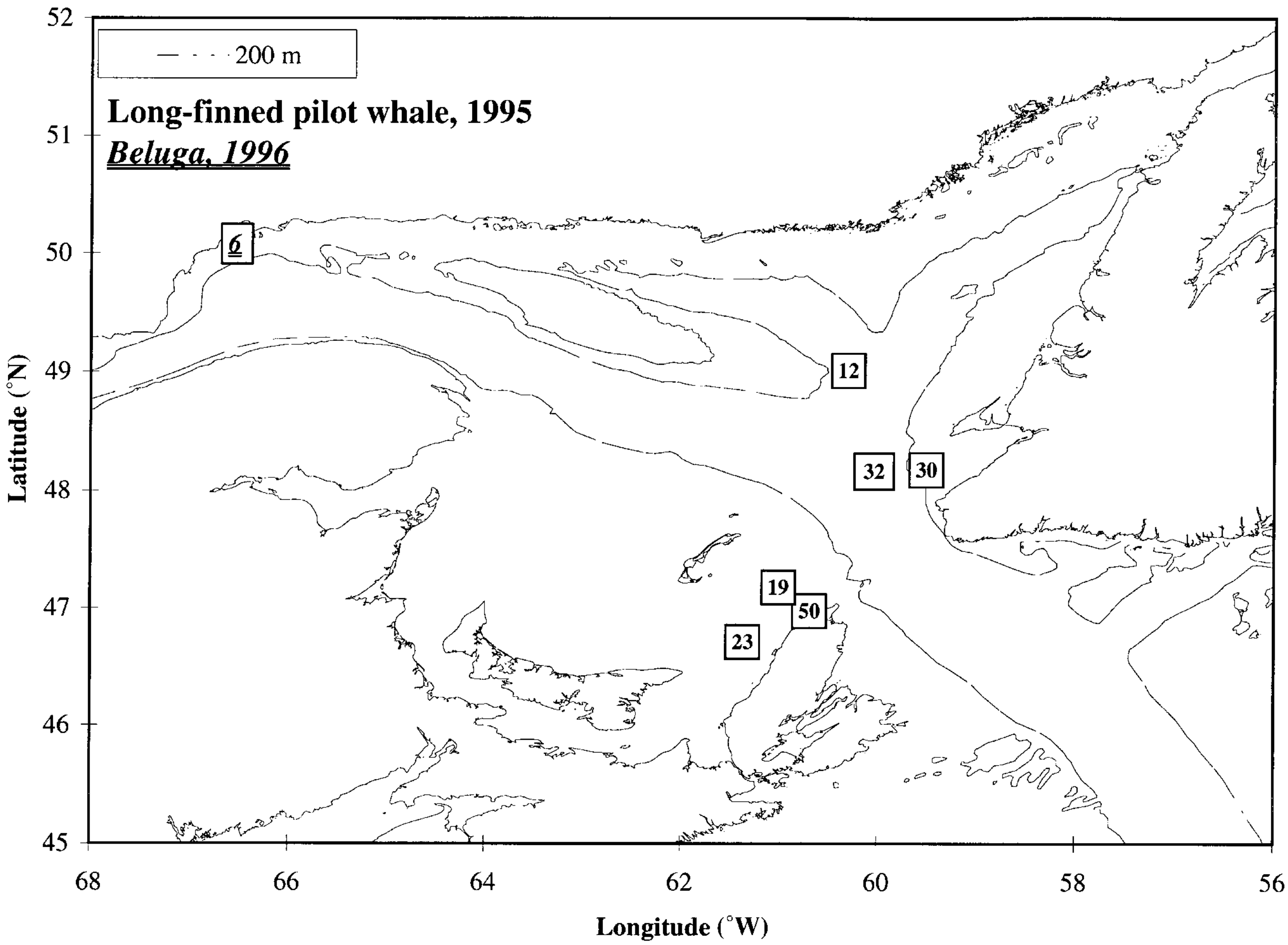


Fig. 13. Sighting positions of long-finned pilot whales in 1995 and of belugas in 1996 in aerial surveys of the Gulf of St. Lawrence.



study area, in water 200 m deep or shallower (Fig. 14). Minke whales were typically seen as single individuals (mean group size = 1.07, SD = 0.26), sometimes with seabirds circling and diving overhead. The line-transect analysis of sighting distances was orderly and produced an uncorrected abundance estimate of about 1000 for the Gulf, of which about 75% were on the north shore shelf. Minke whales are relatively solitary, and even when several are present in the same area, they tend to space themselves well apart and to surface nonsynchronously (Edds and Macfarlane 1987), so they are usually seen singly in aerial surveys (e.g., Gunnlaugsson et al. 1988; Forney et al. 1995). They surface rapidly and briefly, and their visibility from passing aircraft may be low.

Minke whales are regular summer and autumn inhabitants of the St. Lawrence River and the northern shelf region of the Gulf (Sears and Williamson 1982; Edds and Macfarlane 1987). They use inshore waters more freely, and in the St. Lawrence occur farther upstream, than other mysticetes (cf. Perkins and Whitehead 1977). The distribution of sightings in our surveys suggests that minke whales occur rather evenly and in relatively high densities along the north shore, while elsewhere in the Gulf, they are patchily, but widely, distributed. Capelin are generally regarded as the principal prey of minke whales off eastern Newfoundland (Sergeant 1963; Mitchell and Kozicki 1975), and at the head of the Laurentian Channel, they appear to indulge in schools of capelin that have been concentrated by converging currents (Lynas and Sylvestre 1988; Y. Simard, personal communication). Little is known about their feeding habits in the Gulf of St. Lawrence (cf. Edds and Macfarlane 1987), but they are known to prey on a wide variety of fish species elsewhere in the North Atlantic (Haug et al. 1996).

Fin whale

The 18 sightings of 34 fin whales, all of them primary, were made mainly along the margins of the Laurentian Channel or on the north shore shelf (Fig. 15). The fin whale was the most widely distributed of the three identified large whale species (fin, blue, and humpback) in the Gulf at the time of our surveys. Mean group size was 1.89 (SD = 1.64). Some large whales seen well away from the trackline were not identified to species (Table 8), but for most of them, field notes showed that the choice had been narrowed to fin or blue on the basis of the height and shape of the blow.

Like minke whales, fin whales are commonly seen in the St. Lawrence River as far upstream as the Saguenay confluence and along the north shore of the Gulf in summer and autumn (Sears and Williamson 1982; Edds and Macfarlane 1987; Borobia et al. 1995). Sergeant (1977) suggested that the fin whales that summer in the St. Lawrence system associate with the steep contours of the Laurentian Channel, either because tidal and current mixing along such gradients drives high biological production or because changes in depth aid their navigation. Our observations indicate that in the summers of 1995 and 1996, fin whales were the most abundant large whales in the Gulf and that their distribution was centred primarily in or near the Laurentian Channel and on the north shore shelf.

Fin whales in the St. Lawrence feed on euphausiids and probably also on schooling fish such as capelin, herring, and sand lance (*Ammodytes* sp.) (Edds and Macfarlane 1987; Borobia et al. 1995). Those observed along the north shore of the St. Lawrence River typically occur in groups, which surface and blow in synchrony. The larger group sizes recorded for fin whales than for minke whales in our surveys are consistent with what is known about the behaviour of these two species.

Humpback whale

All 14 sightings of humpbacks (21 individuals) were on the north shore shelf, mainly in the Strait of Belle Isle and on the north side of the Esquiman Channel (Fig. 16). The mean group size was 1.5 (SD = 0.85). The effective number of sightings included in the line-transect analysis was only 9.2, and the largest groups were recorded at the limit of visibility. The line-transect estimate of density for this species is unreliable, and its standard error even more so; censoring the data at a smaller distance would halve the estimate.

The humpbacks that visit the St. Lawrence in summer are part of a population that migrates along the east coast of North America and winters mainly near the Lesser Antilles. The whales tend to return to a particular “feeding-group aggregation” area in successive years, and recent genetic tagging results confirm this general summering-area fidelity (Palsbøll et al. 1997). However, some switching occurs, e.g., between the St. Lawrence and the Gulf of Maine, eastern Newfoundland, and western Greenland (Katona and Beard 1990), sometimes even within the same season, as between the northern Gulf of St. Lawrence and the Gulf of Maine (Williamson 1985).

Our results confirm that humpbacks occur mainly on the north shore shelf, particularly along the lower north shore and in the Strait of Belle Isle (Sears and Williamson 1982). However, there are records of humpbacks along the north shore as far west as the head of the Laurentian Channel, and they have also been seen in the mouth of Gaspé Bay (M.C.S. Kingsley, unpublished observations).

Blue whale

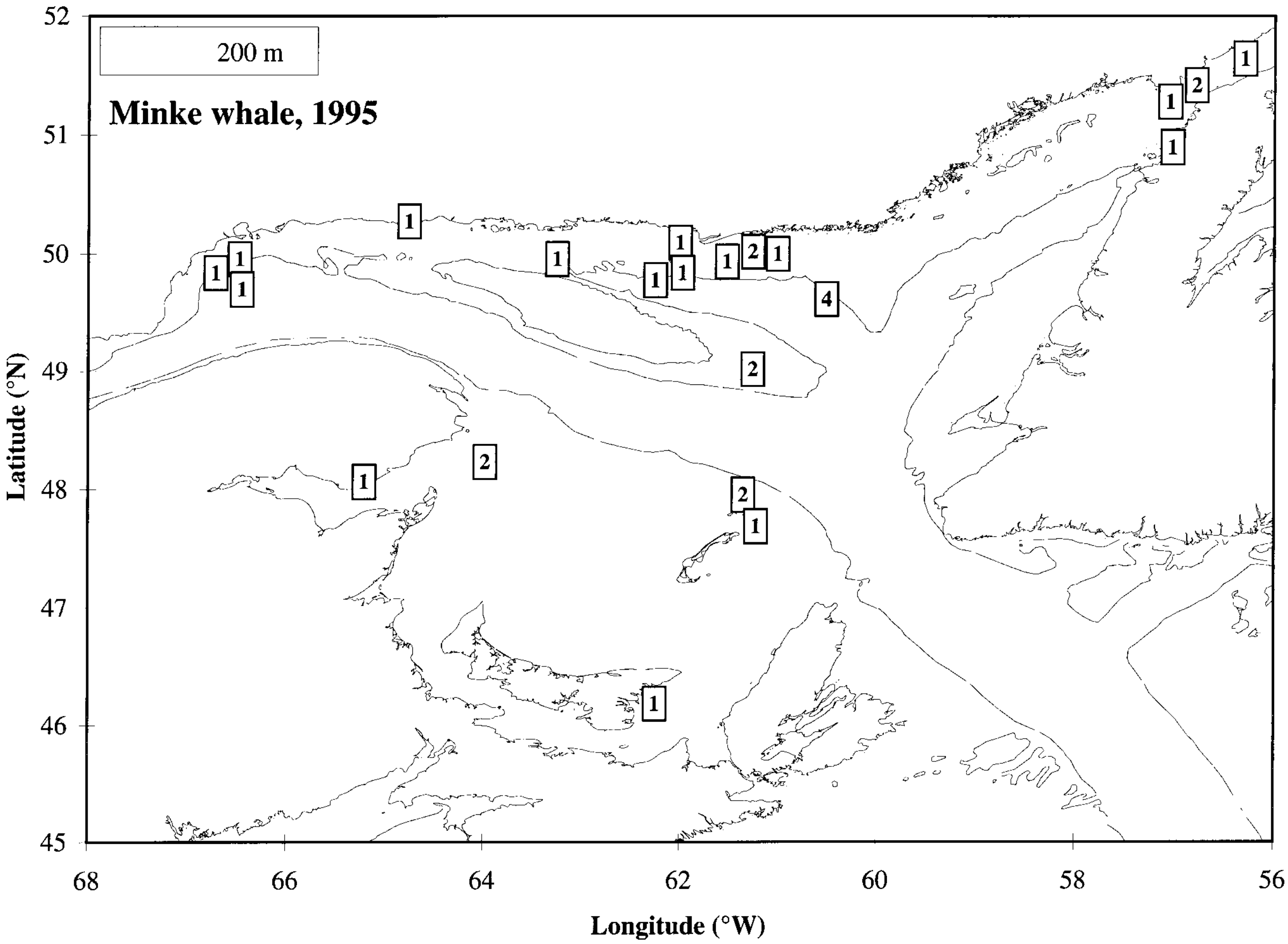
Only two primary and three secondary sightings of blue whales were made, mainly on the north side of the St. Lawrence estuary (Fig. 8). Some “unidentified large whales” could have been blue whales, but even so, the number of blue whale sightings in our survey was lower than we expected.

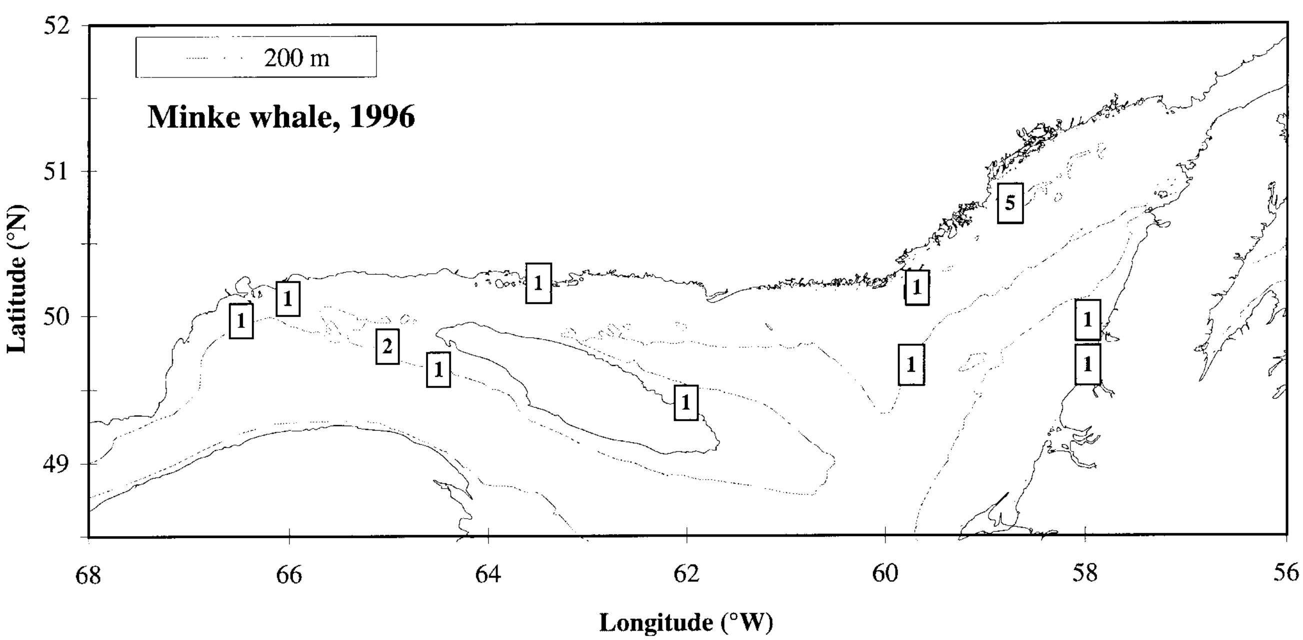
The blue whales in the northern Gulf of St. Lawrence are migratory and belong to a wide-ranging North Atlantic population. Photographs taken in the St. Lawrence and the southern Gulf of Maine (Sears et al. 1990) have been matched to photographs taken in different years in western Greenland (F. Larsen and R. Sears, personal communication), and individual whales have been shown to range widely along the north shore within the same season (Sears et al. 1990).

Areas of local abundance

Aggregating all sightings, we conclude that there are some small areas that are of local interest for their diversity and abundance of cetaceans. The extreme northwestern corner of the Gulf, close northeast of Pointe des Monts, seems to be frequented by a range of cool-water species, including the harbour porpoise, the Atlantic white-sided dolphin, and balaenopterid whales. A small area east of the Gaspé Peninsula seems also to be favoured by these species. The Jacques Cartier Passage and the east end of Anticosti Island seem to have significant numbers of porpoises, and large mysticetes

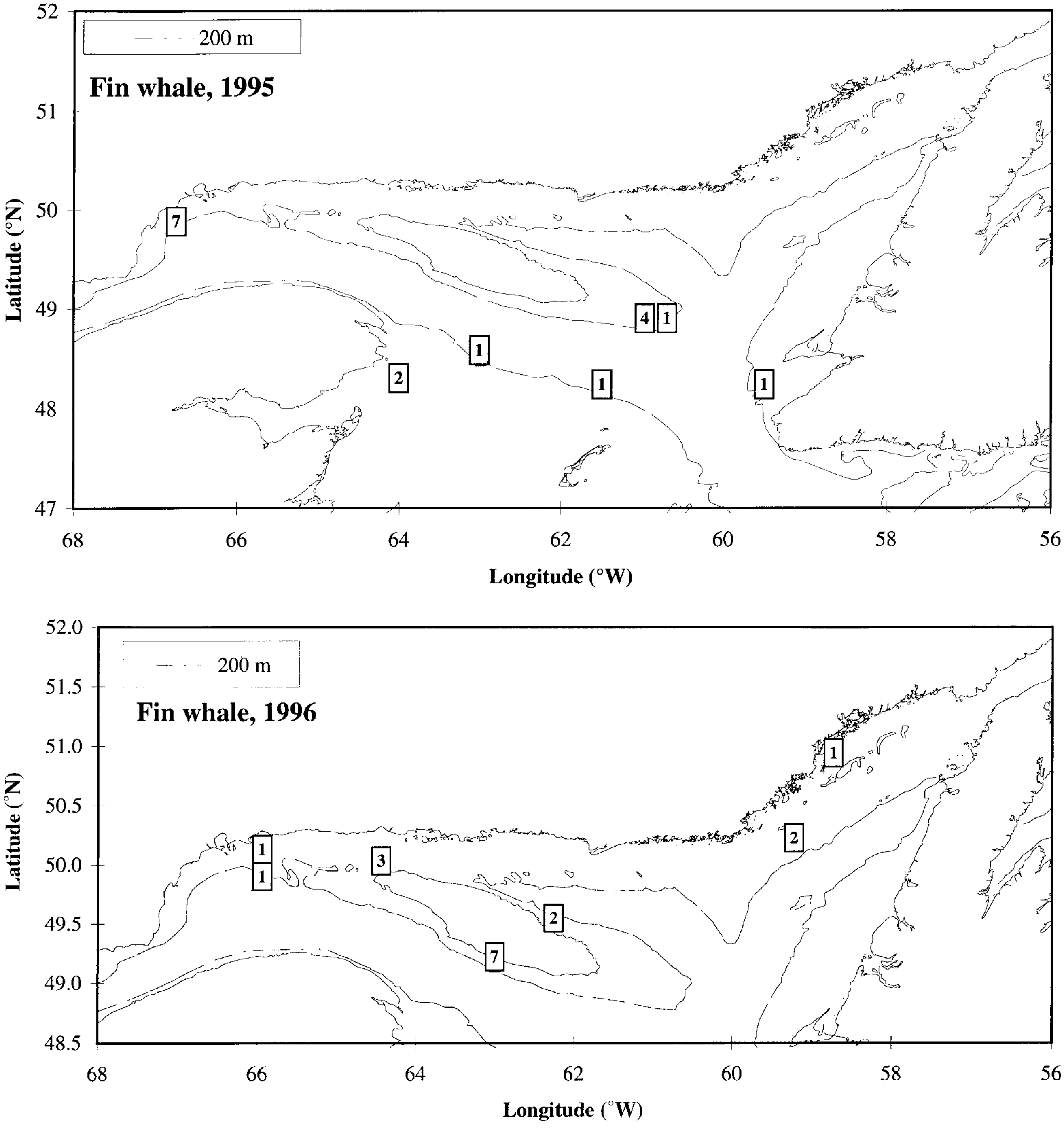
Fig. 14. Sighting positions of minke whales in aerial surveys of the Gulf of St. Lawrence in 1995 and 1996.





(blue and humpback whales) have long been supposed to frequent those areas. The Strait of Belle Isle has, according to our surveys, a notable presence of humpback whales and white-beaked dolphins. The southeastern part of the Gulf appears to differ from the rest in being the summer destination of schools of long-finned pilot whales.

Fig. 15. Sighting positions of fin whales in aerial surveys of the Gulf of St. Lawrence in 1995 and 1996.

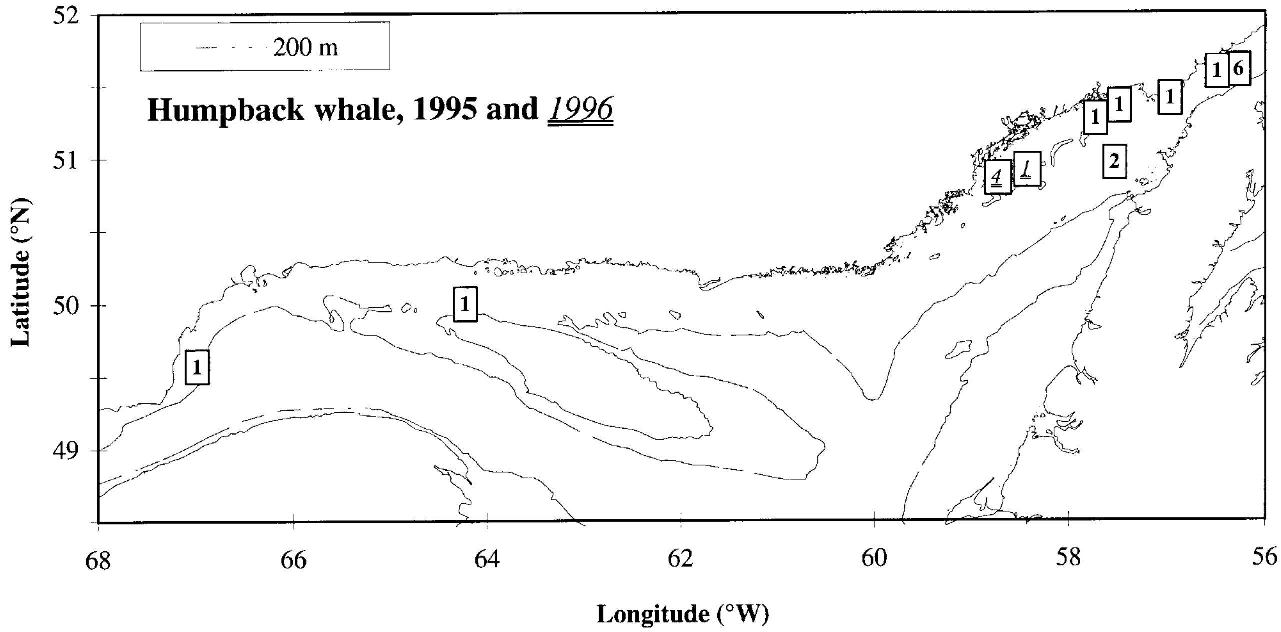


Conclusions

For the most part, these initial surveys of cetaceans in the St. Lawrence confirmed earlier impressions of species composition, spatial partitioning, and relative abundance. The most productive area, with the greatest species diversity, was the north shore shelf (stratum N). The minke whale was the most nearly ubiquitous of the mysticetes. A versatile feeder, it is apparently able to find and exploit patches of prey throughout much of the St. Lawrence system. Of the large mysticetes, the fin whale was the most widely distributed and abundant, while the humpback whale and blue whale were both restricted in their distribution (primarily on the north shore shelf). The blue whale's evident scarcity is not easily explained.

The harbour porpoise was widely distributed throughout the Gulf and occurred in particularly high densities in portions of strata N and C. Our abundance estimates for this species, if adjusted for bias along the lines proposed by Laake et al. (1997), would rival or exceed those for the Gulf of Maine – Bay of Fundy region, which has long been recognized as a major concentration area for the species

Fig. 16. Sighting positions of humpback whales in aerial surveys of the Gulf of St. Lawrence in 1995 and 1996.



(Gaskin 1992*a*; Palka 1995; Palka et al. 1996). The Gulf of St. Lawrence is clearly an important summering ground for harbour porpoises and therefore a promising area for more detailed research on their ecology, stock relationships, and abundance.

The high abundance and wide distribution of Atlantic white-sided dolphins in 1995 were unexpected, judging from published evidence. Gaskin (1992*c*), however, anticipated that once systematic surveys comparable to those done in U.S. waters during the late 1970s and early 1980s were conducted in Canadian waters, additional “prime areas for feeding,” in addition to that in the southwestern Gulf of Maine, would be discovered. In the light of our observations, as well as unpublished mass stranding and sighting records in recent years within the Gulf as far south as Northumberland Strait (M.C.S. Kingsley, unpublished data), we conclude that the St. Lawrence is one such area.

The white-beaked dolphin appeared to be the principal odontocete in the Strait of Belle Isle. The parapatric summer distribution of the two species of *Lagenorhynchus* suggests competitive exclusion between two similar-sized odontocetes. Long-finned pilot whales were relatively abundant in the southeastern corner of the Gulf but absent elsewhere. The sighting of a large school of small delphinids, probably either striped dolphins or short-beaked common dolphins, in association with seabirds and large balaenopterids (probably fin whales) was of special interest.

Several species that are known to occur in the Gulf of St. Lawrence, but in low or very low densities, were not observed. These include the northern right whale, sperm whale, killer whale, and northern bottlenose whale. While sperm and bottlenose whales could have been overlooked because of their long dive times, right and killer whales should have been detected if they were present in substantial numbers.

It is important to emphasize that the study area was defined on an arbitrary geographic basis. Thus, our estimates of abundance should not be interpreted as referring to entire populations or stocks of any species, except for the harbour porpoise, of which our study may have surveyed one or more entire management stocks.

In addition to providing insight about the Gulf-wide distribution and relative abundance of cetaceans during the summers of 1995 and 1996, the results of these surveys should form a useful foundation for designing future surveys. For example, the very different character of the cetacean fauna of the extreme northeastern part of the Gulf (white-beaked dolphins and humpback whales present; relatively low densities of Atlantic white-sided dolphins and harbour porpoises) might argue for a particular configuration of prior stratification that subdivides the north shore shelf into eastern and western strata.

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