Population Indices and Estimates for the Belugas of the St Lawrence Estuary

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Population assessment is the essential component of monitoring species at risk. The belugas (*Delphinapterus leucas*) of the St Lawrence estuary have been monitored by aerial surveys since 1973. The results of the latest survey, by high-altitude aerial photography on 26 August 1997, are reported here and compared with those of earlier surveys. The survey area extended from île-aux-Coudres to île du Bic. Transects 6,000 feet wide spaced 2 n.mi. apart were photographed at a scale of 1:8,000 using colour positive aerial survey film, but 21% of the study area was covered by fog and could not be photographed. Counts were corrected for diving animals by two different factors: a historical standard 15% to yield an index of population size, and a more recent 109% based on behavioural data to yield an estimate of true population. The sequence of survey data was smoothed with linear trends in sets of five points to yield moving averages, current estimates and rates of change.

In the 1997 survey, 284 belugas were counted on 88 of the 832 photo frames taken, and 20 more were counted in the Saguenay Fjord by a simultaneous visual survey. The estimate of the standard index was 681 (SE 91) and of the true population size 1221 (SE 189). From linear smoothing of the most recent five surveys, the current estimate of the standard index was 700 (SE 46), with an increase of 21.4 whales/yr (SE 8.2) and of the true population size 1238 (SE 119) with an increase of 31.4 whales/yr (SE 13.1).

39 vessels from kayaks to barges were counted on the photographs, but there was no evidence of boats tending to be near belugas or seeking to approach them.

RÉSUMÉ

Kingsley, M.C.S. 1999. Population indices and estimates for the belugas of the St Lawrence estuary. Can. Tech. Rep. Fish. Aquat. Sci. 2266 : vii + 27 pp.

L'évaluation des populations constitue l'élement essentiel du monitoring des espèces en péril. Les bélugas (*Delphinapterus leucas*) de l'estuaire du Saint-Laurent ont été inventoriés par relevé aérien depuis 1973. Les résultats du dernier relevé, effectué par photographie aérienne à haute altitude le 26 août 1997, sont présentés ici, et sont comparés avec ceux des relevés antérieurs. L'aire d'étude s'étendait de l'île-aux-Coudres à l'île du Bic. Des transects larges de 6 000 pieds et espacés de 2 milles marins ont été photographiés à une échelle de 1:8 000 en utilisant un film couleur positif spécial pour les relevés aériens. Vingt et un pour cent de l'aire d'étude était couverte de brouillard et n'a pas pu être photographiée. Les dénombrements étaient corrigés pour les animaux en plongée avec deux facteurs différents: un standard historique de 15% donnant un indice d'abondance de la population, et une valeur plus récente de 109% basée sur des données de comportement pour fournir un estimé de la vraie taille de la population. La séquence des données de relevé était lissée de façon linéaire par jeu de 5 points pour fournir des moyennes mobiles, des estimés courants, et des taux de changement de la population.

Lors du relevé de 1997, 284 bélugas ont été identifiés sur 88 des 832 clichés pris, et 20 autres ont été vus dans le fjord du Saguenay lors d'un relevé visuel simultané. L'estimé de l'indice standard était de 681 (ET 91), et celui de la vraie taille de la population était de 1 221 (SE 189). À partir d'un lissage linéaire des 5 survols les plus récents, l'estimé courant de l'indice standard est de 700 (ET 46) avec un taux de croissance de 21,4/an (ET 8,2); et celui de la vraie population est de 1238 (ET 119) avec un taux de croissance de 31,4/an (ET 13,1).

Trente-neuf embarcations allant des kayaks jusqu'aux barges ont été dénombrées sur les photographies, mais aucune tendance à être près des bélugas ou à s'en approcher n'a été détectée.

PREFACE

The work described in this report was carried out under the interjurisdictional programme *Saint Lawrence—Vision 2000*, and complements work carried out under its predecessor the *St Lawrence Action Plan*.

INTRODUCTION

Population assessment is of primary importance in ecosystem and resource management. In determining the status of threatened species, the size and trend of populations is the most important element that must be accurately determined, although other factors such as the size of the inhabited area or the number of independent populations may also deserve to be considered (IUCN 1994). The quality of habitat for wild and even for domestic animals is commonly measured by the density of populations that can be supported, and this is no less true for habitats that are disturbed or degraded: habitat quality cannot be evaluated without considering the size or trend of its carrying capacity.

A population of the beluga whale (*Delphinapterus leucas*) inhabits the estuary and Gulf of St Lawrence, summering in a well-defined stretch of the central estuary between about Kamouraska and Les Escoumins (Figure 1) (Sergeant 1986, Sergeant and Hoek 1988). It is partially migratory, moving in winter toward and into the north-west Gulf of St Lawrence. It was hunted—probably for millenia—by the peoples who came to reside along the river-banks. Relatively intense commercial hunting documented for the late 1800s and the first half of the 20th century (Vladykov 1944, Laurin 1982, Reeves and Mitchell 1987) reduced the population to low numbers.

Serious attempts to assess the size and trend of the population, which was still hunted with no controls of any kind, started in the 1970s. Pippard and Malcolm (1978) carried out a series of aerial surveys in 1975–77 on behalf of the Canadian Parks Service. They estimated the total population to number no more than 350 animals, with a rapidly decreasing trend, and identified both hunting and habitat degradation as causes for concern (Pippard 1985). The Canadian government closed beluga hunting in the St Lawrence in 1979, and in 1983, the Committee on the Status of Endangered Wildlife in Canada (COSEWIC) accepted the 1977 population assessment as a basis for assigning a status of 'Endangered' (i.e. evidently declining to imminent extinction) (Campbell 1992).

Further aerial surveys were carried out in the early 1980s, both visual and photographic (see Kingsley 1998 for review). A conservative population index (i.e. a count of surface-visible animals uncorrected or only partly corrected for those out of sight under water, the true population being possibly much larger) was estimated at 512 (in 1982), 431 (in 1984) and 530 (in 1985) (Sergeant and Hoek 1988). The last of these estimates sparked intense controversy: it was asserted to be an overestimate of a decreasing population that numbered, on the bases both of boat surveys and of a critical review of aerial survey methods, not much over 300 (Béland *et al.* no date, Béland and Martineau 1985, Béland *et al.* 1987). These views obtained considerable credence, and formed the basis for a popular belief that the population was at very low numbers, declining, and critically endangered by pollution (e.g. Katona and Lien 1990, Hoyt 1990).

Photographic aerial surveys in 1988 (491), and in 1990 (607), confirmed estimates of a partly corrected population index at about 500, and although the trend of results was generally upward, there was no clear evidence of population increase (Kingsley and Hammill 1991). The high result of 607 in 1990, although technically unbiased, was unreliable, owing to sampling problems. It had an estimated sampling SE of over 300,

and because of this uncertainty, stratified sampling was finally abandoned and surveys flown in 1992, 1995, and 1997 sampled all the habitat at a constant rate of 50%. In 1992, an estimate of 525 was obtained from an unstratified design, but it still remained unclear whether the population was increasing (Kingsley 1993).

The next survey was flown in 1995, year 3 of the 5-year interjurisdictional programme *Saint Lawrence—Vision 2000.* The standardised index estimate from this survey was 705—34% larger than the previous value and 16% higher than the previous highest (Kingsley 1996). The 1992 estimate of 525 now looked too low, and that of 607 from 1990 gained a little credibility. The evidence for continued growth of the population since the closure of hunting was also strengthened (Kingsley 1998).

This report describes the next survey in the series, a photographic aerial survey carried out repeating the systematic photographic methods used since 1984, the transect orientation across the river first implemented in 1988, and the unstratified sampling used in 1992 and 1995. This survey was flown in the last year of *St Lawrence—Vision 2000* to provide a closing value to the research effort represented by that programme and its predecessor, the *Saint Lawrence Action Plan.*

METHODS

FIELD METHODS

Transects for the photographic sample survey of beluga summering habitat in the St Lawrence were spaced two nautical miles apart and were oriented across the estuary (Figure 1). The transect grid extended from the upstream end of île-aux-Coudres to near Forestville. The survey was flown at 4,000 ft, and used 6-inch lenses and metric mapping cameras that shot 9-inch-square frames of Kodak Aerographic 2448 colour positive aerial survey film. These survey parameters produced a sampling fraction of 49.4%. Two photographic aircraft were used, so as to cover the survey pattern in one flight each without having to stop to refuel. The target forward overlap was 30%.

A third aircraft, carrying one observer, simultaneously carried out a visual survey of the Saguenay Fjord.

PHOTO READING AND ANALYSIS

Photographs were read on light tables by a team of four interpreters, three of whom had previous experience. An acetate transparency marked with a 10x10 square grid was placed under the film in order to provide a frame of reference for the positioning of beluga images, which were then marked on paper sheets printed with the same grid. All frames on which images were reported in the first reading, as well as the frame before and the frame after, were re-read by a different reader, who had no information on where the beluga images were, or on which frames. Frames drawn blank on the first reading were not re-read.

Some beluga images were in the parts of photo frames that overlapped with neighbouring frames. If a similar image occurred on the neighbouring frame, we compared their orientation and size and their position relative to other beluga images, buoys, land, or water turbidity patterns, and decided on that basis whether they were duplicate images of the same animal.

The count of images on the photographs, net of duplicates on neighbouring frames, was multiplied up by the survey expansion factor (equal to the transect spacing divided by the photo strip width) to give an estimate of surface-visible belugas for the entire study area. This estimate was then corrected for belugas out of sight under water. A correction (addition of 15%) considered conservative (Sergeant and Hoek 1988, Kingsley 1993, 1996), was applied to give a standardised population index as for previous surveys.

Another correction factor, besides the standard 15%, has recently become available. It has been derived by watching belugas from the air and measuring the proportion of time for which they are visible. To produce a best estimate of the true population size this correction factor was applied in place of the standard 15%.

An estimate of the standard error of the survey result taken alone was calculated using standard methods based on the serial differences between transect counts (Cochran 1977, Kingsley and Smith 1981, Kingsley 1996). In calculating the standard error of the

estimate of the true population size, the standard error of the estimated correction factor was included.

The coordinates of the boundary of the recently established Saguenay–St-Lawrence Marine Park were plotted (Figure 1) (Saguenay–St.-Lawrence Marine Park Act 1988). The proportion of observations within the park was estimated by assuming that all belugas counted on a frame but not counted on the previous one were at the centre of the frame, and calculating whether the frame centre was inside or outside the park boundary.

SMOOTHED ESTIMATES

Previous estimates of the population index were taken from the literature as published and smoothed with a linear trend model in sets of five consecutive surveys to generate a smoothed value for the index for the central year of each set. The regression statistics also provided an estimate of the uncertainty attaching to the smoothed estimate. The two most recent surveys could not be the central survey of a set of five, so for those years the smoothed estimates were obtained from the most recent set.

A similar approach was taken to smoothing estimates of true population size based on systematic photographic surveys flown since 1984. The counts in the Saguenay Fjord were deducted from the published index estimates, and the correction factors originally applied to partially account for submerged whales (18% added in 1984 and 1985, 15% added in 1988 through 1997) were stripped off to get back to the estimate of surface-visible animals. This photographic estimate of visible belugas was smoothed with a linear model, and the smoothed estimate was corrected using a visibility ratio estimated from aerial observations of beluga groups in summer 1997. As this correction factor was based on sample data, a component of uncertainty related to its value was incorporated into the standard error of the smoothed estimate of the true population size. From the studies carried out there was little basis to vary the correction factor according to the local turbidity (Gauthier in prep.), so a single value was applied to the whole survey. The counts in the Saguenay Fjord were smoothed separately with a single trend line from 1984 through 1997 and added to the smoothed estimate for the estuary, with no correction for visibility.

MARINE TRAFFIC

Concerns are expressed from time to time about the effect of marine traffic on cetaceans, including the belugas of the St Lawrence. An aerial photographic survey provides an opportunity to obtain an unbiased sample of a typical distribution of marine traffic with respect to the distribution of belugas on a fine day in late summer. Boats and ships of all sizes were identified and recorded when the films were read and their locations noted.

RESULTS AND DISCUSSION

DISTRIBUTION IN THE ST LAWRENCE ESTUARY

In late August 1997, there was a period of unstable weather, with humid air, clouds, fog, and windy periods. The first good day in the planned survey window—18 August to 10 September—was 26 August, i.e. one day later than the 1995 survey. The sky was clear and the wind below 5 knots over most of the survey area, although up to 10 kts at the upstream limit of the survey. Owing to the combination of light winds, moist air, and a clear night, a bank of fog covered the north shore of the estuary. It extended downstream from about Les Escoumins and more than half-way across the estuary at the downstream limit of the survey (Figure 1, Appendix 2). Nevertheless, we decided to proceed with the survey, as previous surveys had found few belugas in the foggy area (Kingsley and Hammill 1991, Kingsley 1993, 1996), and we thought that the fog might soon dissipate (which it did not).

The area that was obscured by fog when we flew the photographic survey was visually surveyed from 800 ft by helicopter, with a pilot and one observer, on the first suitable day, which was 9 days later on 4 September.

Photographs were taken from 0850 to 1310 EDT, i.e. about 0930–1350 sun time at Rivière-du-Loup. High tide at Rivière-du-Loup was at 1015 EDT. The tidal range was 7.5 feet, neap tide falling on the following day. Tidal currents in the St Lawrence are complex and strong, with streams and eddies that persist through different stages of the tide, so slack water is hard to define. High-tide slack water between St-Simeon and Trois-Pistoles is from about the time of high water at Rivière-du-Loup to about one hour later, and at the level of the Kamouraska Islands it is about one hour after that (Fisheries and Oceans Canada 1997). High-tide slack water in the study area would have occurred from about 0945 EDT at the downstream end of the study area to about 1230 at the upstream end, and the survey timing roughly coincided with it.

The distribution observed (Figure 2) was in some respects similar to an average of those observed in earlier surveys, but there were also clear differences. The main area of distribution was similar, extending from the Kamouraska Islands to Les Escoumins. The principal differences between this survey and what might be thought an average typical distribution were: few belugas near the north shore downstream of the Saguenay (i.e. between Tadoussac and Les Escoumins; no belugas in the southern part of the river between Cacouna and the west end of île aux Lièvres; unusually large numbers north and south-west of the île-aux-Lièvres, off the north coast of the île Verte, and off Kamouraska.

A few belugas were also recorded on the south shore near Saint-Simon, downstream of the usual distribution (Figure 2). Belugas were recorded in that area in 1990, and are also shown there on distribution maps for 1987–1992 (Michaud 1993). Kingsley (1998) observed that belugas occur off Saint-Simon when counts on the north side of the river between Tadoussac and Les Escoumins are lower than usual. The distribution in 1997 is consistent with that pattern.

The contraharmonic mean[1] of the number of images per frame was 9.3, intermediate between 8.3 in 1992 and 12.1 in 1995.

As there were substantial numbers of belugas close to île Verte and also upstream of Kamouraska, only 51% of belugas photographed in the estuary were within the Marine Park. In the 1995 survey, when there was a concentration of belugas over the Laurentian Channel off Grandes-Bergeronnes, 68% of imaged belugas were within the Park, and in 1992, when again the downstream component of the population was near île Verte, the proportion was 57%. The weighted mean for the three surveys is 59%. The belugas that are in the Saguenay fjord may be added to that proportion, as this area is also comprised within the Marine Park.

INDEX AND POPULATION ESTIMATES FOR THE ST LAWRENCE ESTUARY

Owing to the presence of fog over about 20% of the usual survey area, only 832 usable frames were shot (compared with a usual total of about 1,000). Belugas were on 88 of them (Appendix 3). The count of beluga images for the estuary survey totalled 356, of which 72 were deemed to duplicate images on overlapping adjacent frames; the net count was 284. The net count was multiplied by a survey expansion factor of 2.025 (for survey strips 6,000 feet wide spaced on 2-nautical-mile centres) and a conservative visibility correction of 15% was added resulting in an estimated standard index for the estuary of 661.4 belugas. The serial-difference estimate (Cochran 1977) of the sampling standard error was 90.9.

When the area covered by fog in the photographic survey was surveyed visually on 4 September, no belugas were seen while flying the transects, although one was seen off-transect near Les Escoumins. The estuary estimate was not corrected for the missed area.

In summer 1997, beluga groups in the St Lawrence were watched by airborne observers to measure the proportion of time during which they were visible. It was estimated to be less than 50%, implying that an appropriate factor to correct photographic counts to an estimate of true population size (instead of a conservative index) would be 109% (SE 16%) (Gauthier in prep.) (instead of 15% with SE 0). This estimate is supported by satellite-tag studies of Arctic belugas, which usually spend over half their time in deep dives when in deeper offshore waters (Martin and Smith 1992, Heide-Jørgensen *et al.* 1998, Richard *et al.* 1997, Kingsley unpublished data. Similar results have been obtained also for narwhals, both by tagging (Martin *et al.* 1994) and by direct observation (Dueck 1989). The resulting estimate of true population size for the estuary was 1,201 (SE 189).

COUNT IN THE SAGUENAY FJORD AND OVERALL ESTIMATES

Nineteen belugas were counted in the Saguenay fjord at baie Sainte-Marguerite on the upstream flight, and 20 on the downstream return flight. The higher count was retained.

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[1] I.e. the number of images on the frame containing the average image, and a measure of the degree of aggregation of belugas in their habitat.

The final estimate of the standard index estimate for the study area was therefore 681.4 with SE 90.9. This result tends to confirm that the unexpectedly high result of 705 in 1995 was not entirely due to sampling variation, but was a valid index estimate.

The estimate of true population size for 1997 (still, however, incorporating an uncorrected visual survey total for the Saguenay fjord, and ignoring the bias and uncertainty in the Saguenay count, as well as any bias due to the fog cover in the estuary) was 1221, with SE 189. This estimated standard error includes both the sampling error associated with the photographic survey and the uncertainty in the correction factor used for translating photograph counts into true population numbers.

SMOOTHED INDEX ESTIMATES

Index estimates since 1977 are coherent, with a steadily increasing trend (Table 2, Figure 3). The area surveyed was largest in 1982, when the survey extended from île aux Coudres to Hauterive, some 75 km further downstream than the limit of the present study area. The smaller area surveyed in 1984 was based on the distribution of sightings in the 1982 survey and that in 1985 on the population distribution a few days before the survey. From 1988 on, the survey area was similar to that used in the present survey, and transects were aligned across the estuary. In 1985, 1988, and 1990 there was no survey of the Saguenay Fjord, so trends for 1977–1988 and 1982–1990 may be biased downwards, and trends for 1985–1995 and for 1988–1997 biased upwards.

The standard deviation of survey estimates about the fitted smoothing trend lines is about 60, i.e. smaller than the standard errors estimated for individual surveys. This could show that the surveys are really more precise than their individual estimated standard errors would suggest. Unbiased estimates of standard error do not exist for systematic surveys (Cochran 1977), and conventional calculations usually produce over-estimates. Even the serial-difference estimator used for the recent surveys (Kingsley 1996) probably overestimates the standard error (Kingsley and Smith 1981). The coefficients of variance of smoothed estimates for surveys that are supported by both earlier and later data are 4.5–7%.

The most recent smoothed index estimate is 700 for 1997, with SE 46[1], and the current estimated rate of increase in the index is 21.4 (SE 8.2) belugas/year.

SMOOTHED ESTIMATES OF THE TRUE POPULATION

Fully corrected population estimates and their smoothed values have also increased over the survey series (Table 3, Figure 4). The population trend calculation has been corrected for the intermittent inclusion of the Saguenay Fjord in the surveys by smoothing the Saguenay counts separately. The most recent smoothed estimate of the true population size is 1,238 (SE 119). However, like the most recent smoothed estimate of the standard index, this is an interim value that should be revised if another survey were flown.

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[1] all standard errors calculated from linear smoothing statistics have three degrees of freedom.

The estimated rate of population change from 1988 through 1997 is 31.4 belugas/yr (SE 13.1). Over this period the photographic methods and the study area have been constant. Intermittent coverage of the Saguenay has been corrected for by separately smoothing the Saguenay counts. This trend estimate would therefore be unbiased, except for the downward bias in the 1997 survey result due to fog. These values may be interpreted as a 25% confidence (one chance in four) that the population is increasing by more than 41.4°belugas/yr, 50% confidence in an increase between 21.4/yr and 41.4/yr, and 25% confidence in growth of less than 21.4/yr. Confidence that the population is decreasing would be about 4.8% (about 1 chance in 21), but that this is now considered not to be occurring, and not to have occurred since hunting was closed (Anon. 1998, p. 89).

These estimates of how fast the population is changing in size are based only on survey data, and we should consider whether they are consistent with the apparent dynamic status of the population. Life history variables such as birth rates and life expectancies are not easy to measure on wild populations, especially of cetaceans, and information for this population is mostly indirect. The proportion of juveniles counted on aerial photographs appeared near normal (Kingsley 1996), even uncorrected for their being harder to see (Gauthier in prep.), as did the proportion of grey juveniles counted in boat survey (Michaud 1993). From study of beach-cast carcasses, the mean age at death and the life expectancy at maturity both appear reasonably high, and there is no evidence of mass mortality or of unusual mortality of animals of prime reproductive age (Béland *et al.* 1988, Béland *et al.* 1992, D. Martineau and DFO, unpublished strandings records). From signs of recent reproductive activity (or their absence) in beach-cast adult females, it has been estimated that the birth-rate was depressed, but such data is necessarily derived from the sick and senile, not from the young and fit. Stranding data does not provide a good estimate of the age at first reproduction, as animals of about that age, i.e. 5–8 years old, are rarely found dead. The maximum growth rate of unexploited monodontid populations has been estimated at 3–5%/yr (Sergeant 19xx, Kingsley 19xx). An increase of 30/yr on a population of over 1,000 is below this range, and the life-history evidence available gives little reason for considering it an overestimate.

Part of the life-history data consists of records obtained from beach-cast carcasses, which have been examined since about 1982. If the population has not increased over that period, its size is estimated by the 1992 smoothed estimate of 1,080; if it had increased at an average rate of 30/yr, the average population from 1982 to 1997 would be about 1020. Either way, the annual average of about 15 carcasses/yr is about 1.5% of the population, and if the population had an average death rate of 10%/yr (Burns and Seaman 1988) would be about 15% of the deaths. There is no data on stranding rates of naturally dead belugas, overall or by age, reproductive status, or cause of death. However, if the beach-cast carcasses represented such a low proportion of the total deaths, sampling bias might be present; if, for example, younger, reproductively active belugas were more apt to sink when dead and were therefore under-sampled in the stranding record, life expectancies deduced from the stranding data would be over-estimates.

The dive behaviour of belugas in summer has been studied in the Arctic with satellite-linked depth recorders. Such studies have shown that typically only about 50% of time is

spent at the surface, and that it might be appropriate to correct aerial surveys by adding of the order of 100% to the counts. On that basis, it was thought that a true population size in 1995 might have been between 900 and 1300 (Kingsley 1996, Innes 1996), but there were obvious reasons to hesitate before applying Arctic data to the St Lawrence population (Kingsley 1993: p. 8, 1995, p. 16). However, direct visual data from the St Lawrence leads to a similar conclusion about the visibility of belugas, and the resulting smoothed estimate for the true 1995 population size is within the range suggested.

While most of the belugas in the St Lawrence population summer in the estuary and are included in these surveys, small numbers of live belugas are sometimes reported in the northern Gulf of St Lawrence in summer. For example: a crew flying a sample survey for cetaceans in the northern Gulf saw 6 belugas off Sept-Îles in August 1996 (Kingsley and Reeves in press); a beluga was reported off Corrosol Island (also off Sept-Îles) in summer 1997; and in 1998 a single juvenile beluga took up residence off Chevery in the north-eastern Gulf in early summer (M. Kingsley unpublished notes), 4 adult belugas were seen off the Mingan Islands, and another at La Tabatière (R. Michaud, pers. comm. to DFO). Such sightings are not new, but have been reported on and off for years. They occur too sporadically and involve numbers too small for it to be possible to say whether they are getting more frequent or less. There have also been reports in early summer (May or June) of small numbers of belugas in the western Gulf, on or near the New Brunswick shore, about 1 year in 2 (M. Kingsley unpublished notes); such animals may however find their way into the main summer range in the estuary before surveys are flown at the end of summer.

BOATS AND MARINE TRAFFIC

Omitting those anchored and moored, 39 vessels of all sizes were counted on the 49.4% sample of the estuary, possibly indicating about 78 in total on the estuary (Figure 5). The most numerous classes were small power-boats—mostly work-boats 20–45 feet long (13)—and kayaks (10). There were 5 inflatables. Power-boats were spread fairly widely, but the kayaks were all in two groups downstream, near St-Simon and the Parc du Bic respectively. Large cargo vessels—either ships or barge tows—numbered only four, but one barge tow comprised a tug and three barges. Of the 4 ferries operating in the study area, the camera captured all except that which operates between Trois-Pistoles and Les Escoumins. Small 'personal watercraft' of the Jet-Ski or Sea-Doo type are sometimes suspected of being a source of harassment of marine life, but none were seen on these survey photographs.

Small boats were concentrated, as expected, near marinas and population centres: in the channel north of île aux Coudres, between Rivière-du-Loup and île aux Lièvres, and off Tadoussac and Grandes-Bergeronnes (Figure 5). Most of the areas where boats were numerous were areas with few belugas, so there was a small negative correlation between boats and belugas. However, the number of frames containing either was so small—10½% of frames had belugas and 4½% had boats—that if occurrences were independent, only four frames would have been expected to have both boats and belugas; 1 frame did. This data provided no conclusive evidence about disturbance of belugas by marine traffic.

There was no sign of boats harassing belugas or even seeking to approach them. There were a few belugas around one anchored sailing vessel. The only evidence of belugas generating boat traffic was that one of the boats near Tadoussac was a vessel of the Department of Fisheries and Oceans doing beluga research, and another appeared to be a patrol boat of the Saguenay-St-Lawrence Marine Park.

These results must be qualified with the observation that the survey took place at the very end of summer, when tourist activities and summer recreation are winding down. The high summer season on the St Lawrence is very short, lasting only from about the beginning of July to the middle of August, and these surveys are typically outside that period. In the high season, there are reports of boats seeking to approach belugas and of harassment by personal watercraft.

CONCLUSIONS

A smoothed estimate of a standard index of population size for the St Lawrence belugas, based on systematic aerial photographic survey, was 700 (SE 46) in 1997, providing further evidence for continued growth of the population. The photograph counts were corrected using a visibility factor based on aerial observation of beluga dive behaviour, and smoothed with a linear trend line through the most recent five survey estimates. The resulting estimate of true population size in 1977 was 1238 (SE 119, and the estimated average rate of change in population from 1988–1997 was 31.4 (SE 13.1) belugas/yr. This growth rate was so calculated as to be free of bias due to variation in survey methods or area covered.

From three aerial surveys—in 1992, 1995, and 1997—it is concluded that about 60% of the belugas counted in the St Lawrence estuary are within the boundaries of the Saguenay–St-Lawrence Marine Park.

Thirty-nine vessels under way were counted on survey film, ranging from kayaks to large cargo tows; however, none appeared to be harassing or attempting to approach belugas, and only one was on a photo frame that also contained belugas.

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Table 1. Counts of belugas by transect on a photographic aerial survey of the St Lawrence estuary on 26 August 1997.

Transect	Count	Transect	Count	Transect	Count
16.15	1	20.25	5	24.15	20
16.25	4	21.05	33	24.25	12
17.05	1	21.15	4	25.05	1
17.15	14	21.25	9	25.15	9
18.15	3	22.05	2	25.25	9
18.25	5	22.15	6	26.05	33
19.05	1	22.25	4	26.15	2
19.15	6	23.05	11	28.25	1
19.25	5	23.15	16	29.15	1
20.05	7	23.25	20	29.25	2
20.15	33	24.05	4		

49 transects—14.05 through 30.05—were flown; 17 on which no belugas were seen are left out of this Table.

Table 2. Smoothed[1] estimates of a standard index of population size for the belugas of the St Lawrence, 1977–1997

Year	Published estimate (SE)	Straight-line smoothing		
		Growth rate of index (/yr) (SE)	SD of points about smoothing line	Estimate (SE)
1977	325			370 (61)
1982	512			429 (33)
1984	431	18.3 (8.5)	62.8	466 (32)
1985	530	11.9 (9.3)	59.4	505 (28)
1988	491 (69)	11.5 (8.8)	59.0	519 (26)
1990	607 (308)	16.3 (9.0)	68.6	572 (31)
1992	525 (71)	21.4 (8.2)	59.9	593 (27)
1995	705 (108)			657 (34)
1997	681 (91)			700 (46)

[1]published index estimates have been smoothed with a linear growth model in sets of five consecutive estimates. E.g., the smoothing statistics tabulated for 1992 are based on 5 surveys from 1988 through 1997. Standard errors for the smoothed estimates have been estimated from the regression statistics.

Sources: Pippard 1985, Sergeant and Hoek 1988, Kingsley and Hammill 1991, Kingsley 1993, 1996, this report. Population estimates of 300-350 for 1985 (Béland and Martineau 1985, Béland *et al.* 1987) have been left out.

Table 3. Smoothed[1] estimates of fully corrected[2] population size for the belugas of the St Lawrence from photographic aerial survey, 1984–1997.

Year	Published index estimate			Source	Corrected population estimates				
	Includes				Calculated	Smoothed			
		Saguenay count	Correction factor (%)			Estuary	Saguenay	Total (SE)[3]	Rate of change (/yr) (SE)
1984	431	30	18	Sergeant & Hoek 1988	740	812	25	836 (109)	
1985	530		18	"	939	840	25	865 (99)	
1988	491		15	Kingsley & Hammill 1991	892	924	25	950 (90)	28.3 (18.2)
1990	607		15	"	1103	1015	26	1040 (91)	23.7 (13.6)
1992	525	3	15	Kingsley 1993	952	1055	26	1080 (92)	31.4 (13.1)
1995	705	50	15	Kingsley 1996	1240	1149	26	1175 (104)	
1997	681	20	15	this report	1221	1211	26	1238 (119)	

[1]Sets of five consecutive estimates for the estuary have been smoothed by linear regression: e.g. the smoothed estimate for 1992 is based on five surveys from 1988 through 1997. Saguenay counts have been smoothed by a single straight line from 1984 to 1997.

[2]published index estimates have been dismantled and the original estuary correction factor (18% or 15%) replaced with a value of 109% (Gauthier in prep.). Saguenay counts have not been corrected for availability.

[3]Standard errors for the smoothed estimates have been estimated from the regression statistics, are on 3 degrees of freedom, and include all identifiable components of uncertainty.

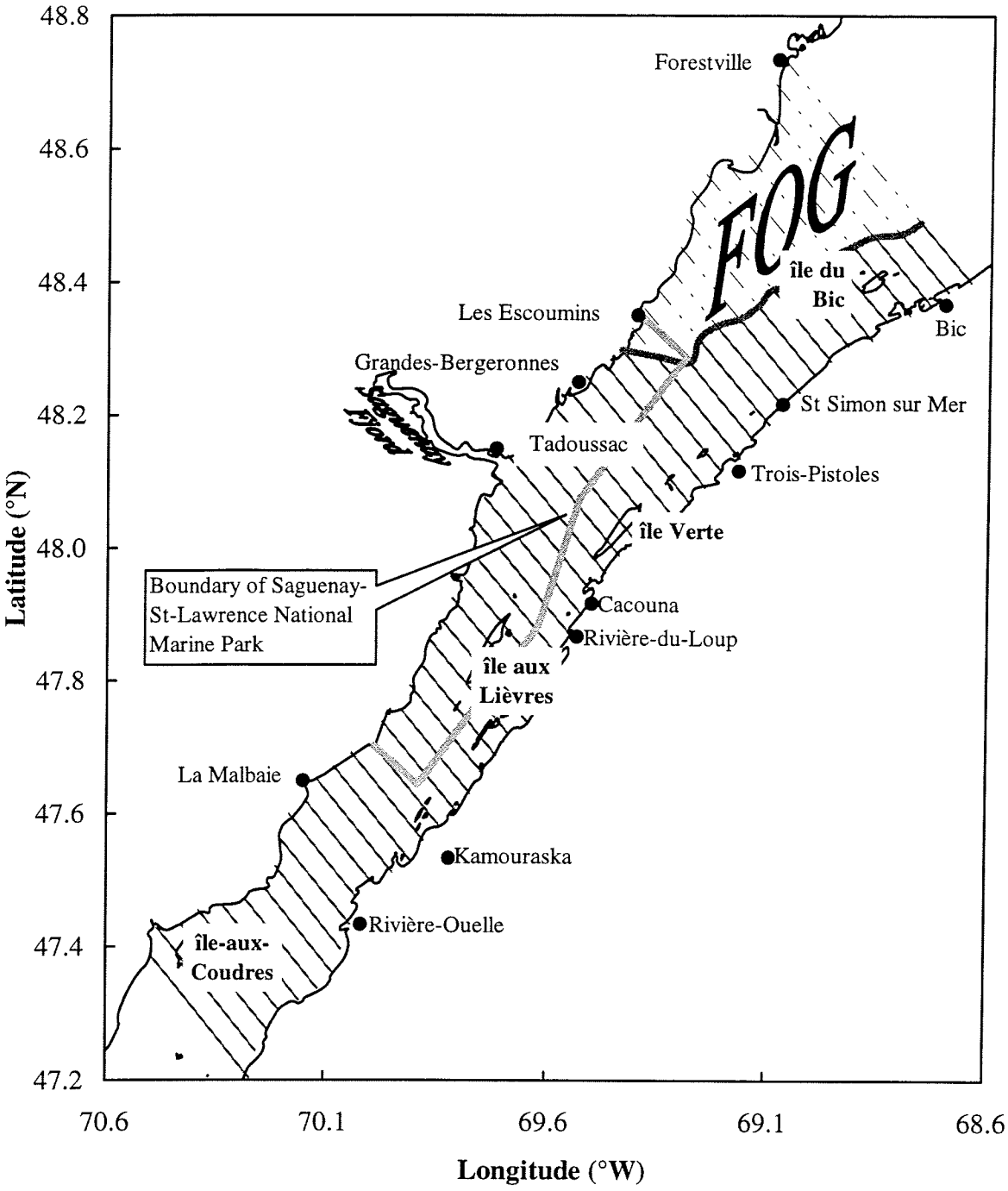

Figure 1. Transect design for aerial photographic survey of the St Lawrence estuary in 1997.

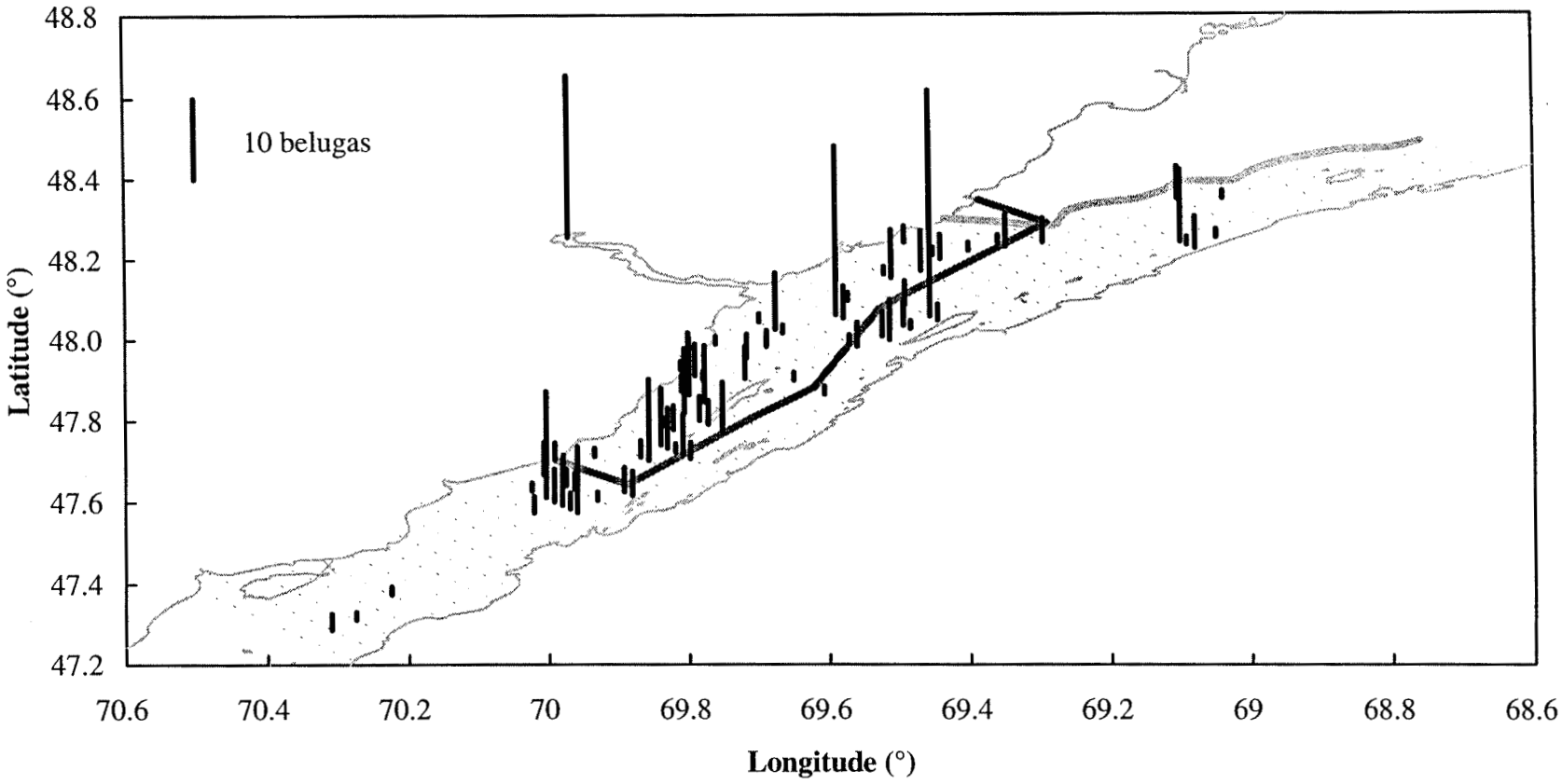

Figure 2. Observations of belugas on aerial photographic survey of the St Lawrence estuary and on simultaneous visual survey of the Saguenay fjord, 26 August 1977.

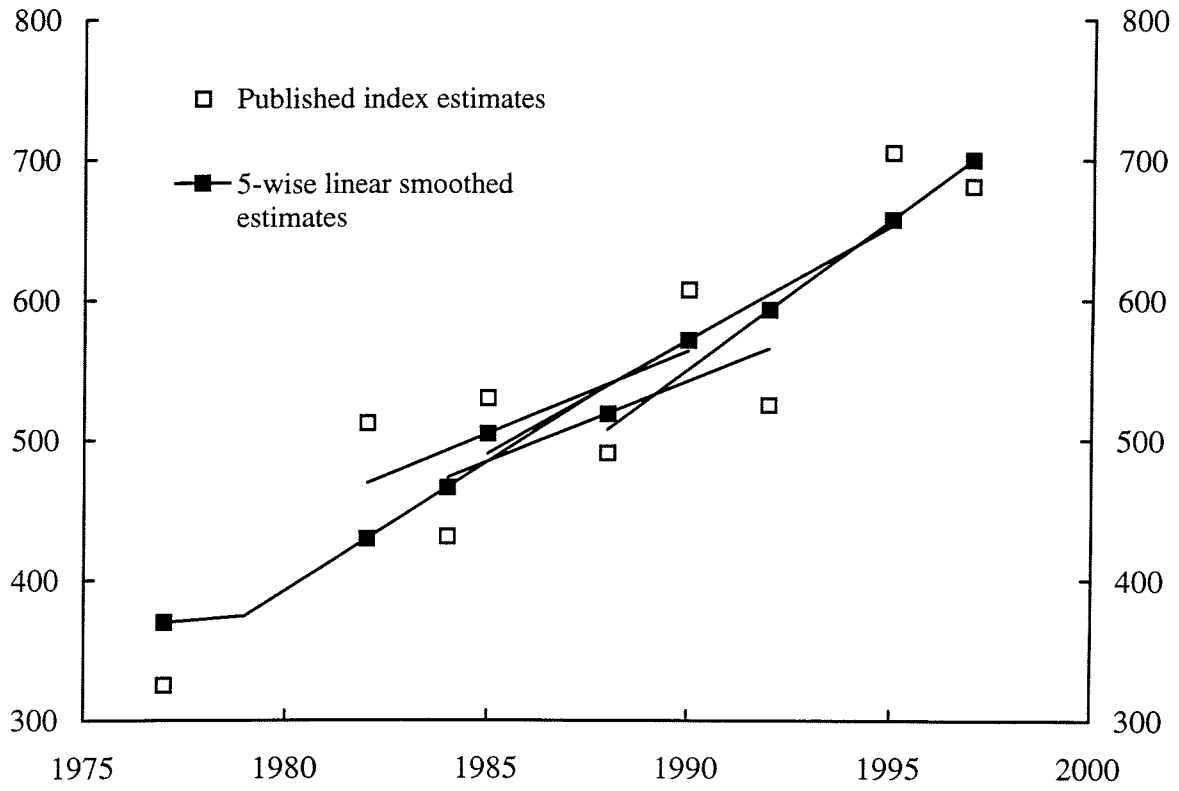

Figure 3. Published estimates of population indices for the St Lawrence belugas, 1977–1997, with straight-line smoothed values.

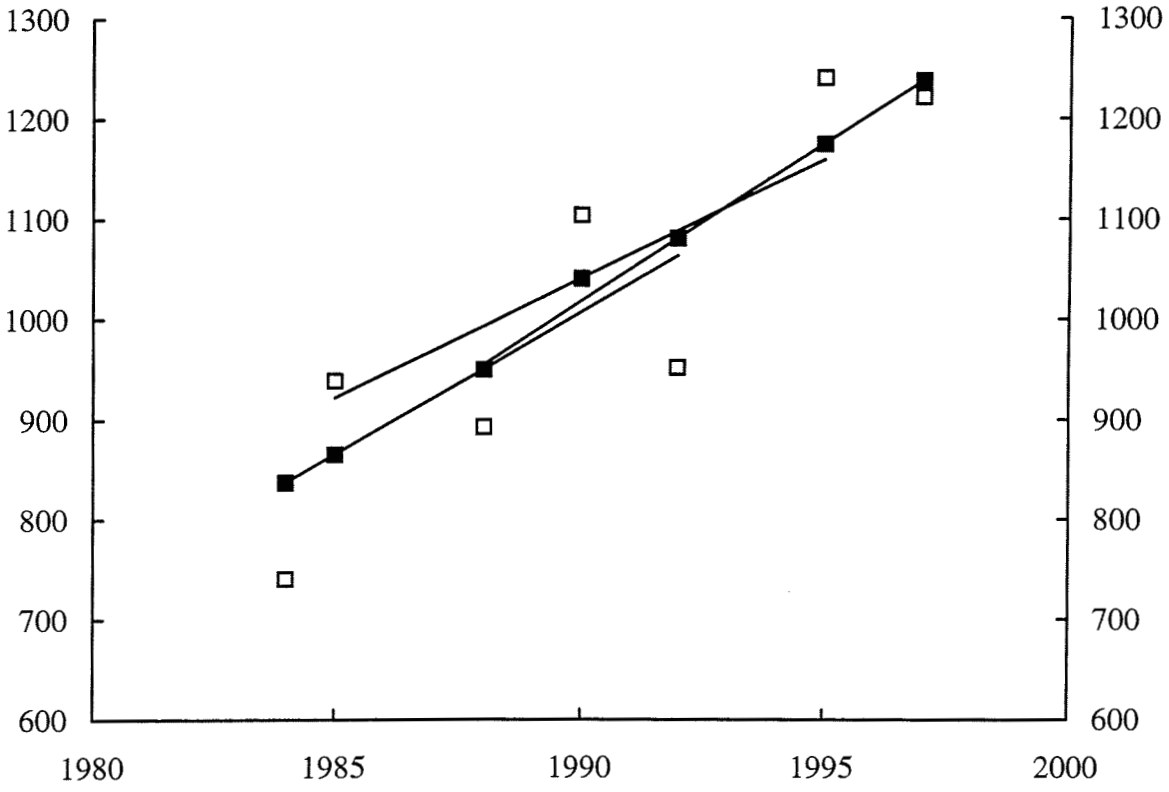

Figure 4. Estimates of true population size, fully corrected for visibility, for the St Lawrence belugas, 1984–1997, with linear smoothing.

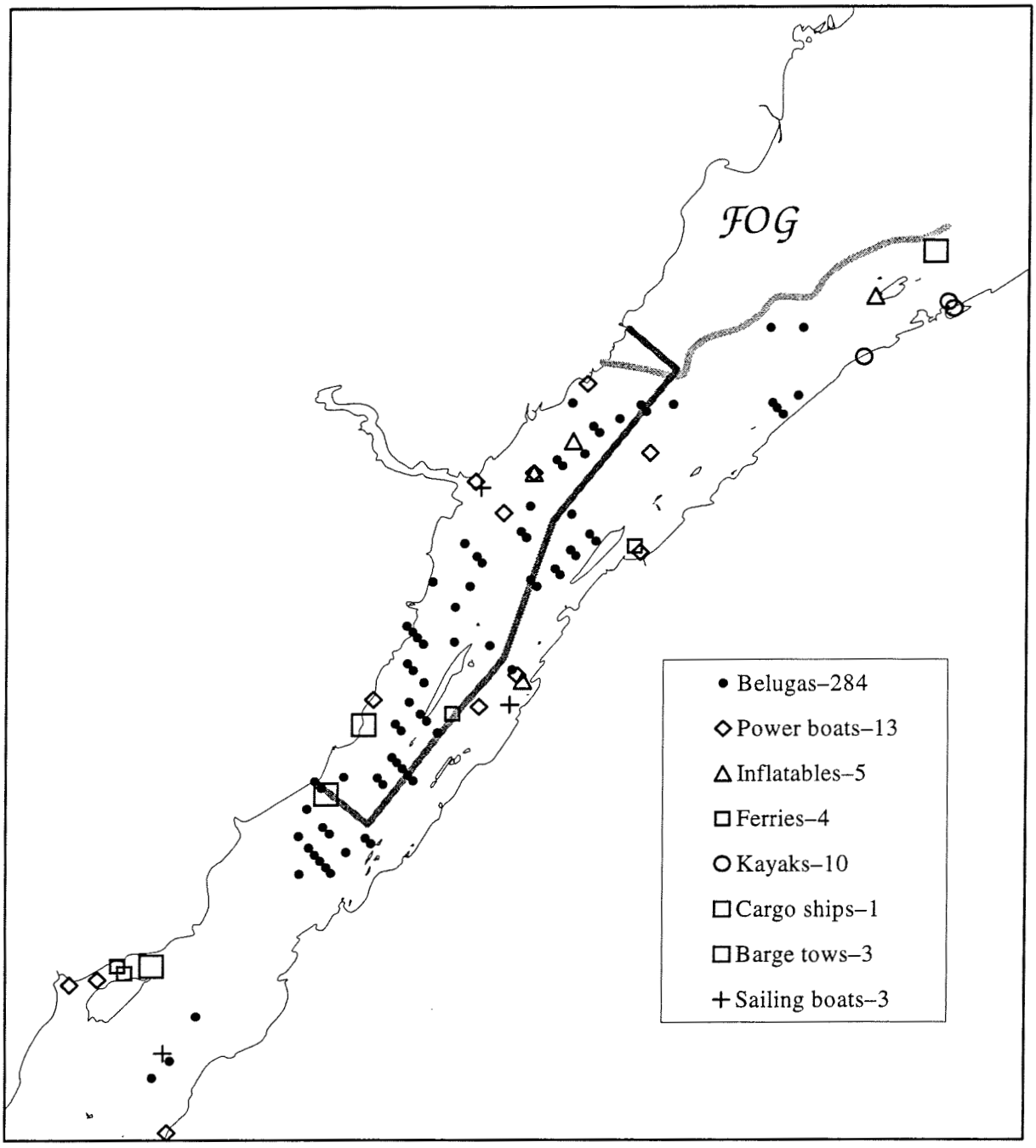

Figure 5. Observations of marine traffic and surface-visible belugas in aerial photography of a 49.4% systematic sample of the St Lawrence estuary, 26 August 1997.

			Beluga images		Latitude[1]		Longitude[1]	
Roll[2]	Frame	Transect	Total	New[3]	deg.	min.	deg.	min.
A31752	6	20.15	29	28	48	3.34	69	27.40
A31752	9	20.15	3	3	48	5.04	69	29.52
A31754	4	20.25	1	1	48	1.51	69	29.03
A31754	5	20.25	3	3	48	1.98	69	29.64
A31754	6	20.25	2		48	2.59	69	30.32
A31754	11	20.25	1	1	48	5.71	69	34.37
A31754	28	21.05	21	21	48	3.57	69	35.42
A31754	29	21.05	23	4	48	3.07	69	34.79
A31754	34	21.05	3	3	48	0.40	69	31.45
A31754	35	21.05	7	5	47	59.88	69	30.81
A31754	45	21.15	3	3	47	58.89	69	33.58
A31754	46	21.15	3	1	47	59.43	69	34.26
A31754	65	21.25	1	1	48	2.53	69	41.97
A31754	67	21.25	7	7	48	1.43	69	40.59
A31754	68	21.25	1	1	48	0.92	69	39.96
A31754	95	22.05	2	2	47	58.90	69	41.34
A31754	104	22.15	1	1	47	59.28	69	45.72
A31754	108	22.15	3	3	47	57.12	69	43.06
A31754	114	22.15	1	1	47	53.86	69	39.01
A31754	118	22.15	1	1	47	51.81	69	36.37
A31754	134	22.25	4	4	47	54.14	69	43.20
A31754	135	22.25	1		47	54.71	69	43.90
A31754	141	23.05	1	1	47	55.50	69	48.75
A31754	142	23.05	6	5	47	54.98	69	48.09
A31754	143	23.05	4	4	47	54.52	69	47.51
A31754	144	23.05	2	1	47	53.98	69	46.83
A31754	172	23.15	7	7	47	50.69	69	46.68
A31754	173	23.15	3		47	51.21	69	47.34
A31754	174	23.15	7	7	47	51.74	69	47.99
A31754	175	23.15	6	2	47	52.30	69	48.64
A31754	183	23.25	8	8	47	49.05	69	48.43
A31754	185	23.25	3	3	47	48.00	69	47.13
A31754	186	23.25	3	3	47	47.42	69	46.39

Roll[2]	Frame	Transect	Beluga images		Latitude[1]		Longitude[1]	
			Total	New[3]	deg.	min.	deg.	min.
A31754	188	23.25	6	6	47	46.43	69	45.15
A31754	205	24.05	3	3	47	46.60	69	49.38
A31754	206	24.05	1	1	47	47.16	69	50.07
A31755	7	24.15	7	7	47	44.34	69	50.43
A31755	8	24.15	5	5	47	43.90	69	49.87
A31755	9	24.15	2	1	47	43.38	69	49.21
A31755	10	24.15	6	5	47	42.84	69	48.55
A31755	11	24.15	2	2	47	42.36	69	47.93
A31755	25	24.25	10	10	47	42.06	69	51.48
A31755	26	24.25	9	2	47	42.60	69	52.16
A31755	35	25.05	1	1	47	42.69	69	56.13
A31755	52	25.15	3	3	47	37.00	69	52.88
A31755	53	25.15	3	3	47	37.50	69	53.58
A31755	61	25.15	1	1	47	41.72	69	58.78
A31755	62	25.15	3	2	47	42.30	69	59.52
A31755	66	25.25	4	4	47	39.97	70	0.44
A31755	67	25.25	1		47	39.45	69	59.80
A31755	69	25.25	2	2	47	38.40	69	58.53
A31755	70	25.25	2	2	47	37.85	69	57.82
A31755	73	25.25	1	1	47	36.27	69	55.85
A31755	84	26.05	8	8	47	34.51	69	57.61
A31755	85	26.05	5	2	47	34.99	69	58.19
A31755	86	26.05	6	5	47	35.54	69	58.87
A31755	87	26.05	5	4	47	36.06	69	59.53
A31755	88	26.05	13	13	47	36.65	70	0.25
A31755	90	26.05	1	1	47	37.64	70	1.44
A31755	91	26.05	1		47	38.20	70	2.15
A31755	105	26.15	2	2	47	34.44	70	1.30
A31756	7	28.25	1	1	47	22.41	70	13.46
A31756	40	29.15	1	1	47	18.67	70	16.50
A31756	71	29.25	2	2	47	17.21	70	18.55