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Population Index Estimate for the Belugas of the St Lawrence in 1995

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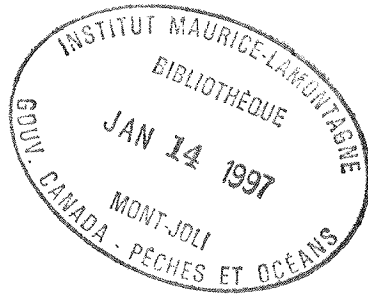
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ABSTRACT

Kingsley, M.C.S. 1996. Population index estimate for the belugas of the St Lawrence in 1995. Can. Tech. Rep. Fish. Aquat. Sci. 2117. vi + 38 p.

On 25 August 1995 a survey flight was carried out to estimate a population index for the St Lawrence population of belugas (*Delphinapterus leucas*). Two aircraft, each equipped with a metric mapping camera shooting 9"x 9" frames through a 6" lens, flew at 4000 feet over a systematic grid of transects, aligned from northwest to southeast, that stretched from Île aux Coudres to Île du Bic. The transects were spaced 2 nautical miles apart, giving a 50% coverage of the estuary. One thousand and ninety-two frames were shot on colour positive aerial survey film. At the same time, another aircraft surveyed the length of the Saguenay Fjord with a single visual observer.

The wind was light over the whole survey area and the sky was clear, so good-quality photography was obtained. The film was analysed on a light table using low-power microscopy. A total of 377 belugas were counted on 86 frames. Ninety-three were judged to be duplicates of belugas also seen on the adjacent frame, so the net count was 284. Fifty of 197 (25%) appeared from their small size to be juveniles. The resulting estimate of visible belugas was 568 (sampling S.E. 94.0). A 15% visibility correction gave an estimated index for the St Lawrence of 653.2 (S.E. 108.1). The counts were not corrected for sun glare reflected from the water surface and appearing on the photo frames. On the simultaneous visual survey of the Saguenay Fjord, 51 more belugas were seen at baie Ste-Marguerite and one further upstream; these counts were not corrected for visibility. The final total estimated population index, including the Saguenay, was 705.2.

This index estimate is 34% bigger than the value of 525 obtained on a windier day in 1992 using the same methods, and a 16% increase over the 1990 estimate.

RÉSUMÉ

Kingsley, M.C.S. 1996. Population index estimate for the belugas of the St Lawrence in 1995. Can. Tech. Rep. Fish. Aquat. Sci. 2117. vi + 38 p.

Un recensement aérien de la population de bélugas (*Delphinapterus leucas*) du fleuve Saint-Laurent eut lieu le 25 août 1995. Deux avions, volant à 4000 pieds d'altitude, équipés chacun d'une caméra de cartographie métrique prenaient des clichés de 9"x 9" avec une lentille de 6" selon une grille systématique de transects orientés nord-ouest-sud-est s'étendant de l'Île aux Coudres à l'Île du Bic. Un transect tous les 2 milles nautiques procura un recouvrement de 50% de l'estuaire. Mille quatre-vingt-douze clichés furent pris sur film couleur positif pour survol aérien. En même temps, un seul observateur recensait visuellement le fjord du Saguenay à bord d'un autre avion.

Le vent fut léger et le ciel clair sur toute l'aire de survol, permettant la prise d'images de haute qualité. Le film fut scruté sur une table lumineuse avec un microscope à faible grossissement. Un total de 377 bélugas furent comptés sur 86 clichés. Quatre-vingt-treize fut jugés être des répétitions des images apparaissant sur le cliché précédant, donc le compte final fut de 284. Cinquante sur 197 (25%), de petite taille, semblaient être juvéniles. Ceci a permis un estimé de 568 (erreur type d'échantillonnage 94.0) bélugas visibles en surface. Après une correction de 15% pour les bélugas en plongée, nous obtînmes une estimation de 653.2 (erreur type d'échantillonnage 108.1). Aucune correction pour la lumière solaire reflétée de la surface de l'eau et apparaissant sur les clichés ne fut portée au décompte. Lors du relevé visuel simultané du fjord du Saguenay, cinquante-un autres bélugas furent observés à la baie Ste-Marguerite et un autre plus en amont; ces chiffres ne furent pas corrigés pour la visibilité. L'estimé final de l'indice total de la population fut alors de 705.2.

Cet estimé de l'indice de la population fut de 34% plus élevé que celui obtenu en 1992 avec les mêmes méthodes, et de 16% plus élevé que celui de 1990.

PREFACE

This report describes work carried out under the interjurisdictional programme St Lawrence—Vision 2000.

INTRODUCTION

The population of belugas (*Delphinapterus leucas*) inhabiting the St Lawrence estuary has had 'Endangered' status since it was evaluated by COSEWIC in 1983 (Pippard 1985; Campbell 1992). In the earlier history of the St Lawrence, belugas were harvested, at some periods in large numbers (Reeves and Mitchell 1984, 1987; Breton 1990). In this century, belugas were not always favourably regarded, being suspected of adverse effects on stocks of commercially valuable fishes, and were for a time subject to a bounty hunt (Reeves and Mitchell 1987). Declining numbers destroyed the commerce in beluga products after the Second World War, and low population counts led to the legislation of an increased level of protection. The belugas of the St Lawrence River were fully protected by the Canadian government in 1979, by amendment to the Beluga Protection Regulations of the Fisheries Act.

By the time 'Endangered' status was assigned in 1983 the condition of the environment in general, and the prevalence in the environment of persistent artificial organochlorines—pesticides and others—had become a subject of attention. The propensity of long-lived marine mammals to accumulate persistent liposoluble compounds led to high levels of such pollutants in the belugas of the St Lawrence (Sergeant 1986), and observations of the population appeared to support the view that it was still declining in size (Béland and Martineau 1985; Béland *et al.* 1987).

The Interdepartmental Action Plan for the Survival of the Beluga of the St Lawrence included a research component designed to augment knowledge of the population so that management and protective measures could be effectively chosen and applied. The research included aerial surveys to study the size, distribution and movements of the population. These activities have been continued under the auspices of the interjurisdictional programme 'St Lawrence-Vision 2000'. This report presents an estimation of a standard index of the size of the population, carried out by aerial photographic sample survey in August 1995. It followed other surveys carried out using the same methods in 1988, 1990 (Kingsley and Hammill 1991), and 1992 (Kingsley 1993).

METHODS

STUDY AREA, SURVEY DESIGN, AND FIELD METHODS

The survey area covered the middle estuary of the St Lawrence. Aerial surveys had shown that the seasonal distribution of the beluga population extended at least as far upstream as Île aux Coudres, sometimes as far as the Battures des Loups Marins off Saint-Jean-Port-Joli (Michaud, 1993; M.C.S. Kingsley, unpublished data).

Previous photographic aerial surveys used closely spaced lines, so belugas could move from one line to another in time to be photographed twice (Béland and Martineau 1985). This problem was aggravated by navigational errors, which caused misplaced lines to cover areas of high frequentation more than once (Béland and Martineau 1985), and by the interruption of the survey to refuel the (single) aircraft used. To avoid such problems, this survey, like others flown since 1988, used lines that were aligned across the river, to be short and quickly covered, and that were so far apart that belugas were unlikely to move from one to another; furthermore, two photographic aircraft were used so that the job could be done in a single flight with no interruption for refuelling.

The study area was sampled by a systematic strip transect design (Figure 1, Appendix 1). As large counts on widely spaced transects inflate the estimate of the standard error, a uniform transect spacing was used for the whole study area, even in the downstream areas where the expected density was low. Coverage extended from transect 14.0, between Forestville and Bic, to the Île aux Coudres at the upstream end, transect 30.0. The transects were spaced two nautical miles, i.e. 3.704 km, apart and crossed the estuary on headings of 320° and 140° true.

The photographic survey was flown using two aircraft simultaneously, to cover the survey area as quickly as possible and within the same day. The transects were flown from the centre outwards, i.e. in opposite directions, to reduce biases due to possible coordinated movements of belugas upstream or downstream. The work to be done by the two aircraft was equalised by dividing the transect pattern at Île Verte.

The observation platforms were light twin-engined aircraft: Rockwell 'Aero Commanders'. The cameras were metric mapping cameras taking frames 9" (228.6 mm) square and fitted with 6" (153.1-mm) lenses. The cameras were loaded with Kodak 2448 colour positive aerial survey film in 200-foot rolls.

The target survey altitude was 4000 feet, i.e. about 1220 m, giving a coverage of 50%, a nominal scale of 1:8000, and a target image size of 0.5 mm for adult belugas and about 0.2 mm for neonates. As it was a clear day, this altitude was achieved throughout. Altitude was controlled by certified pressure altimeter and satellite-linked Global Positioning System. The target frame overlap was 33%, and frames were shot at intervals of 14–17 seconds.

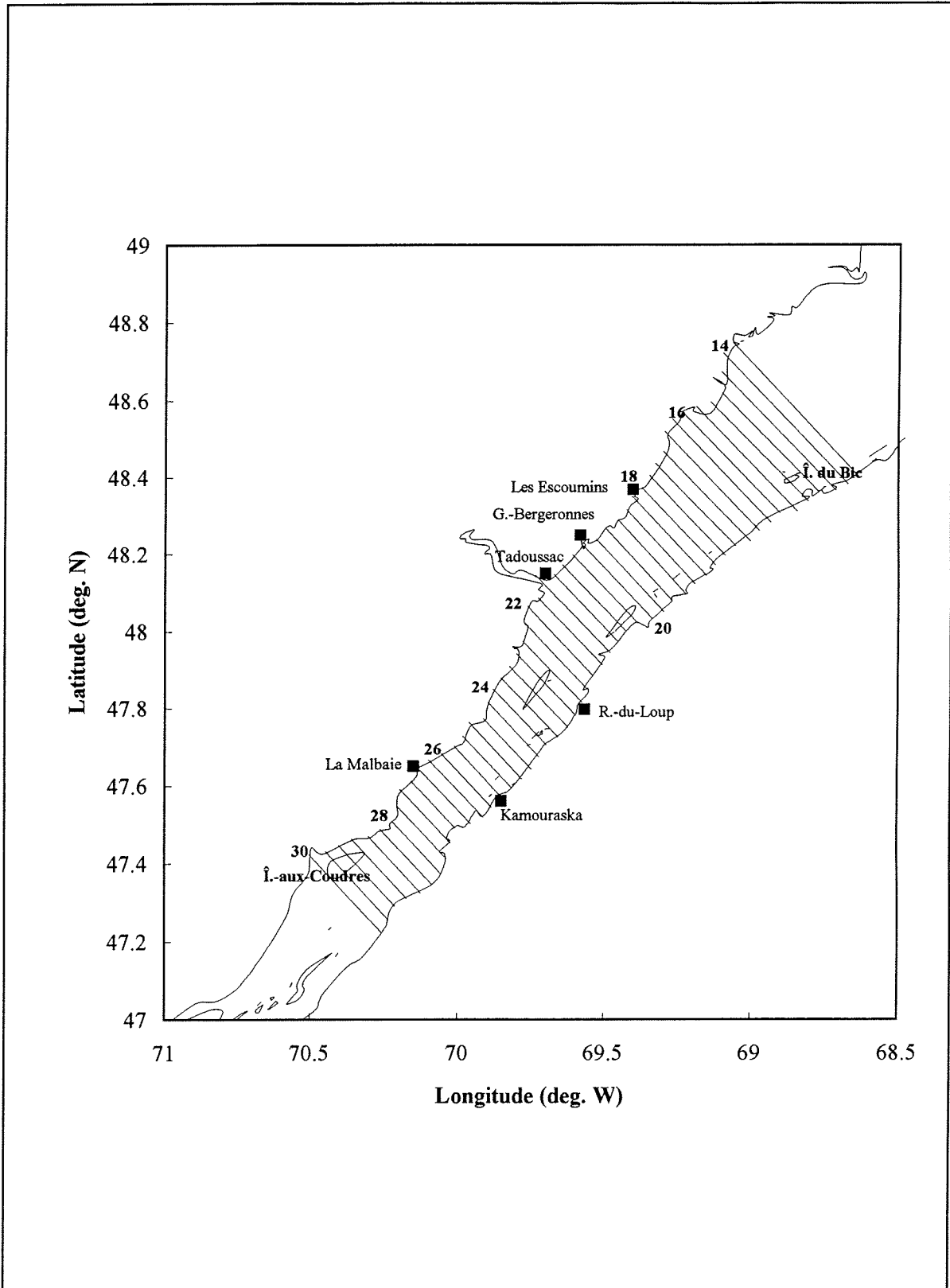


Figure 1. Transects for a photographic aerial survey of the St Lawrence estuary.

FILM INTERPRETATION AND DATA ANALYSIS

Beluga images were counted by examining the film on a light table using a dissecting microscope. The search for images was controlled by placing a transparent grid of 10 columns by 10 rows as a background to the frame; each of the 100 squares was checked in turn. Low magnifications were used, as the film grain was the limiting factor in identifying whale images. The film was counted once by a team comprising one experienced technician and three people without previous experience. A check reader had previous survey experience. The first pass of the film was made without consultation, but doubtful images were subsequently discussed among the reading team.

Because it was such a clear day, almost all frames had areas of sun glare, a diffuse solar reflection that prevents images from being seen in part of some frames. The survey was flown at around midday, to get the best light, but the latitude was so high and the season so late that the direct reflection of the sun was not on the film; the glare consisted of reflections from ripples and wavelets. Glare areas were searched for whales, and some were found. But this often happened when the film interpreters could expect images to be there because there were some in the overlap area of the adjacent frame. The frame overlap was so large that glare areas on most frames were contained in it, and so no glare correction was applied.

For data analysis, the counts were summed over transects, omitting images that were repeated on consecutive frames. To reject an image as a repetition, the frame overlap was measured, and the position of the image relative to buoys, convergence lines, land features, or other fixed objects was checked. A group or individual would be recorded as a repetition if it was within 4 body lengths of its position on the neighbouring frame, heading in the same direction, and of a similar size. The expansion factor, k , for the survey was calculated as

$$\begin{aligned} k &= S / W \\ &= S / (H \times B/L) \end{aligned} \quad [1]$$

where: S = transect spacing;
 W = transect width;
 H = flying height;
 B = photo frame breadth (228.6 mm for the metric mapping cameras used);
 and L = lens focal length (153.1 mm for these lenses).

The estimate of numbers of visible whales for the area sampled by the transect grid was then given by

$$\hat{N} = k \sum_{j=1}^J x_j \quad [2]$$

where: J = the number of transects, and
 x_j = the number of whales counted on the j^{th} transect.

The serial difference methods of Kingsley and Smith (1981) for calculating error variances for density estimates from systematic surveys were modified for this case, in which the valid study area, i.e. the habitat area actually used by the population, was not precisely known and the statistic of interest was the total size of a separate population rather than the spatial density of organisms. The expression used followed Eq. 8.44 of Cochran (1977) and was

$$\hat{V} = \frac{k(k-1)J}{2(J-1)} \sum_{j=1}^{J-1} (x_j - x_{j+1})^2 \quad [3]$$

including the finite population correction. To calculate confidence intervals on the estimate of the population index, recourse was had to Taylor's (1961) law, and confidence limits L were calculated from:

$$L + t \sqrt{\hat{V} \left(\frac{L}{\hat{N}} \right)^b} = \hat{N} \quad [4]$$

where t is an appropriate critical level of 'Student's' t -distribution, and b is the Taylor's-law exponent.

VISIBILITY CORRECTION

A correction for submerged animals is appropriate for photographic aerial surveys of marine mammals, but is difficult to estimate without information both on the diving behaviour of the population and on the turbidity of the water. A minimal correction can be estimated from the images in the frame overlap areas at the ends of each frame, as follows.

The target frame overlap for the 1995 survey was 33%, and was achieved or exceeded. We assumed that images in the 30% of each end of each frame therefore had a chance of being detected in the next frame. For each frame we assigned a 'glare end', which contained a diffused reflection of the sun where it was harder to see beluga images, and a 'plain end' where detection was unhindered. For each image in the three columns at each end of each frame, we checked whether it could be seen in the next frame. We counted n_g images detected in glare ends only, n_p images in plain ends only, and n_b detected in both frames. Assuming that detection of a beluga in the two overlapping frames is not independent, but positively associated,

$$\begin{aligned} n_g &< Np_g(1-p_p) , \\ n_p &< Np_p(1-p_g) , \\ n_b &> Np_p p_g \end{aligned} \quad [5]$$

where N is the (true) number of belugas, including surfaced and submerged animals, in the areas concerned, p_p is the probability of detecting a beluga in the plain end, and p_g is the probability of detecting a beluga in the glare end.

From these inequalities,

$$\begin{aligned} p_g &< \frac{n_b}{n_p + n_b} \\ p_p &< \frac{n_b}{n_g + n_b} . \end{aligned} \quad [6]$$

The probability of detecting a beluga in the non-overlap area in the centre of each frame, p_{-o} , is assumed equal to p_p , since the centres of frames are not affected by glare. Assuming that detection probabilities in the two overlapping frame ends are not independent but are positively associated, the detection probability in the overlap area, p_o , is bounded by:

$$p_o < 1 - (1 - p_p)(1 - p_g) \quad [7]$$

If the overlap is o , the proportion of each transect that is photographed twice is $o/(1-o)$, that photographed once is $(1-2o)/(1-o)$, and the overall detection probability is:

$$p = \frac{op_o + (1-2o)p_{-o}}{1-o} \quad [8]$$

These estimates are sensitive to wind and cloud cover: if the glare is strong, owing to wind or a clear sky, the counts in glare ends are as much affected by glare as by the dive behaviour of the belugas.

Uncorrected estimates, i.e. of visible whales, were calculated and are presented here, and such information as is available on diving correction factors, potential or previously applied, was reviewed and a correction factor applied to estimate a standard population index.

SURVEY OF THE SAGUENAY FJORD

As opposed to the estuary, there was no photographic coverage of the Saguenay Fjord because it is too narrow and tortuous to be satisfactorily sampled by this method. Instead, a visual overflight was made in a light high-wing aircraft (Rockwell 'Aero Commander') up the entire length of the fjord from Tadoussac to La Baie and Saint-Fulgence, and back again, while the photographic aircraft were covering the St Lawrence. The aircraft was flown at 1500 feet (454.5 m). Heading upstream, the aircraft was flown along the south-western shoreline of the fjord, so that the observer was looking down-sun at the full width of the fjord, and down the centre of the fjord on the downstream pass. The observer sat on the north-eastern side of the aircraft, and recorded the size and position of beluga groups as they were seen.

The count of belugas in the Saguenay Fjord was not corrected for visibility, for two reasons: first, the count adopted for each sighting is the higher of the upstream and downstream

passes, so to some extent a visibility correction is already built in; and second, visual survey allows a longer look at the surface than photographic methods do.

PROPORTION AND DISTRIBUTION OF YOUNG BELUGAS

Young belugas may be identified and classified by colour, as they change with age from the dark grey of the neonate and yearling stages through paler grey to the white adult coloration. However, we were unable to differentiate colour gradations: owing to the exposure of the aerial survey film, even the smallest calf images that we could detect under the microscope looked white. Previous analyses of high-altitude aerial survey films have used subjective judgements of length, assigning animals to classes of 'calves at heel', 'independent juvenile', 'adult', and 'unclassifiable'. A quantitative analysis of the 1992 and 1995 film showed that animals much shorter than full adult length were apt to be classified as adult if they were alone with no other animals nearby for reference (Gauthier 1996). Therefore, we measured the length of all images that were not too deeply submerged, curved, or inclined, as well as the film grain permitted. We rejected all images in the 'glare end' of all frames, where small animals tend to disappear. We defined four classes: short animals below 4 graduations in length (considered juveniles), intermediates 4 to 4½ graduations long, long animals over 4½ graduations, and animals that could not be classified owing to poor quality of image. We used 12x magnification, at which 4 graduations equal 2¾ m and 4½, 3 m.

To calibrate the measured lengths from the film, we fitted a Gompertz growth curve:

$$\hat{l}(t) = L_{\infty} \left(\frac{l_0}{L_{\infty}} \right)^{\exp\left(\frac{k_0 t}{l_0 \ln(l_0/L_{\infty})}\right)} \quad [9]$$

where L_{∞} is the asymptotic length, l_0 is the absolute length at birth, and k_0 is the absolute rate of growth at birth, to age-length data obtained from beach-cast belugas in the St Lawrence (Béland *et al.* 1992; Department of Fisheries and Oceans and National Institute for Ecotoxicology of the St Lawrence, unpublished data). A constant residual coefficient of variation was assumed, and the parameters of the Gompertz curve were fitted by minimising a weighted sum of squares:

$$S = \sum_i \frac{(l_i - \hat{l}_i)^2}{a^2 \hat{l}_i^2} + \sum_i \ln(a^2 \hat{l}_i^2) \quad [10]$$

where l_i and \hat{l}_i are the observed and predicted lengths, and a is the error coefficient of variation. The sexes did not differ significantly in length at birth, growth rate at birth, or residual coefficient of variation, which were therefore constrained to be the same for both.

RESULTS AND DISCUSSION

DISTRIBUTION AND INDEX ESTIMATE, ST LAWRENCE ESTUARY

The weather on 25 August was ideal for aerial survey, with light or no winds all day throughout the survey area. Belugas were concentrated in the central area of highest frequentation that extends from transect 26.1 to about transect 18.1 (Figure 2). This may be regarded as a typical distribution and occurred also in 1988 (Kingsley and Hammill 1991) and 1992 (Kingsley 1993). The 1995 distribution extended slightly farther downstream than in 1992 (Figure 2). Of the belugas included in the final count, 4.9% were upstream, and 4.9% downstream, of this central area. In 1990, a different distribution was recorded with higher proportions of the count in the areas both upstream and downstream of the core range (Kingsley and Hammill 1991).

The detailed map of observations (Figure 3) shows several distinct concentration areas. It has long been known that the St Lawrence belugas particularly favour these restricted areas and are often found there (Pippard 1985; Michaud 1993). From transect 19.0 through transect 20.2, the frames with high counts can be seen to lie side by side (Figure 3), showing

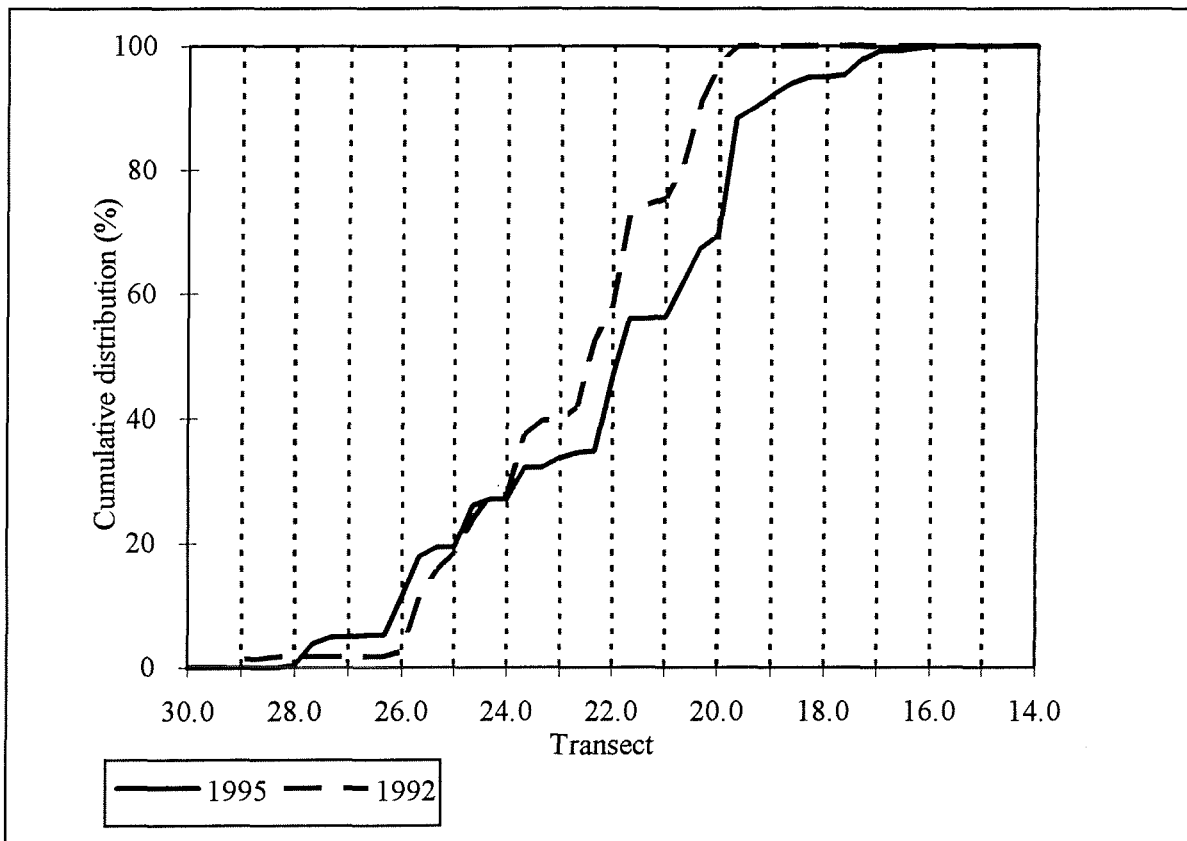


Figure 2. Distribution of beluga counts between transects on photographic aerial surveys of the St Lawrence in 1992 and 1995.

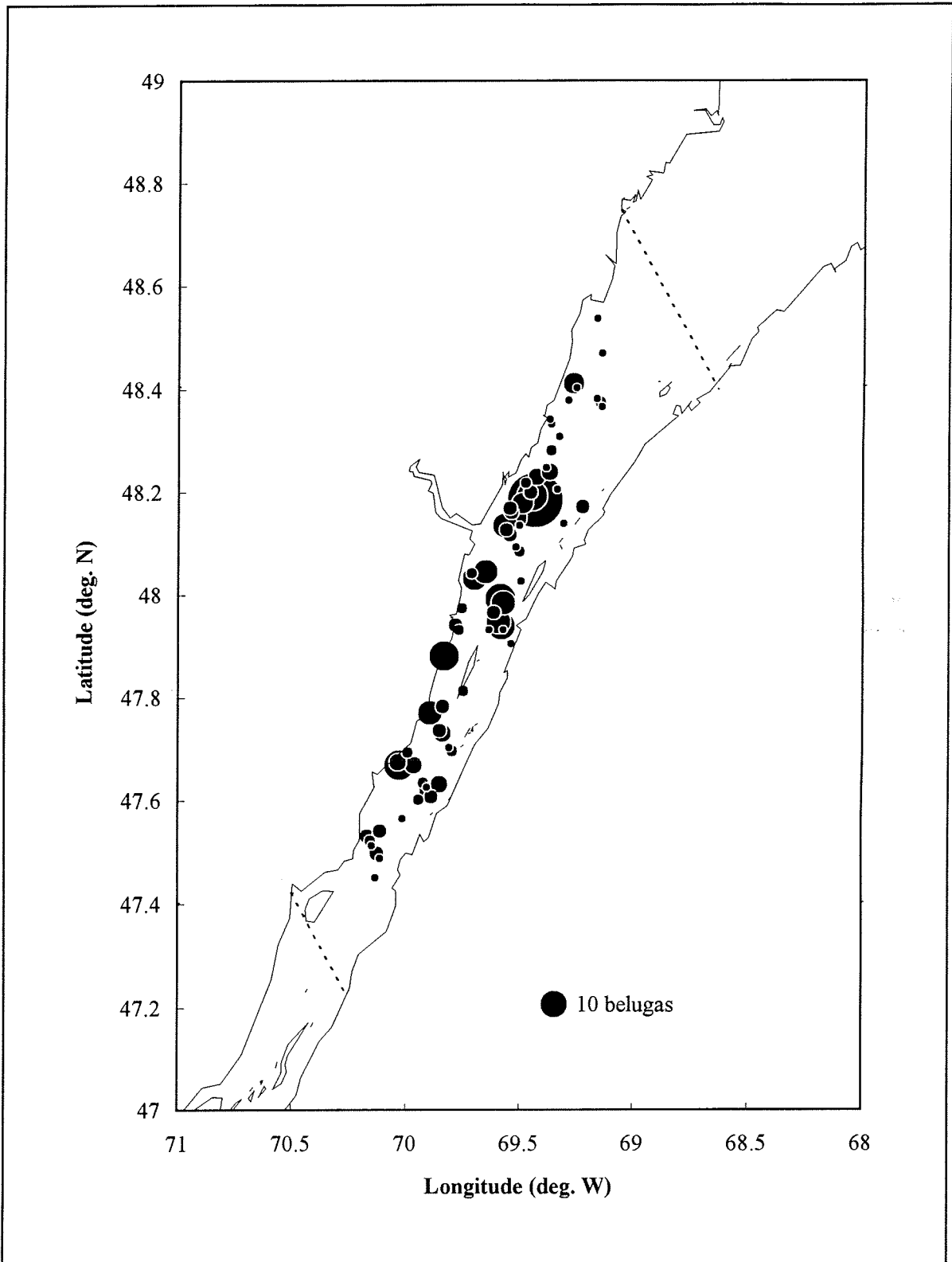


Figure 3. Observations of belugas on a photographic aerial survey of the St Lawrence estuary on 25 August 1995.

Table 1. Non-zero counts of beluga whales on photographic survey transects of the St Lawrence estuary on 25 August 1995.

Transect No	Count	Transect No	Count	Transect No	Count
$S = 2$ n. mi.; $H = 4000$ ft; $k = 2$					
16.0	1	20.0	6	24.1	3
16.1	1	20.1	15	24.2	19
17.0	4	20.2	16	25.1	4
17.1	7	21.0	1	25.2	18
17.2	1	21.2	27	26.0	18
18.1	3	22.0	33	26.2	1
18.2	5	22.1	1	27.1	3
19.0	6	22.2	2	27.2	10
19.1	5	23.0	5	28.0	1
19.2	54	23.2	14		

that these transects were probably crossing a single continuous patch of belugas some 11 miles long and up to 3 miles wide.

We found 377 images of belugas on 86 film frames, distributed among 29 of 49 transects flown (Table 1, Appendix II). Of these, 93 were judged to be repeated images from neighbouring frames. Inserting the flight parameters into Equation 1 and the transect counts into Equations 2 and 3 gave an estimate of 568 whales visible in the estuary, with an estimated sampling standard error of 94.0. The serial correlation of counts between transects was positive but very small. The clump factor (Kingsley *et al.* 1985) for the estuary survey was higher in 1995 than in 1992 (7.8 vs 4.2), and the mean crowding (Lloyd 1967), measured by the contraharmonic mean of total belugas per frame, was also higher in 1995 (12.1) than in 1992 (8.3). The distribution of the population is consistent with Hanski's (1982) model of spatial organisation, in which increased numbers are associated with crowding at a restricted number of favoured sites. The Taylor (1961) exponent derived from the 1995 and 1992 results was 3.7. Hanski (1982) suggests that Taylor exponents much below 2 would be associated with species at carrying capacity; conversely, a value apparently so far above 2 might indicate that this population was still well below carrying capacity on its summer range.

VISIBILITY CORRECTION

Counts of images in the frame overlap indicated an overall mean probability of detection less than 88.4%, which would justify a correction factor greater than 13.1% (11.6/88.4) (Table 2). This estimate is affected by the diving behaviour of belugas as follows. If

belugas appeared and disappeared quickly and often, i.e. several times in the 14- to 17-second interval between photo frames, the correction factor would be roughly unbiased; if belugas often had a diving cycle of about 25–35 seconds, so that being in sight at one instant, they would tend to be out of sight for the next frame, the correction factor would be too high. Watching St Lawrence belugas from aircraft and from land shows that they do not behave according to either of these models, but stay at the surface for several minutes at a time. Furthermore, satellite-linked time-depth recorders on Arctic belugas have shown that they dive, often to the bottom, for 6-10 minutes at a time. Given this behaviour, the inequalities of Eqq. 5–8 and Table 2 are valid and the visibility correction calculated from the 1995 photographs is a minimum. Sergeant and Hoek (1988), analysing overlap images a bit differently and much more simply, estimated visibility corrections of 15% and 21%, which they also recognised as minimums, for photographic surveys of the St Lawrence

Table 2. Visibility corrections for photographic aerial survey of belugas, calculated from duplicated images on overlapping frames.

Counts	
Glare end only	19
Plain end only	54
Both plain end and glare end	93
Probabilities	
Detection in glare end	< 63.3%
Detection in plain end	< 83.0%
Detection in overlap area	< 93.8%
Target Overlap	33. %
Overall mean probability of detection	< 88.4%
Correction factor	> 13.1%

belugas in 1984 and 1985. They used 18%, the mean of these two values as a standard value for both of those surveys. In analysing the data from photographic aerial surveys of the St Lawrence since 1988, a value of 15% has been used. This was selected as the lower of the two estimates calculated by Sergeant and Hoek (1988), and therefore consistent enough with their treatment of survey data but with a slight conservative bias. The lower bound of 13.1% obtained in 1995 is not sufficiently different to justify starting to use different values, so the standard value of 15% has been kept in use.

Information on dive behaviour obtained from satellite-linked time-depth recorders deployed on Arctic belugas in the deep waters of Barrow Strait (Martin and Smith 1992) and in the shallower waters of eastern Hudson Bay (Kingsley unpublished data) and on narwhals

(*Monodon monoceros*) (Martin *et al.* 1994) indicates that correction factors may be as high as 75–80% for Arctic monodontids in deep water, and direct observations on narwhals have indicated values up to 100% (Dueck 1989). The same values may not apply in the shallower, but more turbid, St Lawrence, but these results indicate that values of 20% or less are probably very conservative.

When the 15% correction factor was added to the visible estimate of 568, the resulting conservative population index estimate for the St Lawrence estuary was 653.2.

COUNTS IN THE SAGUENAY FJORD

On distribution surveys in previous years up to 59 belugas have been counted in the Saguenay Fjord (M.C.S. Kingsley, unpublished data), so it was surveyed by direct visual observation while the photographic survey was going on. Conditions in the fjord were excellent for visual aerial survey: there was no wind and the surface was smooth. Belugas were seen close to both shores near the mouth of baie Ste-Marguerite on both the upstream and downstream passes, and a single white beluga was seen in the middle of the fjord near Cap Trinité. After eliminating probable duplications, the total count for the Saguenay was 52 (Table 4), and was added to the estimated index for the estuary without being corrected

Table 3. Sightings of belugas on visual aerial survey of the Saguenay Fjord on 25 August 1995.

Group	Time	Location	Count
A	1043	SW side, opposite baie Ste-Marguerite	4
B	1045	NE side, upstream of baie Ste-Marguerite	15 in 5 groups: 4, 2, 2, 6, 1
C	1058	Centre of fjord, nr Cap Éternité	1
D	1136	NE side, downstream corner of the mouth of baie Ste-Marguerite	47 in 12 groups: 1, 5, 1, 1, 4, 2, 2, 4, 4, 2, 2, 19
E	1136	same place as A	2
Assume: E is contained in A; B is contained in D; A, C and D are distinct			
Total: 52			

for visibility. The total estimated index of population size for 1995, including the Saguenay, is 705.2, with estimated sampling standard error of 108.1. Assuming a Taylor exponent of 2, a symmetrical 95% confidence interval on the 1995 population index estimate was calculated using Eq. 4 as 540–1035. This interval excluded the 1992 index estimate. A similar interval calculated for the 1992 index estimate using the same assumptions was 410–725.

COMPARISON WITH PREVIOUS RESULTS

Taken together, the published population indices show a steady increase (Table 4, Figure 4), and *prima facie* the population is increasing.

This inference is probably correct, especially considering what is known about the dynamics of this population. The birth rate does not appear to be much less than the normal value (Kingsley 1993; see also pp. 17-21 of this report); the number of juvenile deaths is small (Béland *et al.* 1988); and the life expectancy at maturity, estimated from strandings age data, is about 16 years (Bailey and Zinger 1995). Unusual deaths, for example from ship strikes or fishery by-catches, are rare. Thus, the population dynamics information agrees with the trend in population index estimates in suggesting that the population is increasing.

However, quantitative estimation of the rate of increase is subject to caveats on the comparability of the various surveys, which did not all cover exactly the same area or use exactly the same methods. In particular, earlier surveys tended to be more restricted to the core range where densities were highest (Sergeant and Hoek 1988; Figures 2 and 3) and which usually held most of the belugas in the population. However, since 1988 surveys have included outer areas of potential range where there are few belugas. (In 1992, a total of 5

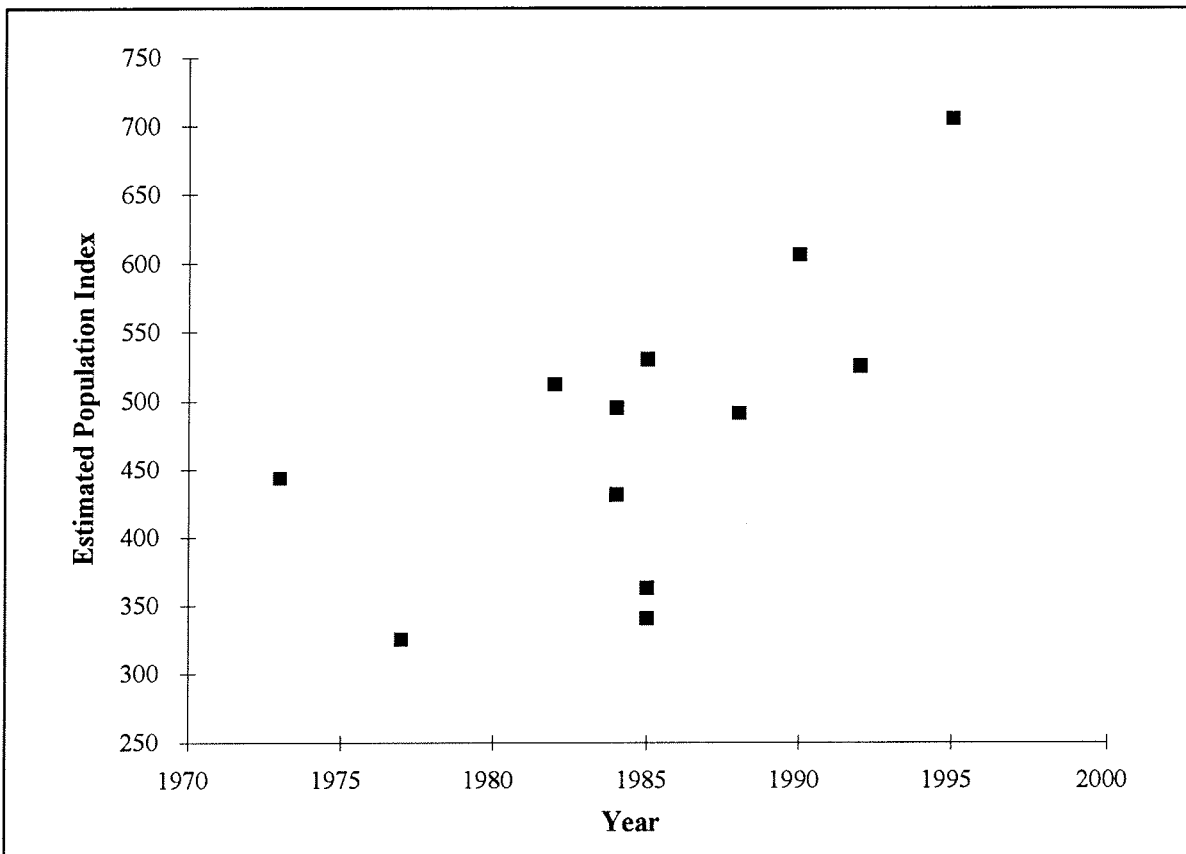


Figure 4. Population index estimates for the St Lawrence beluga from 1973 through 1995.

Table 4. Population index estimates for belugas of the St Lawrence estuary made from 1973 through 1995.

Year	Method	Index estimate	Limits (-) or standard error (\pm)	Source
1973	Photo (air)	443 ^{ab}	229–658	Sergeant and Hoek 1988
1977	Visual (air)		300–350 ^{bce}	Pippard 1985
1982	Visual (air)	512 ^{def}	360–715	Sergeant and Hoek 1988
1984	Photo (air)	431 ^{abc}	187–773	”
1984	Visual (boat)	495 ^{bd}	± 245	Lynas 1984
1985	Visual (boat)		< 340 ^{bdeg}	Béland <i>et al.</i> 1987
1985	Photo (air)	530 ^{abhi}	285–775	Sergeant and Hoek 1988
1985	Photo (air)		275–450 ^{hij}	Béland and Martineau 1985
1988	Photo (air)	491 ^{fhk}	± 69	Kingsley and Hammill 1991
1990	Photo (air)	606 ^{fhk}	± 308	”
1992	Photo (air)	525 ^{efk}	± 71	Kingsley 1993
1995	Photo (air)	705 ^{efk}	± 108	this report

^a corrected for diving by adding 18% to photo counts;

^b sampled core main range only, i.e. from transect 18.1 to transect 26.1;

^c of 8 visual helicopter surveys flown in 1975 and 1977 over the most densely frequented parts of the core range, the highest two counts (both in July 1977) were 266 and 262. Pippard (1985) corrected this count to the published interval (i.e. 300–350) to allow for belugas in peripheral areas;

^d uncorrected for diving;

^e included coverage of the Saguenay Fjord;

^f covered the estuary from transect 14.0 to transect 29.2 or 30.0;

^g did not cover areas further upstream than about transect 25.0;

^h did not cover the Saguenay Fjord;

ⁱ these two estimates are based on the same aerial survey film, independently analysed by Sergeant and Hoek and by Béland and Martineau;

^j corrected for double counting of beluga groups photographed on more than one pass; the upper limit includes a ‘generous’ correction of 25% for all non-photographed belugas, whether diving or in unphotographed areas;

^k corrected for diving by adding 15% to photo counts.

belugas, or 2.8% of the estuary count, were found on the photographs from the 12 transects furthest upstream, and none on the 17 downstream transects; in 1995, there were 6 blank transects at each end of the pattern) (Figure 2). The range of the population would normally expand as its numbers increase (Brown 1984; Gaston and Lawton 1990), so the proportion at the edges of the range would be expected to have been less when the population was smaller than it is now. In response to the 1995 estimate Michaud (1996, unpublished)¹ has revised the index estimates from earlier surveys on the basis of their coverage of the estuary (Table 5). The revised estimates appear to show that the smoothed population index has never been less than about 550.

Other variations were that some surveys included the Saguenay fjord, but those flown in 1985 (Sergeant and Hoek 1988), 1988 and 1990 (Kingsley and Hammill 1991) did not; and later photographic counts (1988 through 1995) have been corrected for visibility by only 15% (Kingsley and Hammill 1991; Kingsley 1993; this report) in place of the 18% used in 1984 and 1985 (Sergeant and Hoek 1988).

The 1992 survey was carried out using the same methods as in 1995, including flying height, film type, and transect pattern; the only difference was that in 1992 we used cameras that

Table 5. Revision of previously published index estimates for the St Lawrence population of belugas, according to Michaud (1996, unpublished).

Survey and year	Original published estimate		Michaud (1996, unpublished) revised estimate
Pippard 1977	300-350	(Pippard 1985)	548
Sergeant 1982	512	(Sergeant and Hoek 1988)	585
Sergeant 1984	431	"	499
Sergeant 1985	530	"	708
Béland 1985	340	(Béland <i>et al.</i> 1987)	517

moved the film while the shutter was open to compensate for the moving aircraft, which gave a sharper image. The distribution of sightings between transects was similar for the two surveys (Figure 2) which confirms that this design is sensitive for detecting change in population size. The difference between the index estimates is 180, with an estimated sampling standard error of 113.7. This change includes components due to change in true population size and weather-related behaviour as well as sampling error. A currently accepted maximum rate at which beluga populations can increase is 4% per year (Innes 1996), which would raise an index of 525 to only about 590 in 3 years.

¹Michaud, R. 1996. Revised estimates of beluga populations presented to the National Marine Mammal Peer Review Committee, Department of Fisheries and Oceans, Winnipeg, 7-8 March 1996. Unpublished.

The wind was stronger in 1992 than in 1995, especially in the Saguenay Fjord, and may have depressed the counts in that year, either because belugas spend less time at the surface when it is windy, or because surface waves make them harder to see both on film and in visual survey. The component of variation due to weather is difficult to evaluate. If the population indices resulting from several years' surveys are smoothed by a simple model, the scatter about the model, i.e. the residual error variance, represents the sum of several distinct components. These are: the variation in the realised rate of population change; the variable distribution of belugas between surveyed and non-surveyed areas; and average visibility, which is affected by equipment, methods, wind, clouds, and turbidity. The variance of index estimates for this population about simple linear or exponential growth models of is no greater than the estimated sampling standard errors for the individual surveys. Two conclusions follow: that the year-to-year variations are small, and that the between-transect differences overestimate the between-years sampling variation for these systematic surveys.

If it were to be assumed that the population is now stationary, and the transect counts from the 1992 and 1995 surveys were averaged to generate one overall estimate for that period, the result would be 615 with an estimated sampling standard error of 71.4.

The data available to date indicate, by linear smoothing of previous and current values, that the standardised population index is now probably near to 650. There are difficulties in interpreting this value as an estimate of the true population size, because we do not know accurately how much to correct photographic counts for unseen diving animals. The visibility correction that we do apply has been chosen to be conservative. If St Lawrence belugas behave in their summering areas like Arctic populations, the true population size may well be in the range 900 to 1300 (Innes 1996).

In determining the status of a possibly endangered population, criteria approved by the International Union for the Conservation of Nature (IUCN) for the evaluation of its 'Red List' species consider population trend, population size, and distribution (extent of distribution and area of occupancy), as well as other factors such as stability (IUCN 1994). If there is no evidence of 'continuing decline' in population size or index of abundance, status evaluation depends on absolute numbers and area of occupancy.

Although there are difficulties in measuring the rate of growth of the St Lawrence beluga population, owing to the inherent variability of survey results, it shows no sign of a continuing decrease in size (*pace* Béland and Martineau 1985 p. 48) (Figure 4). According to the IUCN criteria, in such a case population trend is less important in determining status and absolute size more important. The IUCN quantitative criteria for absolute population size are: 'critically endangered'—less than 50 mature individuals; 'endangered'—less than 250; 'vulnerable'—less than 1000. The present smoothed estimate of population index is about 650, of which about 60%, or 390, could be assumed mature (Burns and Seaman 1985). This puts the St Lawrence beluga population in the IUCN 'vulnerable' range, but not far above the criterion for 'endangered' status. But it is based on a correction factor that is known to be conservative. A more realistic correction factor would place the true population not far from 1000, of which 600 could be assumed mature. Knowing more accurately how

to correct film counts to true numbers of belugas would be helpful in defining the status of this population.

NUMBERS AND DISTRIBUTION OF YOUNG BELUGAS

Gompertz curves (Eq. 9), weighted and constrained to have the same length and growth rate at birth for the two sexes, were fitted to age-length data for beach-cast belugas (Figure 5). Males grew to be about 15.5% longer than adult females. Birth length was estimated at 43% of female asymptotic length, and initial growth at 13% of the latter per year. Seventy percent of female length was predicted at 2.2 years for males and 2.4 for females. Doidge (1990, after exchanging the k and b columns of Table 1), using samples that contained few very young animals, predicted 1.9 to 2.8 years for the same relative length in various populations; however, his biggest difference between sexes within a population was 0.35 years. The limit chosen for 'short' belugas, viz. 4 graduations at 12x magnification, corresponded to 2.67 m, or about 2.6 years for males, 2.8 for females; 4.5 graduations, 3 m, was about 3.5 years for males, 4 for females. The shortest adult female in the beach-cast sample was 3.2 m long at 24.5 years old. These estimates of age at length are not very accurate, for the following reasons: 1) the Gompertz curve may not be a true representation of the juvenile growth

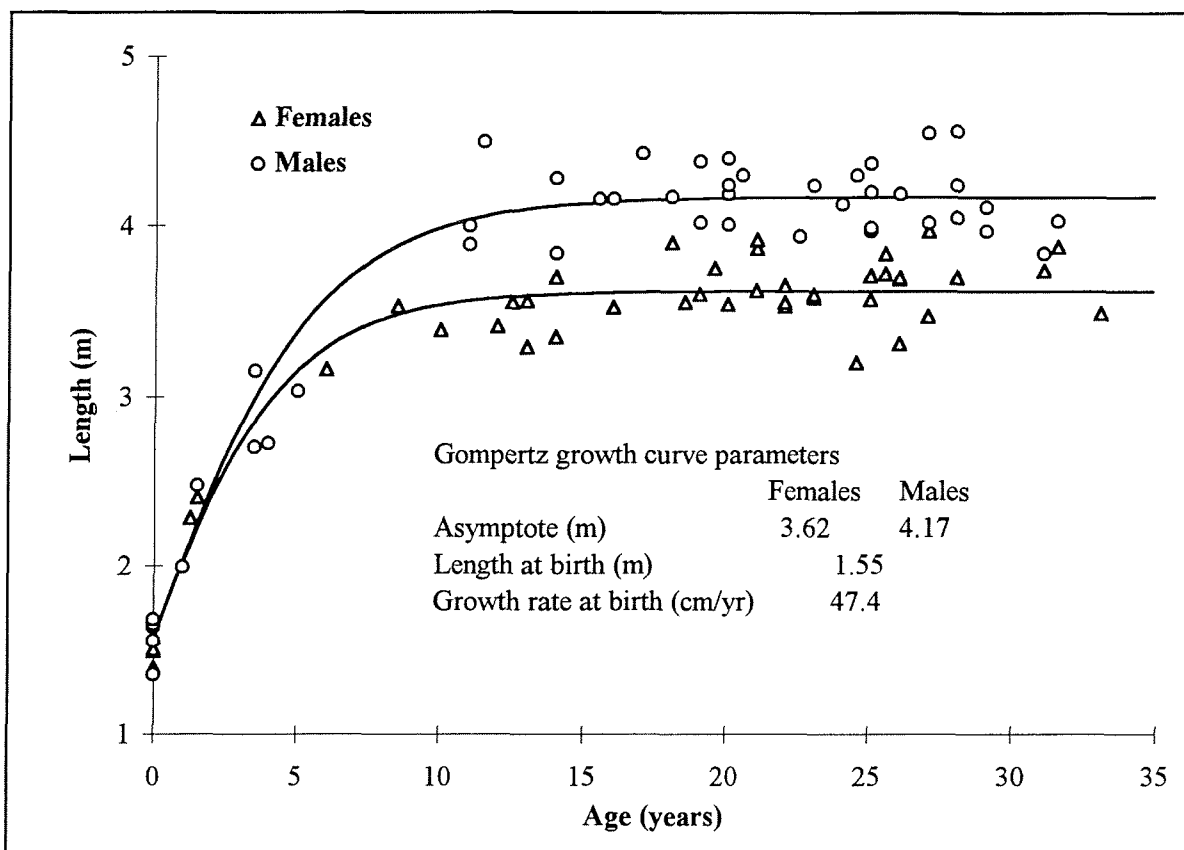


Figure 5. Ages and lengths of beach-cast St Lawrence belugas, with fitted Gompertz growth curves.

Table 6. Juvenile belugas counted on aerial survey photographs of the St Lawrence estuary from 1988 through 1995.

Year	Total count	Juveniles				Total	as % of total count
		At heel	Independent	Questionable			
1988	152	3	6	10	19	12.50	
1990	148	23	4	-	27	18.24	
1992	227	33	12	-	45	19.87	
1995	197 ^a	9	22	19	50	25.4	

^athis is the count of classified images; the total count of belugas on the film from which we estimated the population index was 284, net of repetitions but including images too indistinct to classify.

pattern; 2) few juvenile beluga are found cast ashore dead, so the juvenile part of the curve is fitted to little data; 3) the growth curve describes average, not individual, growth, and there is a 5.5% scatter about the fitted line; and 4) the age-length data for dead beach-cast juveniles may be biased with respect to the live ones.

An estimate of population composition was obtained by measuring the clearer images on the film. Of the 197 images measured, we counted 138 long, 19 limit, 22 short, and 9 cow-calf pairs (Table 6). So short animals (including those in cow-calf pairs) were 16% of the measured images and 'limit' animals were 10%, for a total of 25%. Small animals and large ones may not be equally visible, because they behave differently, are differently distributed between turbid and clear water, or simply because small ones are harder to see.

The birth rate of the St Lawrence population has been estimated at 8–9%/yr, which would be low compared with values of 12–14% suggested for Arctic populations (Sergeant 1986, Table V). However, there are reasons to examine these latter values more closely: if females bear every three years, a 14% birth rate would require that the population contain 42% adult females, and with an adult sex ratio near unity, 42% adult males as well. These three components (neonates, adults females, adult males) then compose 98% of the population, leaving only 2% for all the older juvenile age classes. Even a 12% birth rate would leave only 16%. As first calving does not occur until 6–7 years of age, these proportions must accommodate 5 or 6 age classes, and are too small to do so. Therefore, Sergeant's Arctic birth-rate estimates may be somewhat too high; especially considering his estimate of 40% for immatures. Burns and Seaman (1985) reconstructed a beluga population profile and estimated the gross population annual birth rate at 9.4%; similar calculations to those above then estimate 34.2% for the 5 age-classes of older juveniles, which seems more possible. After calving, but before *any* perinatal mortality, the first four age classes, aged 0–3 years, sum to about 27% of the population, and the 0–4 group, 32% (Burns and Seaman 1985). These estimates of population proportions do agree with Sergeant's (1986, Table V) observations for the St Lawrence.

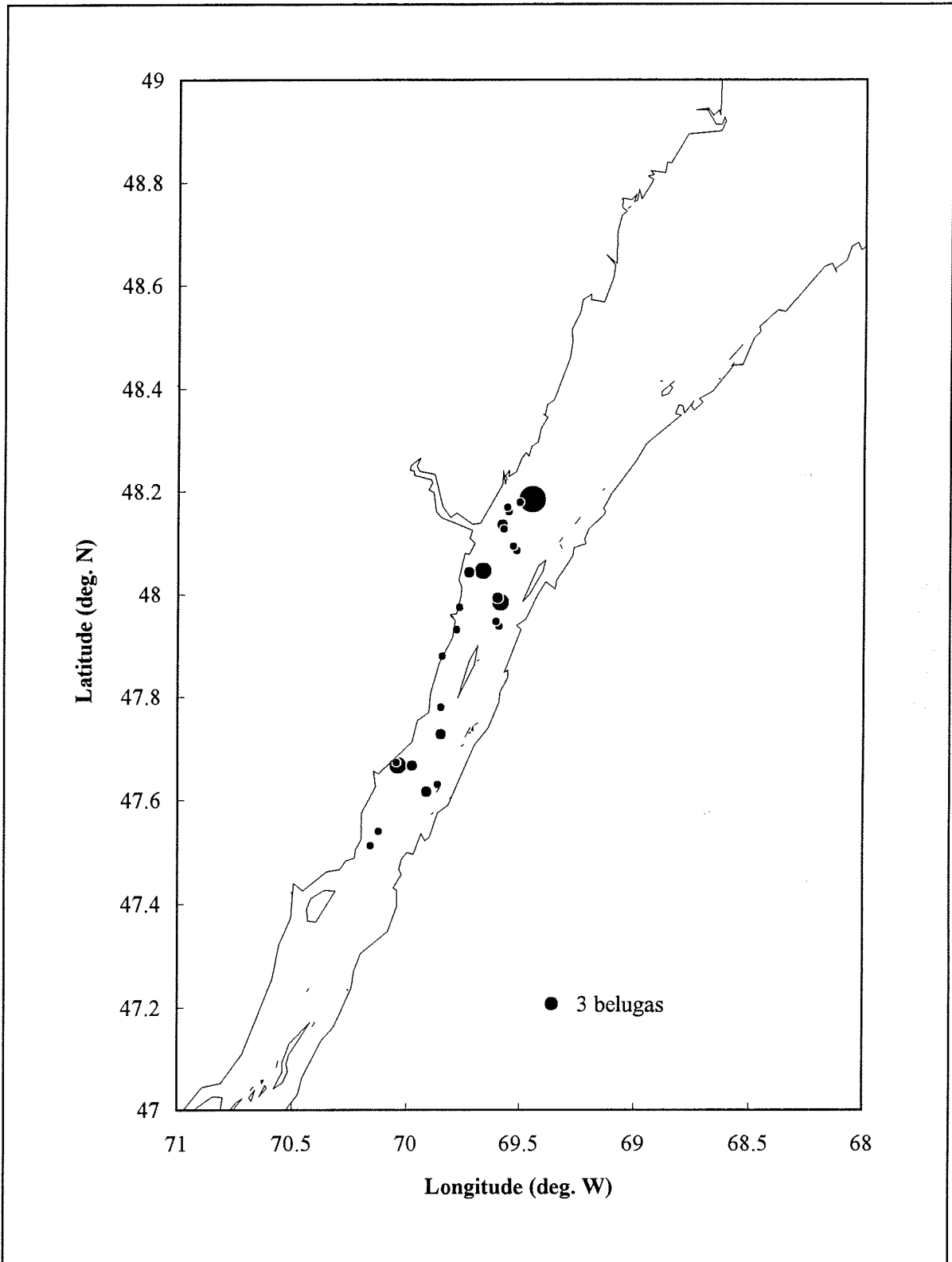


Table 7. Distribution of juvenile belugas in the St Lawrence estuary determined from photographic aerial surveys from 1988 through 1995.

Year	Upstream of Saguenay			Downstream of Saguenay		
	Calves	Others	%	Calves	Others	%
1988	15	53	22.1	4	80	4.8
1990	24	76	24.0	3	45	6.3
1992	36	133	21.3	9	49	15.5
	Small	Large		Small	Large	
1995	34	57	37.4	16	90	15.1

The results above, considered in the light of their probable downward bias, indicate that the proportion of small animals in the population is not seriously reduced in comparison with what may be considered normal; we emphasise, however, that they are approximate.

In previous years, the classification of belugas by size was subjective. In both 1990 and 1992, about 15% of very small juveniles closely associated with a large animal were noted, which contrasted strongly with the small number in 1988 (Table 6; Kingsley and Hammill 1991; Kingsley 1993). In 1995, there were only 9 such small calves; there were only 8 other cases of close groups which included a small and a large animal. It looks as though births were down in 1995. Kingsley and Hammill (1991) suggested that the reproductive cycles of adult female belugas might drift, in response to variations in their environment, into partial synchrony, which would increase the year-to-year variation in number of births; the 1995 result supports that idea. If correct, this would lend weight to the suggestion (Béland *et al.* 1988) that counting all juveniles would provide a better, since averaged, index of reproductive performance than counts only of calves of the year.

All young animals were 15% of the images on transects downstream of the Saguenay, and 37% upstream (Table 7; Figure 6). This segregation of the population, with fewer juveniles in the deep-water areas downstream, was similar in kind to what had been noted in the past (Pippard 1985, Sergeant 1986) but the 1995 result, like that of 1992, indicated a less marked segregation than in 1988 or 1990.

CONCLUSION

An index of the size of the St Lawrence population of belugas in 1995 was estimated at 705 with estimated sampling standard error 108. This index was calculated using a visibility correction applied to photographic counts which is conservative, so it was a deliberate underestimate of the true population size. The population has probably increased since hunting was banned; at about that time it was estimated at no more than 350. The proportion of visibly short juveniles in the images counted on the aerial survey film in 1995 was 25%, which is consistent with a normal rate of reproduction, allowing for the difficulty of both seeing juveniles on the film, and confidently identifying them as such when they are seen.

However, the population is still isolated from its conspecifics, no significant immigration or regular exchange with other beluga groups being known, and it continues to occupy a single, contiguous, and small summer range.

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Appendix I. Coordinates of transects for systematic sample survey of the St Lawrence estuary.

Transect number	North end latitude	North end longitude	South end latitude	South end longitude
14.0	48°44.9'	69°3.8'	48°24.0'	68°37.9'
14.1	48°43.3'	69°5.7'	48°23.0'	68°40.3'
14.2	48°40.4'	69°6.1'	48°22.0'	68°42.8'
15.0	48°37.2'	69°6.0'	48°21.8'	68°46.3'
15.1	48°35.8'	69°8.3'	48°20.3'	68°48.4'
15.2	48°35.1'	69°11.2'	48°18.8'	68°50.7'
16.0	48°34.3'	69°14.0'	48°18.5'	68°54.1'
16.1	48°33.2'	69°16.1'	48°17.0'	68°56.0'
16.2	48°31.3'	69°17.6'	48°15.7'	68°58.2'
17.0	48°28.1'	69°17.8'	48°14.0'	69°0.0'
17.1	48°26.3'	69°19.5'	48°13.3'	69°3.0'
17.2	48°24.4'	69°20.7'	48°11.8'	69°5.0'
18.0	48°22.5'	69°22.2'	48°10.3'	69°7.0'
18.1	48°20.8'	69°23.8'	48°8.7'	69°8.9'
18.2	48°19.0'	69°25.3'	48°7.4'	69°11.2'
19.0	48°17.3'	69°27.0'	48°5.9'	69°13.2'
19.1	48°16.2'	69°29.8'	48°4.7'	69°15.7'
19.2	48°14.4'	69°31.6'	48°3.1'	69°17.6'
20.0	48°13.4'	69°34.3'	48°2.0'	69°20.0'
20.1	48°11.9'	69°36.4'	48°1.4'	69°23.1'
20.2	48°10.4'	69°38.6'	48°0.0'	69°25.3'
21.0	48°8.9'	69°40.4'	47°58.5'	69°27.2'
21.1	48°8.8'	69°44.2'	47°56.6'	69°28.6'
21.2	48°5.2'	69°43.6'	47°54.8'	69°30.3'
22.0	48°3.9'	69°45.7'	47°53.1'	69°32.2'
22.1	48°1.4'	69°46.3'	47°51.1'	69°33.6'
22.2	47°58.5'	69°46.8'	47°48.8'	69°34.4'
23.0	47°56.5'	69°48.0'	47°46.8'	69°35.7'
23.1	47°54.5'	69°49.4'	47°45.0'	69°37.3'
23.2	47°52.7'	69°51.2'	47°43.5'	69°39.3'
24.0	47°51.0'	69°52.8'	47°42.3'	69°41.7'
24.1	47°48.9'	69°53.9'	47°40.4'	69°43.3'
24.2	47°46.4'	69°54.8'	47°38.5'	69°44.8'
25.0	47°45.8'	69°57.8'	47°37.0'	69°46.8'
25.1	47°43.7'	69°59.0'	47°35.6'	69°48.8'
25.2	47°42.1'	70°0.8'	47°34.4'	69°51.3'
26.0	47°41.0'	70°3.4'	47°32.6'	69°52.9'
26.1	47°40.0'	70°6.0'	47°31.1'	69°54.7'

Appendix I, cont.

Transect number	North end latitude	North end longitude	South end latitude	South end longitude
26.2	47°39.5'	70°9.2'	47°30.1'	69°57.3'
27.0	47°36.7'	70°9.5'	47°29.4'	70°0.5'
27.1	47°35.4'	70°11.8'	47°27.1'	70°1.4'
27.2	47°32.9'	70°12.4'	47°25.0'	70°2.6'
28.0	47°30.5'	70°13.3'	47°22.4'	70°3.3'
28.1	47°29.3'	70°15.7'	47°20.8'	70°5.2'
28.2	47°28.2'	70°18.1'	47°19.5'	70°7.5'
29.0	47°27.8'	70°21.5'	47°18.7'	70°10.3'
29.1	47°26.8'	70°24.0'	47°17.5'	70°12.6'
29.2	47°25.9'	70°26.7'	47°15.4'	70°14.0'
30.0	47°25.4'	70°30.1'	47°13.4'	70°15.3'

Appendix II. Counts of beluga whales on aerial photographs of the St Lawrence estuary taken on 25 August 1995.

Roll and frame numbers referenced in this Appendix are the same as those appearing in Appendix III. The roll numbers are those assigned by the National Air Photo Library of the Canadian Department of Energy, Mines and Resources, and the frame numbers are those assigned by the survey company, not those of the camera frame counter. Transect numbers are those referenced in Appendix I, Table 1 and Figure 1 of this report. Frames are sorted in order of increasing transect number, i.e. working from downstream in an upstream direction, and within transect in order of increasing latitude, i.e. from the southeast end of the transect to the northwest end. Northbound transects have increasing frame numbers reading down the table; southbound ones, decreasing.

The film was read on a light table, emulsion side up, i.e. reversed, with the start of the film (lower-numbered frames) to the reader's right. For northbound transects, South was to the reader's right, North to his left, West at the top of the table, and East at the bottom. On southbound transects, South was to the left, North to the right, West at the bottom, and East at the top. Images were located on the film on a grid of 10 squares each way. The rows were numbered 00 at the top to 90 at the bottom of the light table, the columns were numbered 00 at the left and 09 at the right. Square 00 was at the top left, 09 at the top right, 90 at the bottom left, and 99 at the bottom right. The grid row is given by the first digit of the 'Grid' entry in the table, the grid column by the second. Images that also occur in the next frame are in low-numbered columns, those that also occur in the previous frame are in high-numbered. The 'glare end' of frames on northbound transects comprises the high-numbered (previous-frame) columns; on southbound ones, the low-numbered (next-frame) ones; and vice versa for 'plain ends'.

Roll	Tx	Frame	Lat.	Long.	Grid	Observations
A31705	16.0	121	48°31.4'	69°09.6'	09	A/p
A31705	16.0	120	48°31.9'	69°10.2'	02	A/n
A31705	16.1	105	48°27.9'	69°09.2'	63	A
A31705	17.0	40	48°21.6'	69°09.0'	41	A/n
A31705	17.0	41	48°22.1'	69°09.6'	04	A
A31705	17.0	41	"	"	34	A
A31705	17.0	41	"	"	57	U/p
A31705	17.0	42	48°22.6'	69°10.2'	21	A
A31705	17.1	6	48°23.9'	69°15.7'	55	A

Observations: [] = close group; Cc = ♀ with calf at heel; A = adult; L = limit; J = juvenile; U = unclassified; /p (n) = also on previous (next) frame.

Appendix II, cont.

Roll	Tx	Frame	Lat.	Long.	Grid	Observations
A31705	17.1	5	48°24.4'	69°16.4'	03	A
A31705	17.1	5	"	"	14	2A
A31705	17.1	5	"	"	24	A
A31705	17.1	5	"	"	54	A
A31705	17.1	5	"	"	95	A
A31704	17.2	203	48°22.4'	69°17.9'	03	A/n
A31704	17.2	204	48°23.0'	69°18.5'	09	A/p (deep)
A31704	18.1	153	48°18.1'	69°20.4'	84	U
A31704	18.1	156	48°19.7'	69°22.3'	31	A/n
A31704	18.1	157	48°20.2'	69°22.9'	35	A
A31704	18.1	157	"	"	37	A/p
A31704	18.2	130	48°10.0'	69°14.1'	29	A 2U
A31704	18.2	118	48°16.1'	69°21.7'	79	A/p
A31704	18.2	118	"	"	87	A/p
A31704	18.2	117	48°16.6'	69°22.3'	62	A/n
A31704	18.2	117	"	"	80	A/n
A31704	19.0	102	48°12.0'	69°20.5'	33	A
A31704	19.0	106	48°14.0'	69°23.0'	30	3A/n U/n
A31704	19.0	107	48°14.5'	69°23.7'	24	U
A31704	19.0	107	"	"	37	4A/p
A31704	19.1	84	48°07.9'	69°19.3'	75	A
A31704	19.1	74	48°12.9'	69°25.6'	58	3A/p U/p
A31704	19.1	73	48°13.5'	69°26.2'	51	4A/n
A31704	19.2	60	48°10.7'	69°26.7'	11	U/n
A31704	19.2	60	"	"	12	U/n
A31704	19.2	60	"	"	22	A/n U
A31704	19.2	60	"	"	32	[2Cc] U (3 of these 5 were on the next frame, but it is not sure which)

Observations: [] = close group; Cc = ♀ with calf at heel; A = adult; L = limit; J = juvenile; U = unclassified; /p (n) = also on previous (next) frame.

Appendix II, cont.

Roll	Tx	Frame	Lat.	Long.	Grid	Observations
A31704	19.2	60	"	"	41	3A [LA] J U (6 of these 7 were on the next frame, but it is not sure which)
A31704	19.2	60	"	"	42	A
A31704	19.2	60	"	"	51	[2A] [2A] A J (4 of these 6 were on the next frame, but it is not sure which)
A31704	19.2	60	"	"	52	A
A31704	19.2	60	"	"	61	5A/n 2U/n
A31704	19.2	60	"	"	62	L
A31704	19.2	60	"	"	71	J/n
A31704	19.2	60	"	"	72	A
A31704	19.2	60	"	"	80	L
A31704	19.2	60	"	"	90	A
A31704	19.2	60	"	"	91	A
A31704	19.2	61	48°11.2'	69°27.3'	09	[2U] [AU] [2A]
A31704	19.2	61	"	"	28	A/p
A31704	19.2	61	"	"	29	A/p
A31704	19.2	61	"	"	34	A
A31704	19.2	61	"	"	38	A/p A
A31704	19.2	61	"	"	47	A
A31704	19.2	61	"	"	48	[2A U]/p A
A31704	19.2	61	"	"	58	A/p [2U]/p 3U/p
A31704	19.2	61	"	"	67	U/p
A31704	19.2	61	"	"	68	[2U]/p 2U/p
A31704	19.2	61	"	"	77	A/p 2A
A31704	19.2	61	"	"	78	5A/p U/p
A31704	19.2	62	48°11.7'	69°27.9'	01	A
A31704	19.2	62	"	"	30	A/n
A31704	19.2	62	"	"	80	A/n

Observations: [] = close group; Cc = ♀ with calf at heel; A = adult; L = limit; J = juvenile; U = unclassified; /p (n) = also on previous (next) frame.

Appendix II, cont.

Roll	Tx	Frame	Lat.	Long.	Grid	Observations
A31704	19.2	63	48°12.2'	69°28.6'	46	A/p
A31704	19.2	63	"	"	96	A/p
A31704	19.2	64	48°12.7'	69°29.2'	06	A
A31704	19.2	64	"	"	44	A
A31704	20.0	30	48°09.7'	69°29.4'	29	A/p
A31704	20.0	30	"	"	39	A/p
A31704	20.0	29	48°10.2'	69°30.0'	22	A/n
A31704	20.0	29	"	"	32	A/n
A31704	20.0	29	"	"	33	[2A L]
A31704	20.0	29	"	"	74	A
A31704	20.1	14	48°07.7'	69°30.8'	30	A
A31704	20.1	16	48°08.7'	69°32.1'	14	[3A] [2A] 3A
A31704	20.1	17	48°09.2'	69°32.7'	90	[2A]/n
A31704	20.1	17	"	"	95	J
A31704	20.1	18	48°09.8'	69°33.4'	73	2A
A31704	20.1	18	"	"	74	J
A31704	20.1	18	"	"	97	[A U]/p
A31702	20.2	10	48°04.7'	69°30.9'	70	A/n
A31702	20.2	10	"	"	80	L/n
A31702	20.2	11	48°05.2'	69°31.5'	75	U/p J
A31702	20.2	11	"	"	86	A/p
A31702	20.2	14	48°06.7'	69°33.4'	51	[3A]
A31702	20.2	15	48°07.2'	69°34.0'	94	[2A] L
A31702	20.2	16	48°07.7'	69°34.7'	62	A
A31702	20.2	16	"	"	72	U/n
A31702	20.2	16	"	"	82	2A L U
A31702	20.2	16	"	"	93	J
A31702	20.2	17	48°08.2'	69°35.3'	78	A/p
A31702	21.0	37	48°01.2'	69°30.5'	67	A
A31702	21.2	79	47°58.6'	69°35.1'	16	A J
A31702	21.2	79	"	"	26	A

Observations: [] = close group; Cc = ♀ with calf at heel; A = adult; L = limit; J = juvenile; U = unclassified; /p (n) = also on previous (next) frame.

Appendix II, cont.

Roll	Tx	Frame	Lat.	Long.	Grid	Observations
A31702	21.2	79	"	"	27	L
A31702	21.2	79	"	"	37	2A
A31702	21.2	79	"	"	56	A/p
A31702	21.2	79	"	"	68	U/p
A31702	21.2	79	"	"	75	A/p 2L
A31702	21.2	79	"	"	79	A/p
A31702	21.2	78	47°59.1'	69°35.7'	40	A
A31702	21.2	78	"	"	51	A/n
A31702	21.2	78	"	"	54	Cc
A31702	21.2	78	"	"	56	[Cc] A
A31702	21.2	78	"	"	60	U
A31702	21.2	78	"	"	63	A/n
A31702	21.2	78	"	"	70	A/n
A31702	21.2	78	"	"	73	A/n
A31702	21.2	78	"	"	75	A
A31702	21.2	73	48°01.7'	69°38.9'	89	[Cc A L 2U]/p
A31702	21.2	72	48°02.2'	69°39.5'	93	[Cc/n C/nc (J L U)/n]
A31702	22.0	88	47°53.9'	69°33.1'	00	A
A31702	22.0	91	47°55.5'	69°34.9'	70	A/n
A31702	22.0	92	47°56.0'	69°35.6'	64	A
A31702	22.0	92	"	"	76	U U/p
A31702	22.0	92	"	"	85	2A L
A31702	22.0	92	"	"	92	U/n (v. deep)
A31702	22.0	92	"	"	93	3U/n U
A31702	22.0	93	47°56.5'	69°36.2'	03	[C/nc]
A31702	22.0	93	"	"	11	A/n
A31702	22.0	93	"	"	41	[3U]
A31702	22.0	93	"	"	98	U [U/p U]
A31702	22.0	93	"	"	99	3U/p
A31702	22.0	94	47°57.0'	69°36.9'	09	U/p
A31702	22.0	94	"	"	27	U/p

Observations: [] = close group; Cc = ♀ with calf at heel; A = adult; L = limit; J = juvenile; U = unclassified; /p (n) = also on previous (next) frame.

Appendix II, cont.

Roll	Tx	Frame	Lat.	Long.	Grid	Observations
A31702	22.0	95	47°57.5'	69°37.5'	19	[2U] (prob. Cc)
A31702	22.0	95	"	"	28	U
A31702	22.0	103	48°01.5'	69°42.6'	00	[8U/n]
A31702	22.0	104	48°02.0'	69°43.2'	16	L/p [3A 2U 2J]/p
A31702	22.0	104	"	"	25	L J
A31702	22.1	122	47°55.0'	69°38.2'	76	A/p
A31702	22.1	121	47°55.5'	69°38.9'	70	U/n
A31702	22.2	149	47°58.0'	69°46.0'	04	A/n
A31702	22.2	149	"	"	74	L
A31702	22.2	150	47°58.5'	69°46.6'	09	A/p
A31702	23.0	152	47°55.6'	69°46.8'	15	A J
A31702	23.0	152	"	"	18	A/p
A31702	23.0	152	"	"	19	U/p
A31702	23.0	152	"	"	89	U/p (prob. A)
A31702	23.0	151	47°56.1'	69°47.4'	12	A/n
A31702	23.0	151	"	"	13	A/n
A31702	23.0	151	"	"	83	A/n
A31702	23.2	197	47°48.4'	69°45.6'	91	2A
A31702	23.2	189	47°52.4'	69°50.6'	07	Cc
A31702	23.2	189	"	"	45	2U
A31702	23.2	189	"	"	46	[3U]
A31702	23.2	189	"	"	55	[2U] 2U
A31702	23.2	189	"	"	56	U
A31703	24.1	22	47°46.5'	69°51.1'	66	Cc A
A31703	24.2	40	47°41.4'	69°48.5'	92	U/n U
A31703	24.2	41	47°41.9'	69°49.1'	99	A/p A
A31703	24.2	44	47°43.4'	69°51.0'	11	A
A31703	24.2	44	"	"	31	U
A31703	24.2	44	"	"	54	J L A
A31703	24.2	45	47°43.9'	69°51.6'	55	U
A31703	24.2	45	"	"	92	A/n U

Observations: [] = close group; Cc = ♀ with calf at heel; A = adult; L = limit; J = juvenile; U = unclassified; /p (n) = also on previous (next) frame.

Appendix II, cont.

Roll	Tx	Frame	Lat.	Long.	Grid	Observations
A31703	24.2	46	47°44.4'	69°52.3'	98	A/p
A31703	24.2	49	47°45.9'	69°54.2'	43	2A
A31703	24.2	49	"	"	44	A
A31703	24.2	49	"	"	53	A
A31703	24.2	49	"	"	55	A
A31703	24.2	49	"	"	63	A
A31703	24.2	49	"	"	91	A
A31703	24.2	49	"	"	92	A
A31703	25.1	71	47°37.6'	69°51.7'	04	[A J 2U]
A31703	25.2	94	47°36.2'	69°53.9'	06	2U/p
A31703	25.2	94	"	"	16	U/p
A31703	25.2	94	"	"	34	U
A31703	25.2	94	"	"	44	2U
A31703	25.2	93	47°36.7'	69°54.5'	01	L/n J/n
A31703	25.2	93	"	"	07	U/p
A31703	25.2	93	"	"	11	U/n
A31703	25.2	93	"	"	14	A
A31703	25.2	93	"	"	20	U
A31703	25.2	92	47°37.2'	69°55.1'	01	U/n
A31703	25.2	92	"	"	26	2U/p (prob. A J)
A31703	25.2	91	47°37.7'	69°55.7'	20	2U/n (prob. A J)
A31703	25.2	87	47°39.7'	69°58.2'	05	J
A31703	25.2	87	"	"	06	U (prob. A)
A31703	25.2	87	"	"	66	[A L]
A31703	25.2	87	"	"	78	U (deep)
A31703	25.2	85	47°40.7'	69°59.5'	78	[2U]/p (deep)
A31703	25.2	84	47°41.3'	70°00.1'	72	[2U]/n (deep, prob. Cc)
A31703	26.0	104	47°35.7'	69°57.1'	41	2A
A31703	26.0	112	47°39.7'	70°02.0'	22	U/n
A31703	26.0	112	47°39.7'	70°02.0'	40	2U (v. deep)
A31703	26.0	112	"	"	42	U

Observations: [] = close group; Cc = ♀ with calf at heel; A = adult; L = limit; J = juvenile; U = unclassified; /p (n) = also on previous (next) frame.

Appendix II, cont.

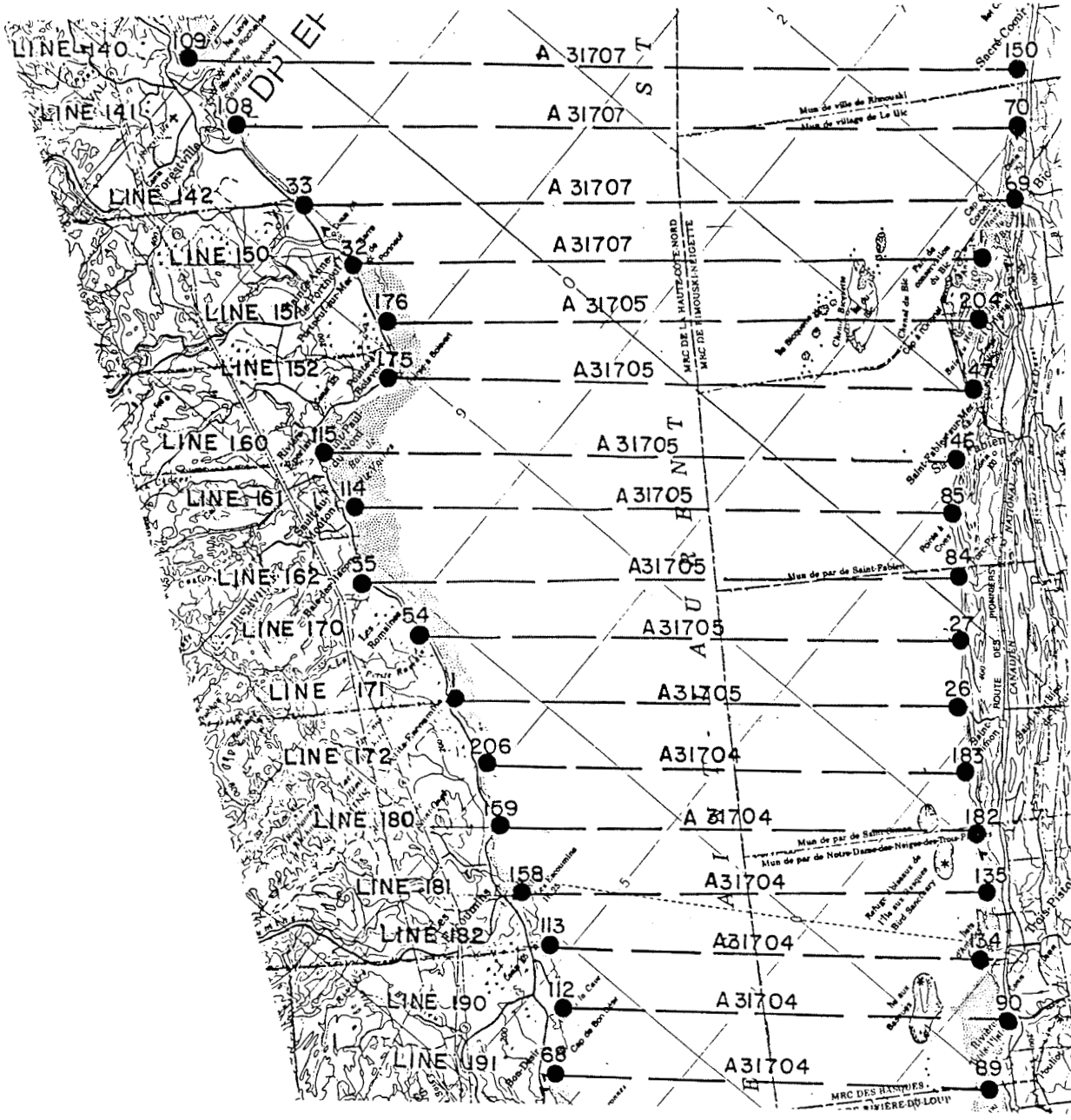
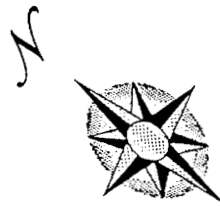
Roll	Tx	Frame	Lat.	Long.	Grid	Observations
A31703	26.0	112	"	"	43	J
A31703	26.0	112	"	"	44	U
A31703	26.0	112	"	"	53	U
A31703	26.0	112	"	"	61	J
A31703	26.0	112	"	"	62	J
A31703	26.0	112	"	"	83	A/n
A31703	26.0	112	"	"	90	A/n J/n
A31703	26.0	113	47°40.2'	70°02.7'	01	A/n
A31703	26.0	113	47°40.2'	70°02.7'	17	U
A31703	26.0	113	"	"	25	A
A31703	26.0	113	"	"	28	U/p
A31703	26.0	113	"	"	34	U
A31703	26.0	113	"	"	88	A/p
A31703	26.0	113	"	"	96	A/p J/p
A31703	26.0	114	47°40.7'	70°03.3'	07	A/p
A31703	26.2	139	47°33.5'	70°01.4'	63	U
A31703	27.1	176	47°32.1'	70°07.4'	03	J
A31703	27.1	176	"	"	04	U
A31703	27.1	176	"	"	22	U
A31703	27.2	190	47°29.0'	70°07.4'	65	A
A31703	27.2	189	47°29.5'	70°08.0'	04	A
A31703	27.2	189	"	"	33	U
A31703	27.2	189	"	"	42	A
A31703	27.2	187	47°30.5'	70°09.3'	76	L
A31703	27.2	186	47°31.0'	70°09.9'	14	U
A31703	27.2	186	"	"	47	A
A31703	27.2	185	47°31.5'	70°10.6'	21	A
A31703	27.2	185	"	"	77	U
A31703	27.2	185	"	"	96	U
A31703	28.0	206	47°26.8'	70°08.4'	73	U/n
A31703	28.0	207	47°27.3'	70°09.1'	79	U/p

Observations: [] = close group; Cc = ♀ with calf at heel; A = adult; L = limit; J = juvenile; U = unclassified; /p (n) = also on previous (next) frame.

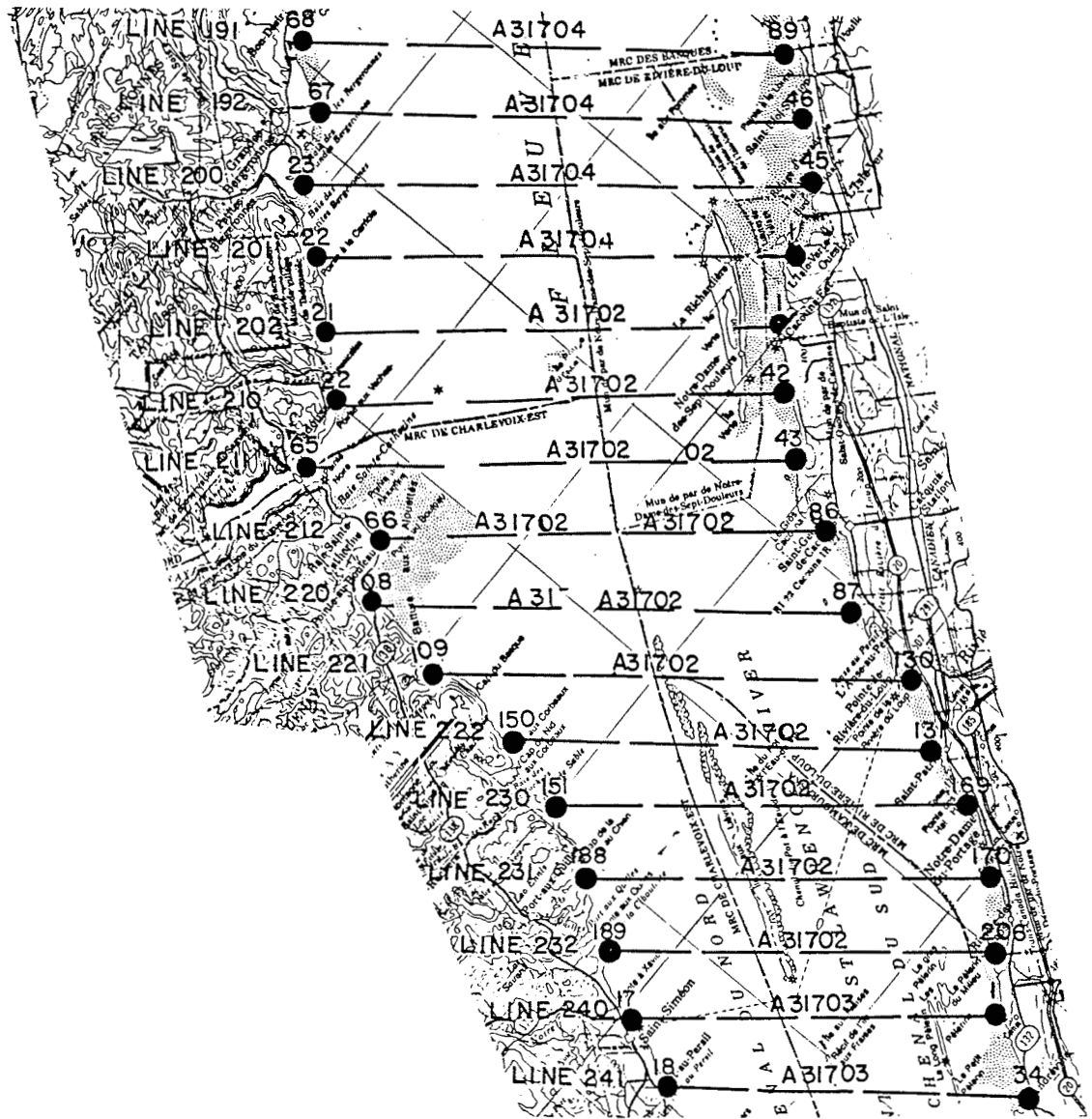
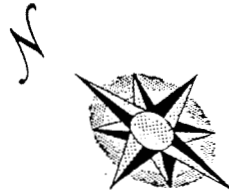
Appendix III. Index maps of aerial photography transect and frame locations.

The maps reproduced in this Appendix are copies of those furnished by the aerial survey company. They provide the best information on the actual location of the transects as flown. The film roll numbers are the standard roll numbers assigned by the National Air Photo Library, Dept of Energy Mines and Resources, where this film is deposited. These roll numbers are referenced in Appendix II. The transect numbers are those assigned by the aerial survey company, and are not necessarily the same as those referenced in the text or tables of this report, or in Appendix II. The frame numbers, which start afresh for each roll and are consecutive within film rolls, are those assigned by the survey company, and are referenced in Appendix II. They are not the same as the camera counter numbers automatically registered on each frame.

Appendix III, cont.



Appendix III, cont.



Appendix III, cont.

