Fisheries and Oceans Science | Pêches et Océans Sciences

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Research Document 2001/049 | Document de recherche 2001/049

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Population index estimate for the beluga of the St Lawrence River Estuary in 2000

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ISSN 1480-4883
Ottawa, 2001

Abstract

Abundance of beluga in the St Lawrence estuary was estimated from an aerial survey flown on 28 August 2000. Two fixed-wing aircrafts equipped with 9"x9" format mapping cameras flew 52 strip transects across the Estuary between Baie St-Paul and Rimouski for a total survey coverage of 49.3%. A visual survey to count beluga in the Saguenay River was flown at the same time. In the estuary, 453 (SE = 54) beluga were estimated to be at the surface between Kamouraska and Les Escoumins after correction for sun glare, and 6 beluga were counted downstream of Baie Ste-Marguerite in the Saguenay River. A 15% correction factor was applied to the estimated number of beluga at the surface in the estuary to account for beluga missed because they were underwater. Adding the Saguenay River count to the corrected estimate resulted in an index count of 527 (SE = 62). This corrected index used in trend analysis along with 5 equivalent survey indices obtained between 1988 and 1997, revealed no significant changes in abundance of beluga in the St Lawrence estuary since 1988.

Résumé

L'abondance de bélugas dans l'estuaire du Saint-Laurent fut estimée par relevé aérien le 28 août 2000. Deux avions munis d'un appareil photographique de cartographie et de films de 9"x9" ont survolé 52 transects en travers de l'estuaire entre Baie St-Paul et Rimouski, couvrant ainsi 49.3% de l'aire d'étude. Un recensement visuel visant à dénombrer les bélugas dans la rivière Saguenay fut parallèlement complété. En incluant une correction pour la réflexion solaire, on estime que 453 (erreur type = 54) bélugas étaient à la surface dans l'estuaire, entre Kamouraska et Les Escoumins, alors que 6 bélugas ont été vus dans la rivière Saguenay, en aval de Baie Ste-Marguerite. Un facteur de correction de 15% fut ajouté au compte de l'estuaire afin de tenir compte des bélugas manqués parce qu'ils étaient sous l'eau. L'addition du compte de la rivière Saguenay et de cette estimation corrigée résulte en un indice de 527 bélugas (erreur type = 62) pour l'ensemble de l'aire d'étude. L'utilisation dans l'analyse de tendance de cet indice, et de 5 indices équivalents obtenus entre 1988 et 1997, ne révèle aucun changement significatif de l'abondance des bélugas dans l'estuaire du Saint-Laurent depuis 1988.

Introduction

The beluga *Delphinapterus leucas* has a circumpolar distribution. The species inhabits cold waters, and is limited to seasonally ice covered Arctic and sub-Arctic waters. The St Lawrence River estuary represents the southern limit of the worldwide distribution of the species, and the presence of beluga in this area is favoured by cold, productive waters and seasonal ice cover (Richard 1991; Lesage and Kingsley 1998). Their distribution in the St Lawrence Estuary varies seasonally. During summer, some animals may be found in the Saguenay River as far upstream as Saint Fulgence. However, the majority of animals are found in the St Lawrence River estuary between the Battures aux Loups Marins and Les Escoumins on the north shore, and Saint-Fabien-sur-Mer on the south shore (Figure 1; Michaud et al. 1990; Michaud 1993a; Kingsley 1993; 1996; 1999). Their current distribution in the Estuary is not as extensive as that described by Vladykov in the late 1930s (1944; reviewed in Lesage and Kingsley 1998).

Beluga in the St Lawrence River estuary might have numbered several thousand individuals at the end of the 1880s (Reeves and Mitchell 1984). However, this species was heavily exploited until the early 1950s, and hunting probably continued throughout the 1970s (Reeves and Mitchell 1984; Pippard and Malcolm 1978). Early attempts to estimate their abundance in the 1970s indicated that there may have been as few as 350 individuals and the population was continuing to decline (Pippard and Malcolm 1978; Sergeant and Hoek 1988). In 1979, the St Lawrence beluga were afforded complete protection from hunting under the *Beluga Protection Regulations*, which is now superseded by the *Marine Mammal Regulations*, of the *Fisheries Act*. On the basis of their low numbers and rapidly decreasing trend, St Lawrence beluga were assigned a status of *Endangered* by the Committee on the Status of Endangered Wildlife in Canada (COSEWIC) in 1983. This status has since been reaffirmed (Lesage and Kingsley 1998).

Early attempts to assess beluga abundance in the St Lawrence used a variety of approaches including boats, helicopters, airplanes, visual and photographic surveys, sample or total counts (Pippard and Malcolm 1978; Béland et al. 1987a; Sergeant and Hoek 1988). These early surveys pointed out that St Lawrence beluga numbers were quite low. Unfortunately, frequent changes in survey methodology and rigor limited their usefulness for monitoring changes in numbers over time (reviewed in Kingsley 1998; see also Michaud 1993b; Bailey and Zinger 1995). Since 1988, aerial photographic surveys, using a systematic design where strip transects were flown across the St Lawrence River estuary, have been used as a standard approach for estimating beluga numbers. Although sampling intensity, and coverage of the Saguenay River have varied between surveys, they provided index estimates of the St Lawrence beluga population in 1988, 1990, 1992, 1995, and 1997 (Kingsley and Hammill 1991; Kingsley 1993; 1996; 1999).

This study extends this temporal series by reporting the results of a beluga survey conducted in 2000.

Methods

Study area, survey design and field methods

The survey design intended to cover the entire summer distribution area of the St Lawrence beluga. The basic survey flew the same transect lines as flown by Kingsley (1999). In order to account for a possible extension of distribution in the Estuary, the study area for this survey was extended four nautical miles in both the upstream and downstream directions (Figure 1). The coverage in the Saguenay River extended from its confluence with the St Lawrence Estuary to La Baie and Saint-Fulgence and thus, was identical to the previous survey in 1997.

The survey design involved both a photographic and a visual component, and was planned so as to cover the entire study area within the same day, while minimising the probability of double counting animals due to movements during the survey. The St Lawrence Estuary portion of the study area was sampled using a systematic strip transect design, and high-altitude photography. Two Piper Aztec aircraft flew a total of 52 transects spaced 2 nautical miles (3.704 km) apart, crossing the estuary on headings of

320° and 140° true. The two aircraft were flown in opposite directions from a starting point (in the Trois-Pistoles area) chosen so as to ensure the completion of the survey by both aircraft without refuelling. Aircraft were equipped with 9" x 9" (228.6 x 228.6 mm) format mapping cameras (Wild-Leitz RC-20) loaded with Kodak Aerographic 2448 colour positive aerial survey film, and fitted with 6" (153.1 mm) lenses and 420 nm 2X filters, and a motion compensation system. Target altitude was 4000 feet (*i.e.* approximately 1223 m), and was controlled by certified pressure altimeter and satellite-linked Global Positioning System. Camera shooting speed was adjusted automatically with the aircraft speed and altitude to allow a 30% forward overlap between frames.

The preferred survey conditions required a ceiling of at least 4000 feet, sun angles ≥ 30°, winds <10 knots, and no fog over the study area during the survey in order to insure good quality frames.

The Saguenay River was surveyed visually by helicopter (Bell 206 Long Ranger) at 1500 feet (457 m) while the photographic survey was being conducted in the Estuary. Two observers, seated on the same side of the aircraft, and looking down-sun at the full width of the fjord which is about 1-2km across, noted the number of beluga and their positions on both the upstream and downstream passes, providing two independent counts of beluga for that area.

Film interpretation

Frames were examined for beluga images, using a light table, and a dissecting microscope. The film was read using the approach outlined by Stenson et al. (2000). Complete reading of frames was assured by superimposing a transparent grid of 10 rows and columns on each frame and the exact location of beluga images was recorded on an overlaid acetate. Both main readers involved in the interpretation of beluga images had no previous experience in reading marine mammal aerial photographs. Before starting to record any sightings, frames with beluga were examined so that readers could become familiar with the shape and size of target images. Film rolls from the 2000 survey were split between the two readers for examination of beluga images. Once a first reading of all films was completed, each reader then re-read their first 100 frames a second time without consultation of previous results. Owing to the low number of beluga found on the frames, the method of re-reading of photos in chronological order until the counts from the first and second readings converged (Stenson et al. 2000) could not be used. Instead, the two readings were treated as independent samples. The first count was regressed against the second count and the resulting relationship was examined to determine if the intercept was significantly different from zero and if the slope differed from 1 using a modified t-test (Scherrer 1984). All frames with beluga or doubtful images were read by both readers. If disagreement still occurred between readers, a third reader experienced in looking at marine mammal aerial photographs examined the imagery, and a consensus was agreed upon by the three readers.

Percent overlap between successive frames was estimated for each frame, using the overlaid grid acetate and landmarks, ocean features, boats, buoys, or other beluga on the film as reference points. Beluga images located within the overlap portion of a frame were compared with those observed on the previous frame to identify duplicates or individuals that had gone undetected. The proportion of each frame that could not be examined due to sun glare (diffuse reflection) and not covered by the non-glare overlap of the next frame was calculated to the nearest one percent.

Data analysis

Data were analysed using the methods developed for surveys flown since 1988 (Kingsley and Hammill 1991; Kingsley 1993; 1996; 1999). Beluga counts were corrected to account for animals that went undetected due to sun glare (Kingsley 1996). The proportion of a frame omitted due to sun glare, p_g, was calculated as

$$p_g = p_{-og} / (1-p_o) \qquad [1]$$

where p_{-og} is the probability of a beluga being present in the glare portion of a frame that is not included in the overlap, and p_o is the probability of a beluga being in the overlap. Since glare conditions were affected by time of day (sun height), wind, and cloud cover, the correction was applied on a transect basis. Reflection-corrected counts of beluga for the j^{th} transect was estimated by:

$$x_{rj} = x_j / (1-p_{gj}) \qquad [2]$$

where x_j is the beluga count and p_{gj} is the average proportion of frames never surveyed due to glare.

In order to obtain an estimate for the Estuary and to compensate for the gaps between transects, the sum of reflection-corrected counts on transects was multiply by an expansion factor, *k*, defined as

$$k = S/W = S/(H \cdot B/L) = 2.028 \qquad [3]$$

where : *S* = transect spacing (3704 m)

W = transect width

H = flying height (1223.2 m)

B = photo frame breadth (229 mm and 228 mm: 0.2285 m)

L = lens focal length (152.861 mm and 153.229 mm: 0.153045 m)

An estimate of the number of visible beluga in the estuary, $\hat{N}$, is then given by

$$\hat{N} = k \sum_{j=1}^{J} x_{rj} \qquad [4]$$

where *J* represents the number of transects.

An estimate of error variance, $V(\hat{N})$, was based on serial differences between transects including the finite population correction (Cochran 1977; Kingsley and Smith 1981) and was calculated as

$$V(\hat{N}) = \frac{k(k-1)J}{2(J-1)} \sum_{j=1}^{J-1} (x_j - x_{j+1})^2 \qquad [5]$$

A correction for animals submerged was applied to the estimated number of visible beluga in the Estuary by adding 15% (SE = 0) to allow comparison of the 2000 results with those of previous surveys (Kingsley and Hammill 1991; Kingsley 1993; 1996; 1999).

The beluga counts obtained during the upstream and downstream passes in the Saguenay River were compared for location and number of individuals to identify duplicate observations. No correction for visibility was applied to these counts, on the basis that a visual search and two passes provided the observer with enough time to detect any beluga in this area. The population index and true population estimates for St Lawrence beluga were obtained by adding the number of beluga observed in the Saguenay River to the estimated beluga numbers obtained for the Estuary portion of the study area.

Trend analysis from 1988 to 2000

Population index estimates obtained since 1988 using a similar survey design were examined to estimate the trend, or average rate of change in the population. Although several aspects of the methodology were consistent between surveys during this period, some adjustments were necessary in order to make the results of these different surveys comparable. Three correction factors were applied to published estimates since 1988. Correction factors proposed by Kingsley (1998) to account for differential conversion of nautical miles to feet in the calculation of the expansion factor were applied to the estimated number of beluga visible in the estuary for 1988 to 1995 surveys. An additional correction factor of 4.9%, reflecting the average proportion of beluga found in the Saguenay River during 9 aerial surveys over their entire summer distribution area (Michaud 1993a), was added to the 1988 and 1990 population index estimates to account for the non-coverage of the Saguenay River. All estimates since 1988 were adjusted using a 15% visibility correction factor for the Estuary portion of the survey, to which was added the counted or estimated number of beluga in the Saguenay. Population trends were examined using least-square linear regression analysis, 1/CV as a weighting factor for the index estimates, and tested against the null hypothesis of a growth rate equal to zero.

Consistency between readers involved in film readings over the years was examined. The two readers were assumed to have attained a plateau of efficiency in detecting beluga images by the time they were requested to participate in this analysis, *i.e.* once the 2000 aerial photograph readings were completed. Both readers were asked to read a subset of 50 frames from each of the 1992, 1995 and 1997 surveys, of which approximately 10% were known to contain no beluga. Detailed counts were not available for the 1988 and 1990 imagery which were not included in this analysis. Once readings for the three surveys were completed, counts obtained by each reader were compared, discussed, and the accepted counts for each frame were linearly regressed against the original team counts. The slope of the regression was used as a coefficient to correct the photographic portion of published index estimates (*i.e.* corrected before the addition of the Saguenay beluga observations).

Between-survey variability in the beluga distribution or tendency to aggregate was examined using clump factors, C_1/C_2 (Kingsley et al. 1985). This ratio is a comparison of the overall variance of density for the whole area as would be calculated for random sampling (C_1), with the systematic variance calculated from the serial differences between consecutive transects (C_2). A value of one would indicate a homogenous distribution of beluga throughout the surveyed area.

Total count and total area are calculated as follows:

$$Y_i = \sum_{j=1}^{J_i} kt_{ij} \qquad [8]$$

$$X_i = \sum_{j=1}^{J_i} kA_{ij} \qquad [9]$$

where Y_i is the expanded number of whales, k is the expansion factor, t_{ij} is the number of beluga counted on the jth frame, J_i is the number of frames on ith transect, X_i is the expanded area for ith transect, and A_{ij} is the area of the jth frame.

For the whole surveyed area, the estimated mean density was (Cochran 1977):

$$\hat{R} = \sum_1^I Y_i \Big/ \sum_1^I X_i \qquad [10]$$

where I is the number of transect.

Variance for random sampling was calculated as follows:

$$S_1^2 = \left\{ I \sum_1^{I-1} (Y_i - \hat{R}X_i)^2 \right\} \Big/ \left\{ 2 \cdot (I-1) \cdot (\sum X_i)^2 \right\} \qquad [11]$$

and variance for based on serial difference in density, d_i, is calculated using

$$S_2^2 = \left\{ I \sum_{1}^{I-1} (d_i - d_{i+1})^2 \right\} \Big/ \left\{ 2 \cdot (I-1) \cdot (\sum X_i)^2 \right\} \quad [12]$$

The clump factor used in the ratio C_1/C_2 was obtained using:

$$C_k = S_k^2 \sum \sum t_{ij} / R^2, \qquad k = 1,2. \quad [13]$$

Results

Aerial survey and film interpretation

The survey was flown on 28 August 2000, between approximately 8:15 am and 2:00 pm. The weather was acceptable for the survey, with clear skies and light winds all day throughout the study area. Winds were recorded at 2 to 5 knots at 9h36 and 3 to 5 knots at 11h35 in Rivière-du-Loup.

The survey was executed with a few changes to its planned design. The two aircraft involved in the photographic portion of the survey initiated the survey at 8h15 when sun angle was 21° and 25° above the horizon and thus, below the prescribed minimal angle of 30° which was attained at 9h00. Starting on transects 1905 and 1915, they proceeded as planned in opposite directions, but transect 3025 at the south-western extreme of the study area was not surveyed (Figure 1). The average time lapse between the start of a transect and the end of an adjacent transect was 17.0 min overall, and was 13.7 min in the area where beluga were observed (*i.e.* transects 1725 to 2615). Longer time lapses to complete adjacent transects were observed when the roll of film had to be changed (*i.e.* 22–23 min for transects 2215 and 2225, and transects 2625 and 2705), and when transect 2825 was flown after transect 2905 contrary to plan (*i.e.* 29 min for transects 2815 and 2825, and 56 min for 2905 and 2915). Except for the 23 min to complete transects 2215 and 2225, all longer time lapses involved transects where no beluga were counted. The visual survey of the Saguenay River was completed between 9:50 and 11:20 am, according to the planned design.

A total of 1144 frames were split equally between the two readers. Both readers had a tendency to admit some false positive images when they started reading. Total counts of beluga for the first 100 frames decreased from 35 beluga on the first reading to 32 beluga on the second reading for reader 1, and from 33 to 29 beluga for reader 2. The difference in counts never exceeded 2 beluga per frame for reader 1, for whom all first and second readings were similar after frame 33. Counts of reader 2 never differed by more than one beluga per frame. In the regressions of the first against the second readings for the first 100 frames, the intercept was not significantly different from zero (p = 0.29 and 0.15) nor was the slope significantly different from 1 (t' = 0.015 and 0.642; df = 98 and 104; p > 0.9 and 0.5).

Interpretation of images was not consistent between two readers. Counts on 107 frames on which beluga or doubtful images were seen during the first reading were compared. Both readers had a total of 221 beluga on these images, but the comparison of the images recorded on the acetates revealed that 36 images were interpreted differently. After interpretation of the third reader and discussion, 219 images were accepted as beluga, from which 20 and 24 images were differently interpreted by reader 1 and 2, respectively. The regression of Reader 1 counts on the accepted counts was not significantly different from unity (slope: 0.976; t' = 1.751; df = 105; p = 0.09). However, the regression of Reader 2 counts on the accepted counts was significantly different than unity (slope: 1.085; t' = 3.043; df = 105; p = 0.005). Reader 2 had a tendency to underestimate slightly the number of whales present when groups were small, and to overestimate slightly compared to the accepted totals when many whales were present.

Population index estimate

A total of 219 beluga images were counted on frames, after excluding 31 animals considered as duplicates (Table 1). Some glare was present, particularly in the upstream portion of the Estuary. As a result of the orientation of transects and the timing of the survey, most of the sun glare fell into the overlap area of the frames, which represented on average 29.1% of each frame (N = 568 frames). Nevertheless, some glare correction was necessary on some transects (Table 1). The proportion of a transect missed because of glare was on average 4.4% (range 0–19.7%) over all transects, but averaged 2.3% (range 0–6.9%) on transects where beluga were seen. The application of a correction factor for sun reflection to individual transects resulted in a 1.8% increase in the number of beluga observed in the sampled area of the Estuary, increasing the total count of beluga on transects from 219 to 223.

From equations 4 and 5, 49.3% of the Estuary was photographed. Applying the corresponding 2.028 expansion factor to the reflection-corrected count resulted in an estimated 453 (SE = 54) beluga present at the surface during the survey. The 15% correction factor applied for submerged animals increased the estimate to 521 (SE = 62).

Six beluga in four distinct groups were seen in the Saguenay River, downstream of Baie Ste-Marguerite on the upstream pass. Five animals were resighted in the same area on the downstream pass (Figure 2). The addition of these six beluga to the photographic estimate, resulted in an estimated standard index (15% correction) of 527 (SE = 62).

Distribution

Beluga were observed in the Estuary both upstream (65%) and downstream (35%) of the Saguenay River. Their distribution was limited to the central portion of the study area, between transects 1805 and 2605 (*i.e.* approximately between Trois-Pistoles and Kamouraska), with no beluga seen on the last 13 upstream and 14 downstream transects (Figure 2 and 3). Concentrations of beluga were observed in the Trois-Pistoles area (34 on 6 frames), in the sector of Rivière-du-Loup, downstream of Île Verte (71 on 16 frames), as well as in the area located between Saint-Siméon and La Malbaie along the north shore (38 on 17 frames). Only a few individuals were observed along the north shore, downstream of the Saguenay River. This aggregation of beluga resulted in a clump factor of 2.2 for the Estuary survey. The median number of animals per frame was 2 beluga, with maximum counts of 17 beluga images on two frames (Figure 4a). If duplicates are not taken into account, the 219 beluga images were obtained from 64 out of 1144, or 5.6% of frames. Frames with one and two beluga represented 35 of these 64 frames (55%), and 21% of the total number of beluga detected. In contrast, groups of more than 10 beluga were found on 5 of 64 frames (8%), and accounted for 33% of the beluga detected on the film.

Trend analysis from 1988 to 2000

No significant change was observed in beluga numbers between 1988 and 2000. The linear regression of six population index estimates obtained since 1988 using a similar approach, and corrected to account for variation in methodology, but not for changes in reader interpretation, indicates an estimated rate of change of 4.1 beluga/year (SE = 9.3; 95% CI -21.4 – 30.2; p = 0.66) (Figure 5).

The re-examination of frames from previous surveys indicated that readers for the 2000 survey identified fewer beluga per frame. Compared to previous photographic survey counts, the 2000 readers identified down to 90% of the beluga on the film (Table 2). The application of a correction to the 1992, 1995 and 1997 surveys to account for changes in readers did not result in significant changes in beluga numbers during the 1992–2000 period (3.4 beluga/year, SE = 18.6; 95% CI -76.6 – 83.4; p = 0.87).

Discussion

This 2000 St Lawrence beluga population survey followed a systematic strip transect design, similar to what has been used during the last five surveys dating back to 1988.

Nevertheless, there were some slight differences. The two photographic aircraft took off earlier than planned when the low angle of the sun might have reduced light penetration and hence reduced detectability of beluga on the photographic imagery. The first frames in this survey were shot at 8h15 with a sun angle of about 21°. Sun angles above 30° are preferred which would not occur until 9h00. Transects 1805 to 2105 were flown before 9h00. These transects lie in the central portion of the study area where most of the animals are located. In 1997 and 2000, 33% (n = 95 beluga) and 34% (n = 75) of the animals were detected on these 11 lines. The similar percentage of animals counted on these transects between the two surveys suggests that few animals were missed by flying earlier.

A second problem associated with aerial surveys flown over water is the presence of glare. As the sun rises, it is often followed by increasing wind speed which throw in wave action. Both phenomena increase the amount of glare on the photos. This occurred on transects upstream of 2705, which were among the last transects to be completed. However, unlike light penetration, glare is recorded and can be measured on the film, and later corrected for. It was estimated that overall, 4.4% of transect surface was not covered or was excluded due to glare. Correcting for the reduction in coverage due to glare resulted in a 1.8% increase in the estimated number of whales.

Another difference from earlier surveys was the use of two inexperienced film readers to count beluga on the film. The problem of consistency for individual readers with no previous film reading experience was assessed by re-reading the first 100 frames a second time, and comparing the two counts. The results showed that the 2 readers were consistent from the first reading, when they were least experienced, to the second reading when they were assumed to have attained maximum efficiency. Owing to the time involved, a total double count of the film was not done. Therefore, we could not verify that single images on frames recorded as "no beluga" on the first reading were systematically missed by either of the readers. However, the frequency of frames showing 1 or 2 beluga were similar to the frequencies observed during the surveys that produced the higher estimates of 1995 and 1997, and were also higher than the same frequency for 1992 for which a total double count was done and which produced a similar estimate (Figure 4).

Some inconsistencies between readers were observed in 2000 for the 107 frames with beluga images. The final count of Reader 1 was in line with the final accepted count. However, Reader 2 had lower counts when low numbers of whales were accepted, and higher counts when high numbers of whales were accepted. Although this illustrates the variability in film interpretation by different readers, the final counts were corrected by the double counting of all imagery containing animals and discussions with a third more experienced reader to arrive at a consensus on the presence or absence of a beluga.

The 2000 readers had a tendency to identify fewer beluga per frame compared to the reading teams of the 3 previous surveys as revealed by the reanalysis of archived films. This difference from earlier readers was close to 10% (correction factor 0.90 for 1992 published estimate), and differences between readers within this survey showed that doubtful images could account for 9.6% of all images. This had no significant impact on the linear trend, because we corrected for reader differences between surveys. However, it is important that between-reader differences be considered since the 10% change in counts is more than double the theoretical rate of increase of 2-5% for beluga and most odontocete populations having similar life-history parameters (Reilly and Barlow 1986). This factor, if not taken into account, could amplify or completely mask population changes in any trend analysis.

The variability associated with the survey estimates will determine the possibility of detecting real changes in abundance. It is a function of the distribution of the animals and is inversely related to the proportion of the population that is surveyed (Smith and Hammill 1986). If animals are uniformly distributed throughout the study area, then a systematic design should produce an unbiased estimate of abundance. The clump factor provides a simple index of distribution, where a clump ratio of 1 indicates a uniform distribution, while a ratio greater than 1 indicates grouping or clumping of animals (Kingsley et al. 1985). In clumped distribution, if the size of the groups exceeds the distance between the transect lines, then the survey should still produce an unbiased estimate. However, if the size of the groups is less than the interval between the transect lines then the survey may be biased in the direction that will depend upon whether the groups fall on or off of transect. Therefore, the detection of these groups or clumps could have a significant impact on the final estimates.

An examination of the surveys flown between 1992 and 2000 indicated that 4 to 7% of the total number of frames containing beluga images showed more than 10 whales, and accounted for 30% (1992 and 1995), 22% (1997) and 33% (2000) of the total number of beluga counted in those years (Figure 4). The clump factor of 2.2 in the 2000 survey was greater than the 1.8, 1.3 and 1.2 estimated in 1992, 1995, and 1997. High clumping increases the concern about the reliability of the estimate, but unfortunately does little to determine if the estimate is biased, nor does it help to determine the direction of potential bias. However, we could expect the importance of this variability to show up in long-term trend analysis of the population. If large single groups do occur (see Sergeant and Hoek 1988; Kingsley 1998), and if the area covered by these groups is small compared to the 2 mile spacing of the transects, then with a survey fraction of 49%, these groups would be expected to be present on frames in every second survey. This would induce an increase in the estimate when they are present on transects, and a reduction of the estimate when they are between transects. One way of dealing with this uncontrolled variation between surveys is to use smoothed estimates by combining estimates from consecutive surveys to evaluate trends (Kingsley 1999).

Recently, Kingsley (1998) examined the trend of this population and applied correction factors to eight published index estimates from 1977 to 1995 in order to standardise results from surveys of different designs. From this analysis, it was concluded that the St Lawrence beluga population was increasing at a rate of 13.7 (SE = 4.9; 80% CI 6.7–20.7) beluga per year, and that the population had increased since 1977. However, the rationale behind the application of some correction factors to standardise the index estimates has been questioned (Michaud and Béland 2001; Kingsley 2001), and it has been suggested that only the systematic surveys flown since 1988 be used in any trend analysis (Bailey and Zinger 1995; Gagné 1999).

The regression of the index estimates (corrected to include calculation differences and the 15% for submerged animals) from the 5 surveys flown between 1988 and 1997, on year results in an increase of 18.0 (SE = 9.2) beluga per year and a predicted index estimate of 753 for 2000. The 527 (SE = 62) index estimate for the 2000 survey is lower than the predicted mean, but lies within the 95% confidence limits of 430 – 1077 predicted from this 1988-97 analysis. Nevertheless, incorporating this new index estimates into the time series results in a lower rate of increase of 4.4 (SE = 9.3; 95% CI -21.4 – 30.2) beluga per year, which is not significantly different from a zero, or a stable population.

A Departmental monitoring program information on the stranding of beluga carcasses in the St Lawrence has been maintained since the 1980's. The number of carcasses recovered has remained constant over time at 15-20 animals per year (Table 3), and there has not been a change in the age distribution of these stranded animals. Also, there is no published data on the variation of reproductive status of live or stranded beluga that could explain the variation in the value of index estimates since 1988. Therefore, in the absence of a visible indication of an increase in mortality in this population, we conclude that the slightly lower estimate obtained in 2000, compared to previous published estimates is most likely a result of sampling error associated with trying to sample a small aggregated population.

In conclusion, the index estimate of 527 (SE = 62) for 2000, including the 15% correction factor for animals submerged during survey of the Estuary, suggests that this population has been relatively stable over the last twelve years. However, it should be pointed out that the estimation with the 15% correction visibility is an index. Work conducted in the Estuary to estimate a correction factor for animals that were not visible at the surface when a survey aircraft passes overhead concluded that a more adequate correction factor for the estimation of a true population for strip transect surveys should be 109% (SE = 16%) (Gauthier 1999). This would provide a total population estimate for 2000 of 952 (SE = 134) beluga in the St Lawrence River estuary.

Acknowledgments

We thank C. Blais, N. Brunette, V. Neron and J.N. Rinfret of Hauts-Monts inc. for completing the survey, A. Leblanc of Canadian Helicopters for help in the survey of the Saguenay River, L. Charbonneau and A. Gagné from Ressources Naturelles Canada for logistical support, and S. Guittard and A.R. for the analyses of the photographic imagery. M.O. Hammill commented on the manuscript. L.N. Measures provided information on beluga strandings. This study was supported by funding under the National Accord for the Protection of Species at Risk.

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Table 1. Number of beluga images counted on the 28 August 2000 film, before and after correcting for sun reflection.

Transect number	Count	% reflection	Glare corrected count
1805	5	0.5	5.02
1815	18	1.1	18.19
1825	3	3.3	3.10
1905	8	1.3	8.11
1915	8	2.2	8.18
1925	5	4.0	5.21
2005	1	4.7	1.05
2015	6	6.9	6.44
2025	7	6.3	7.47
2105	14	5.6	14.83
2115	14	0.7	14.10
2125	39	0	39.00
2205	16	0.9	16.15
2215	10	1.6	10.17
2305	14	0.7	14.10
2315	3	0.6	3.02
2325	2	2.1	2.04
2415	12	2.0	12.24
2505	5	3.7	5.19
2515	10	2.3	10.24
2525	16	2.3	16.38
2605	3	1.7	3.05

Table 2. Population index estimates for St Lawrence beluga obtained from photographic aerial survey, 1988–2000.

Source	Year	Published Index estimate	Correction (%)		Corrected index	Proportion detected by 2000 readers	2000 reader corrected index
			Saguenay coverage[a]	Conversion nautical miles to km[b]			
Kingsley and Hammill 1991	1988	491 (69)	+ 4.9	+ 1.25	519		
Kingsley and Hammill 1991	1990	607 (308)	+ 4.9	+ 1.25	639		
Kingsley 1993	1992	525 (71)		+ 1.24	532	0.90	479
Kingsley 1996	1995	705 (108)		+ 1.16	713	0.96	687
Kingsley 1999	1997	681 (91)			681	0.92	631
This report	2000	527 (62)			527	1.00	527

[a] Based on the average proportion of beluga observed in the Saguenay River during 9 complete aerial surveys (Michaud 1993a)

[b] From Kingsley (1998)

Table 3. Annual number of stranded beluga reported on the coast of Eastern Canada from 1983 to 2000.

Year	Number reported	Source
1983	15	Béland et al. 1987b
1984	12	Béland et al. 1987b
1985	13	Béland et al. 1987b
1986	10	SLNIE*
1987	11	SLNIE*
1988	21	Béland et al. 1992a
1989	20	Béland et al. 1992a
1990	15	Béland et al. 1992a
1991	16	Béland et al. 1992b
1992	15	SLNIE*
1993	21	Béland 1995
1994	14	Béland 1995
1995	17	Béland et al. 1996
1996	14	Martineau & Mikaelian 1997
1997	13	Martineau & Mikaelian 1998
1998	14	Mikaelian & Martineau 1999
1999	17	Dallaire et al. 2000
2000	14	Dallaire and Martineau (in prep.)

*SLNIE: Data assembled and provided by the St. Lawrence National Institute Ecotoxicology, Montreal to the Department of Fisheries and Oceans. Data was provided by L.N. Measures (Maurice-Lamontagne Institute, DFO, Mont-Joli, QC).

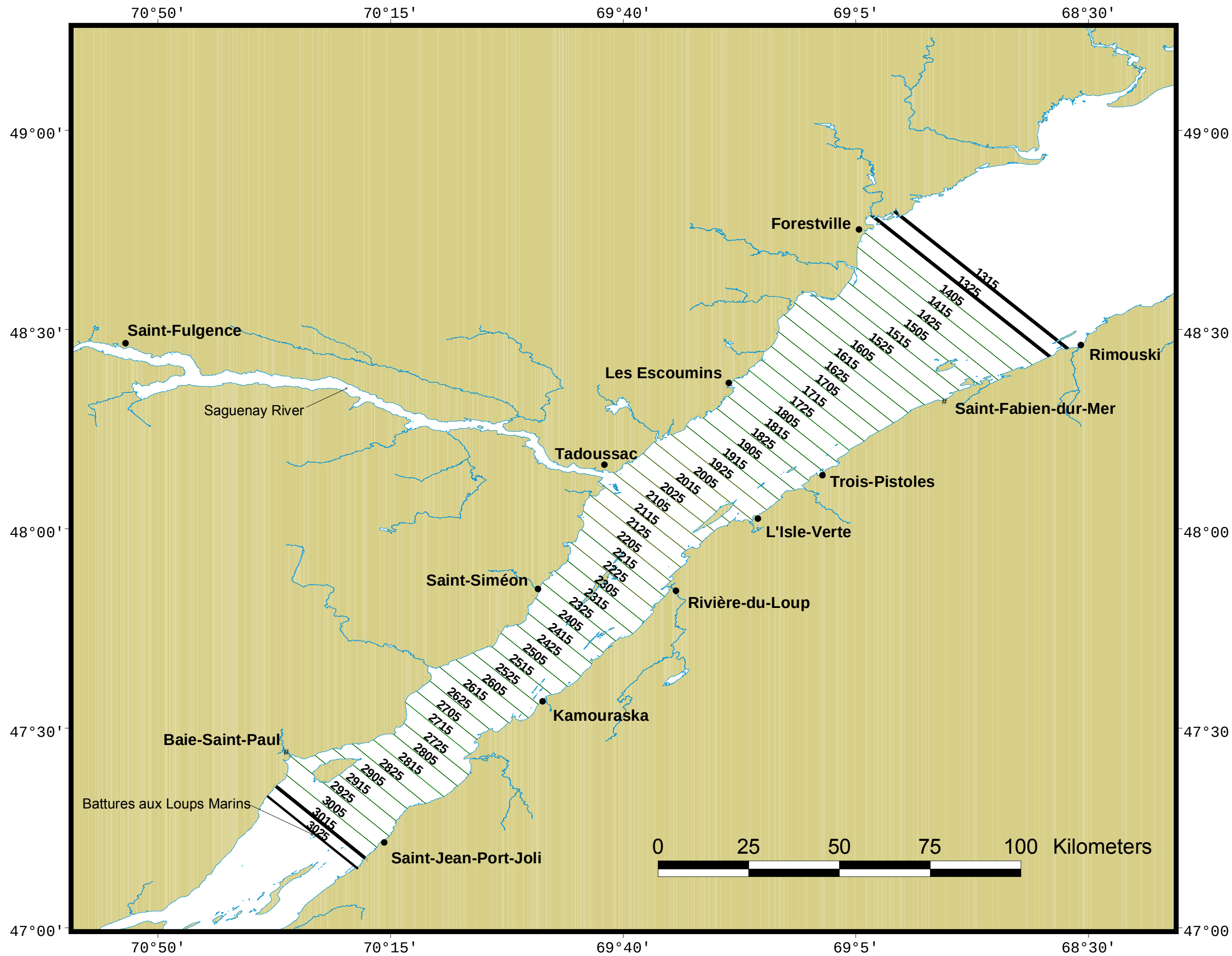

Figure 1. Strip transects flown for the St Lawrence beluga population survey on 28 August 2000.

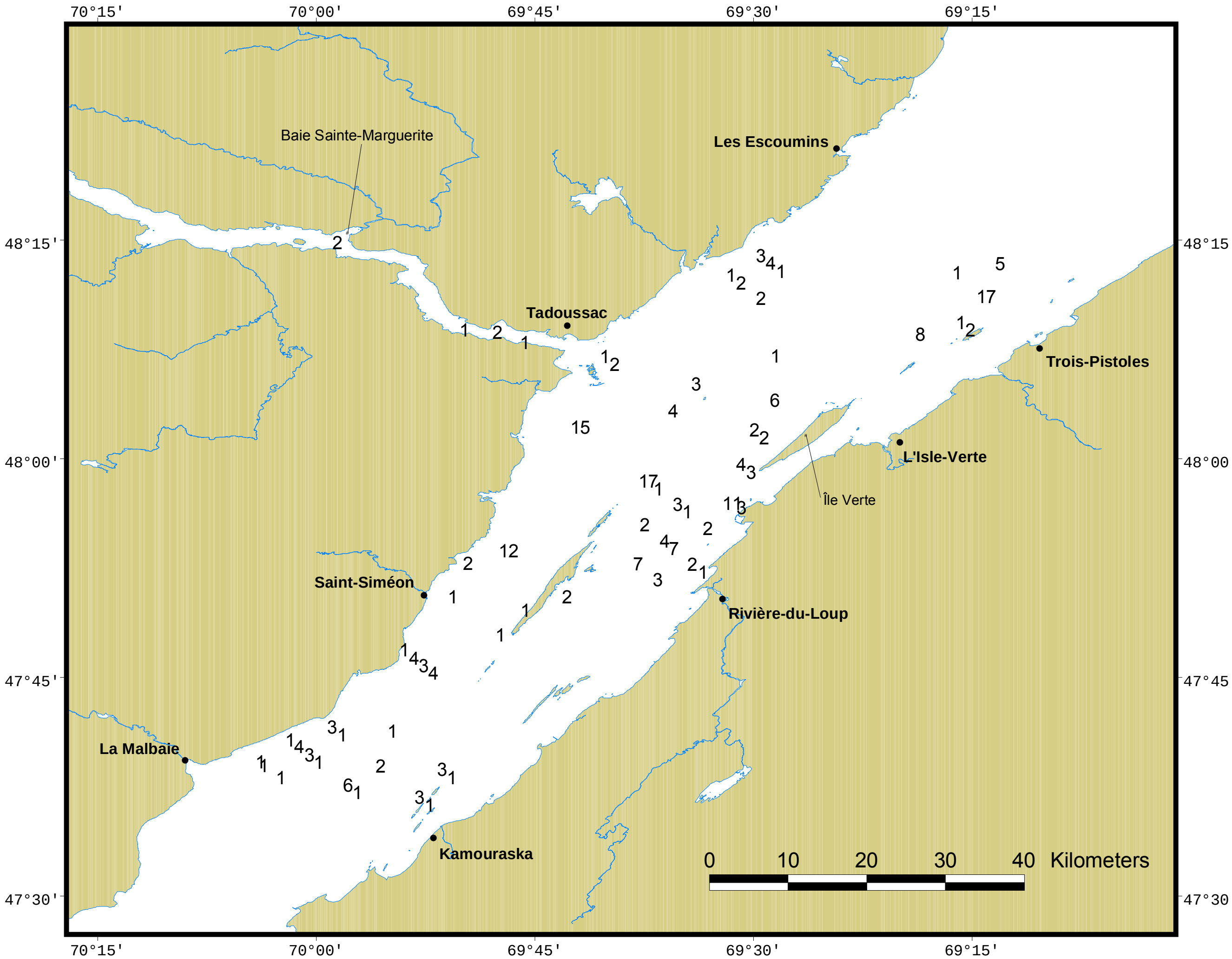

Figure 2. Distribution of the beluga observed on transects during the St Lawrence survey flown on 28 August 2000.

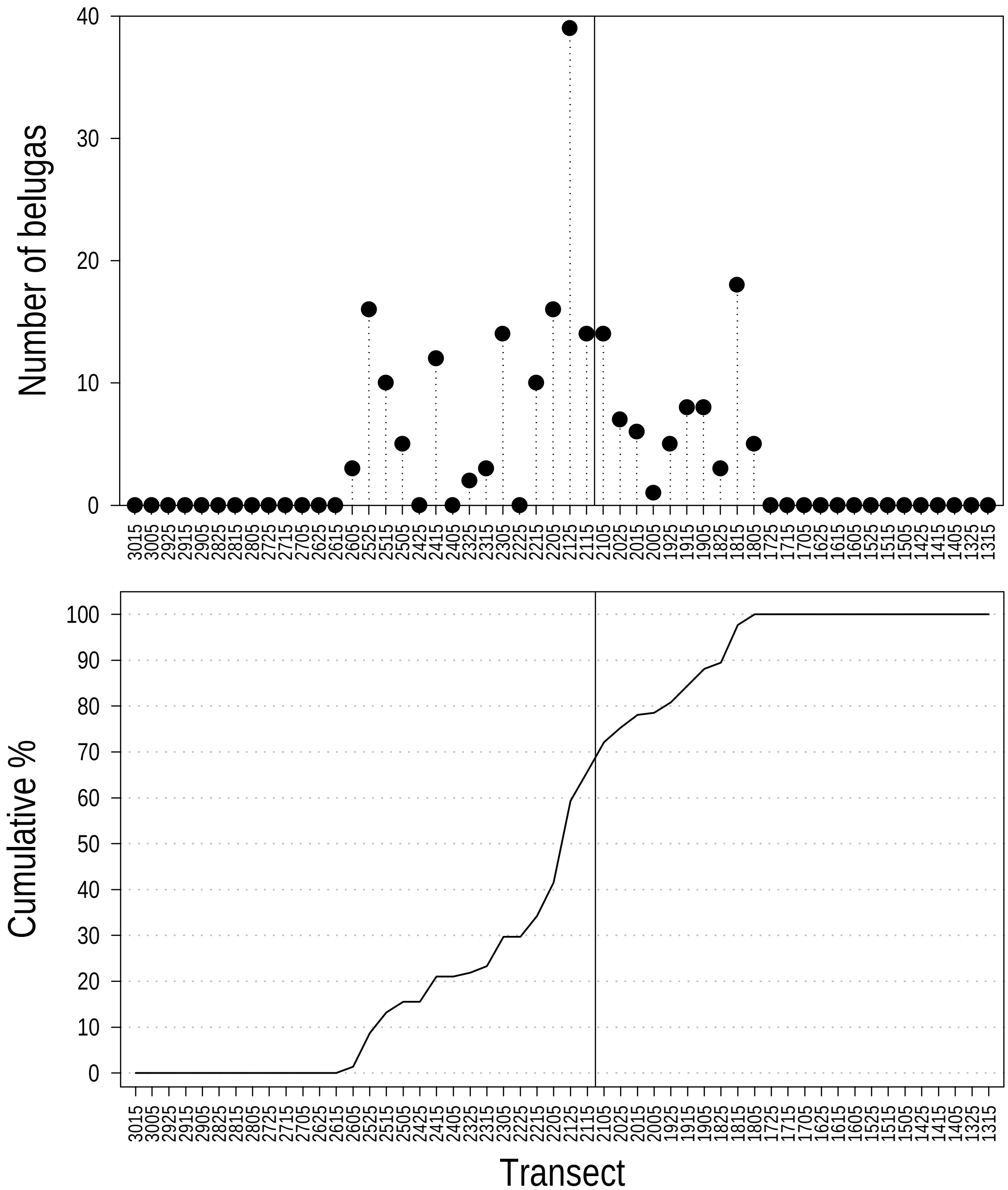

Figure 3. Number of beluga counted per transect during a photographic aerial survey, flown on 28 August 2000. The vertical line indicates the position of the Saguenay River.

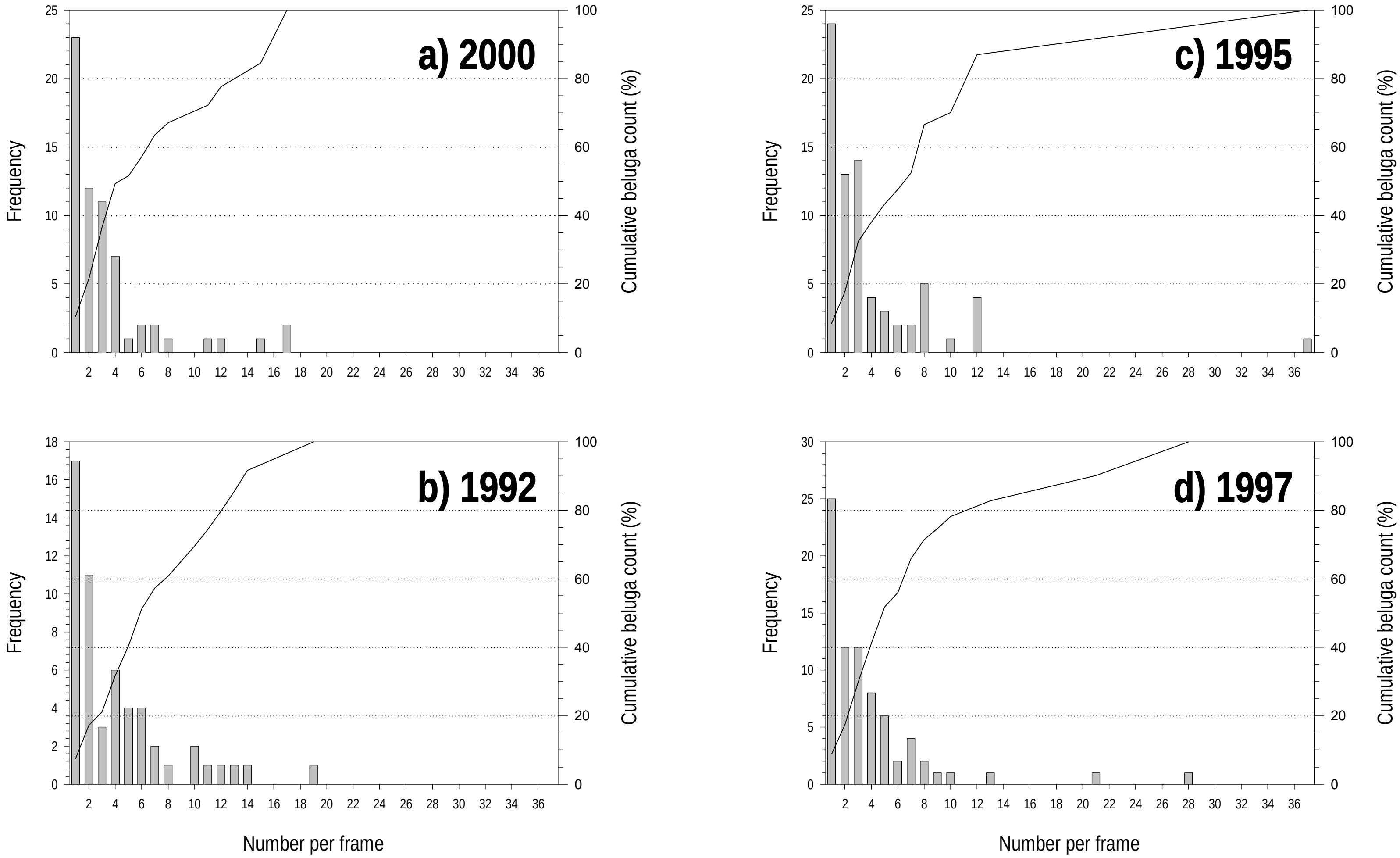

Figure 4. Occurrence of different group sizes of beluga (bars), expressed as the number of beluga counted in a frame, and their contribution (curve) to the total number of beluga counted on aerial photographs during surveys conducted in a) 2000, b) 1992, c) 1995, and d) 1997.

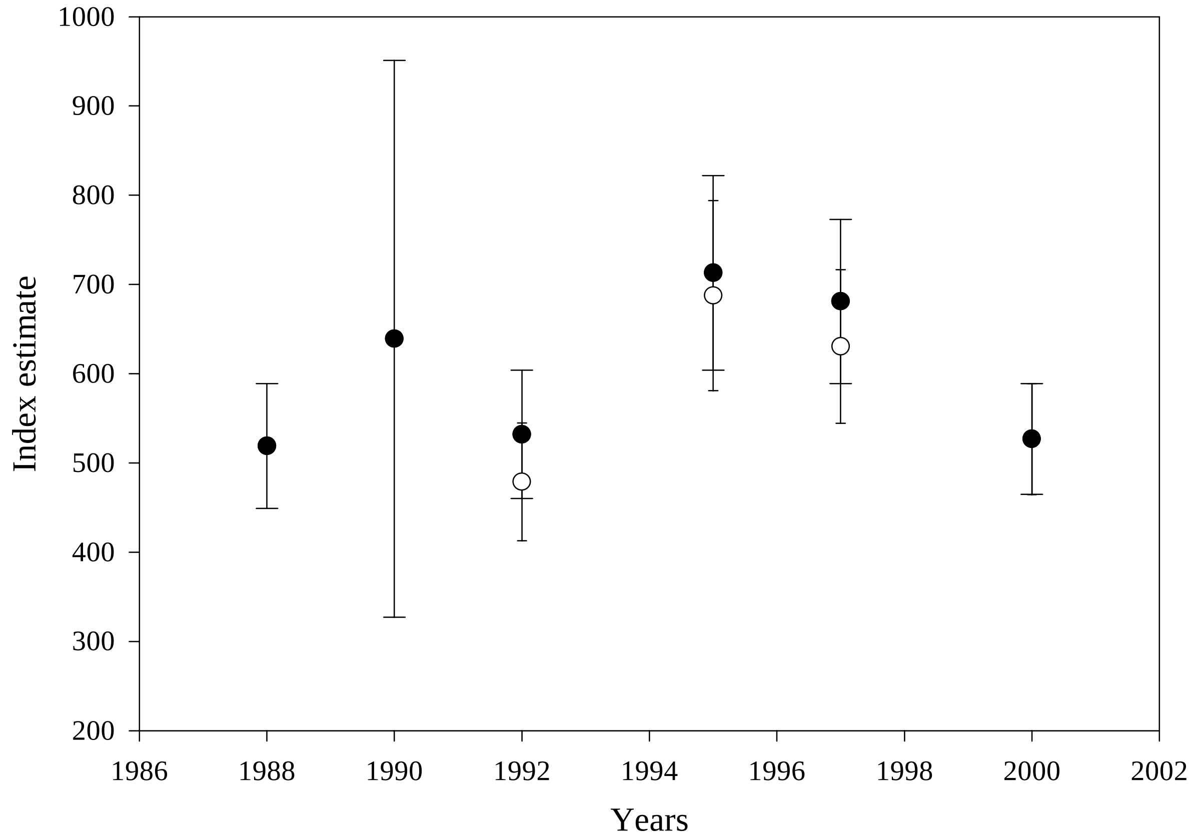

Figure 5. Trend analysis of published index estimates (± SE), including a 15% visibility correction. Empty circles represent index estimates corrected for 2000 readers.