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Abundance index of St. Lawrence Estuary beluga, *Delphinapterus leucas*, from aerial visual surveys flown in August 2014 and an update on reported deaths

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Foreword

This series documents the scientific basis for the evaluation of aquatic resources and ecosystems in Canada. As such, it addresses the issues of the day in the time frames required and the documents it contains are not intended as definitive statements on the subjects addressed but rather as progress reports on ongoing investigations.

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ABSTRACT

The size and trend of the St. Lawrence Estuary (SLE) beluga, *Delphinapterus leucas,* population is monitored using a model that integrates abundance estimates from photographic strip-transect surveys that have been conducted from 1988 to 2009 to which the number of animals detected in the Saguenay River is added as a total count. This model also integrates the number, sex and age of animals found dead, and the proportion of 0-1 year-old calves observed on aerial photos. Since 2001, a second time series of abundance indices has been developed with visual line- transect surveys. In August and September 2014, eight visual line-transect surveys were flown over the summer habitat of beluga in the SLE to produce an index of abundance. Two surveys were conducted in an adjacent downstream area to verify possible expansion of the population summer range. In 2014, abundance indices for animals at the surface in the SLE varied from 400 to 1,169 beluga, and the number of individuals counted in the Saguenay River ranged from 0 to 49. Correcting the surface estimates to account for diving animals, and adding the Saguenay counts resulted in daily abundance indices of 885 to 2,463, with a mean of 1,574 (95% CI: 1,189 to 2,021) beluga in 2014. No photographic survey was flown in 2014. The 2014 visual line-transect abundance index is the second highest of the time series of visual surveys flown since 2001. A linear regression analysis using the 36 comparable visual abundance indices from 2001 to 2014 did not show a trend over time (adjusted $R^2 = 0.06$; $p = 0.08$). There is no trend in the number of adult beluga carcasses reported from 1983 to 2014 with a median of 15 whales annually. Since 2008, the number of reported newborn deaths is higher than the 0 to 3 carcasses reported from 1983 to 2007, and the numbers since the last population assessment were 5 and 6 for 2013 and 2014, respectively. Different correction factors for perception and availability bias have to be applied to photographic and visual survey abundance indices to make them comparable. Until these are developed, it is not possible to use these as comparable indices in the population model. Therefore, the review completed in 2013, which used the photographic survey time series, remains the most recent and complete stock status evaluation for this population.

Indice d'abondance du béluga, *Delphinapterus leucas,* de l'estuaire du Saint-Laurent basé sur des relevés aériens visuels complétés en août 2014 et mise à jour des mortalités rapportées

RÉSUMÉ

Le suivi de la taille et de la tendance de la population de bélugas, *Delphinapterus leucas*, de l'estuaire du Saint-Laurent (ESL) est réalisé grâce à un modèle qui intègre les estimations d'abondance de relevés photographiques par bandes réalisés de 1988 à 2009 auxquels est additionné le nombre d'animaux détectés dans la rivière Saguenay considéré comme un décompte total. Ce modèle intègre aussi le nombre, le sexe et l'âge des animaux morts retrouvés, et la proportion de veaux de 0-1 an observée sur les photographies aériennes. Depuis 2001, une seconde série temporelle d'indices d'abondance est développée à partir de relevés visuels en ligne. En août et septembre 2014, huit relevés visuels en ligne ont couvert l'habitat d'été des bélugas de l'ESL pour produire un indice d'abondance. Deux relevés ont couvert une région adjacente en aval pour vérifier une possible expansion de l'aire de répartition estivale de la population. En 2014, les indices d'abondance d'animaux en surface dans l'ESL variaient de 400 à 1 169 bélugas et le nombre d'individus comptés dans la rivière Saguenay variait de 0 à 49. En corrigeant les indices d'animaux en surface pour considérer les animaux en plongée et en additionnant les comptes dans le Saguenay ont a obtenu des indices d'abondance quotidiens variant de 885 à 2 463, avec une moyenne de 1 574 (IC 95 % : 1 189 à 2 021) bélugas en 2014. Aucun relevé photographique n'a été complété en 2014. L'indice d'abondance visuel en ligne de 2014 est le second indice le plus élevé de la série temporelle de relevés visuels réalisés depuis 2001. Une analyse de régression des 36 indices d'abondance visuels comparables de 2001 à 2014 n'a montré aucune tendance temporelle (R^2 ajusté = 0,06; p = 0,08). Il n'y a aucune tendance du nombre de carcasses de béluga adultes rapportées de 1983 à 2014 avec une médiane de 15 baleines annuellement. Depuis 2008, le nombre de mortalités de nouveaux-nés rapportées est plus élevé que les 0 à 3 carcasses rapportées de 1983 à 2007 et les nombres depuis la dernière évaluation de la population étaient de 5 et 6 respectivement pour 2013 et 2014. Différents facteurs de correction pour les biais de détection et de disponibilité doivent être appliqués aux indices d'abondance des relevés photographiques et visuels pour les rendre comparables. Jusqu'à ce qu'ils soient développés, il est impossible d'utiliser ceux-ci comme des indices comparables dans le modèle de population. Ainsi, la revue effectuée en 2013, qui a utilisé la série temporelle de relevés photographiques, demeure toujours l'évaluation la plus récente et la plus complète du statut de cette population.

INTRODUCTION

The beluga is an Arctic species, and the St. Lawrence Estuary (SLE) population is at the southernmost limit of the species distribution. It occurs primarily in the SLE in summer and individuals are reported seasonally in the Gulf of St. Lawrence. Its current range is about 65% of the extent used historically, whereas the size of its annual core distribution is at the lower limit of areas of occupancy described for any population of this species. Up until 2007, the population appeared to be stable. However, unusually high numbers of young of the year found dead in 2008 and 2012, and a low aerial photographic estimate of abundance in 2009, triggered a review of the population status in 2013. Based largely on this review, the Committee on the Status of Endangered Wildlife in Canada (COSEWIC) re-evaluated the status of SLE beluga in 2014, and recommended that the population be designated as ‘Endangered’ (COSEWIC 2014).

The 1995 SLE beluga recovery plan recommended that a standard method, large format photographic aerial systematic strip-transect surveys, be adopted to estimate abundance and improve the monitoring of the population (DFO and WWF 1995). Eight surveys following that standard protocol have been carried out between 1988 and 2009 (Kingsley and Hammill 1991; Kingsley 1993, 1996, 1998, 1999, 2002, Gosselin et al. 2001, 2007, 2014). Considerable variability has been observed in the resulting survey indices. This variability is thought to result from challenges in trying to survey a small population with non-random or contagious distribution with individuals that spend most of their time below the surface (Gosselin et al. 2007, 2014, Kingsley and Gauthier 2002).

A possible solution to this problem is to capture the variability associated with the contagious distribution using repeated surveys. Line-transect surveys are more efficient than strip-transect surveys to estimate abundance of scarcely distributed animals over a large geographic area (Buckland et al. 2001). Furthermore, visual aerial line-transect surveys are generally less costly than aerial large format photographic surveys, making them more practical for repeated surveys. Multiple visual line-transect surveys have been flown in the SLE in 2001, 2003, 2005, 2007, 2008, and 2009 (Gosselin et al. 2014). These surveys have been used to evaluate the variability associated with clumping for this population (e.g., Gosselin et al. 2007).

These visual surveys also overlapped with the timing of the 2003 and 2009 photographic aerial survey, allowing comparison of the indices obtained using visual line-transect surveys and photographic strip-transect surveys (Gosselin et al. 2001, 2007, 2014; Lawson and Gosselin 2009). Indices from both methods are subject to different biases as some animals are underwater for the whole time they are in visible range from the passing aircraft (*re.* availability bias) and as some animals that come to the surface while in visible range from the aircraft are missed by the observers or photo readers (*re.* perception bias). In theory, both types of biases have different values for photographic and visual surveys. Photographic surveys take instantaneous images of the water surface, while observers during visual surveys have a longer time period to monitor any given location at the surface. This provides more time for animals to come to the surface while any given point at the surface is in visible range; this would imply a greater correction factor for availability for photographic than for visual surveys. On the other hand, during photographic surveys photo readers can take the time they need to carefully examine the recorded images, while observers during visual aerial surveys only have a given number of seconds to examine the water surface passing in front of them. This would imply a lower correction factor for perception bias for photographic than for visual surveys.

A correction factor for availability bias was specifically developed for photographic aerial survey of SLE beluga, and estimated that the animals had a probability of being detected at the surface of, P_s=0.478 (SE=0.0625, df=71) equivalent to the inverse correction factor of 2.09 (Kingsley and Gauthier 2002). A specific availability correction factor was not developed for visual surveys in the SLE, but the 2.09 correction factor falls within the range (1.66 to 2.90) of values estimated from time spent at surface from telemetric studies on belugas in the Arctic, and that have been used for correcting beluga surveys in other areas (Heide-Jorgensen et al. 1998, Martin et al. 1994, Martin and Smith 1992, Frost et al. 1985). It is also close to the availability correction factor of 2.03 (range: 0.88 to 3.62) used for video counts of Cook Inlet beluga (Hobbs et al 2000b).

Perception bias correction factors are usually estimated using double platforms with independent observers during visual line-transect surveys or by comparing reader photo counts. In 2005 and 2009, all photographs were examined by two readers, whereas in 2001, all photos with possible belugas were examined by two readers. For these three surveys, reader's interpretation differed on 9% to 17% of beluga images, but the final count was determined by consensus after interpretation by a third reader, and no perception correction was applied (Gosselin et al., 2001, 2007, 2014). The probability of detecting beluga at the surface during visual line-transect surveys of the North Water Polynya has been estimated at 0.97 (CV = 0.02) in 2009 and 0.92 (CV =0.03) in 2010, and these values were used to correct for perception bias (Heide-Jorgensen et al. 2013). The correction for missed groups, *i.e.* for perception bias, was estimated at 1.015 (CV = 0.03) and 1.021 (CV = 0.01) for surveys of Cook Inlet belugas during two different periods, 1994-1998 and 1999-2000 (Hobbs et al. 2000a). These values suggest that perception correction factors may be small for beluga surveys.

Here, we present a new abundance index of SLE beluga from a series of eight visual aerial systematic line-transect surveys flown in August and September 2014. This will be used to evaluate trends in abundance along with the 36 visual surveys completed with similar methods since 2001. We also present an update on the number of beluga carcasses that have been recovered since the last assessment (DFO 2014).

MATERIAL AND METHODS

STUDY AREA

Systematic surveys covered two strata in the SLE, and the Saguenay River fjord was covered using two passes from Tadoussac to Saint-Fulgence. The upstream stratum in the SLE covered the recognized summering range of belugas, centered at the confluence with the Saguenay River (Figure 1). Downstream of the Saguenay river, this stratum is characterized by the 300 m deep Laurentian channel in the northern half that rises to 40 m at the confluence of the Saguenay River, and a shelf less than 40 meters with a few islands in the southern half. Upstream, of the Saguenay River, there is a channel with depths varying from 40 m to 140 m in the northern half, and a narrow channel reaching 40 meters with wide 10 meters banks along the coast and several islands in the southern half. This stratum is also characterized by a water turbidity gradient, with more turbid waters at the upstream end than at the downstream end (Figure 2). The effects of tidal currents are most noticeable at the confluence of the Saguenay River and the Estuary, and around islands and reefs, creating local variations in apparent Beaufort sea states affecting the detection of beluga. The downstream stratum is recognized as being used by belugas outside of summer, and is characterized by a wider extent of the Laurentian channel. The Saguenay fjord surveyed from Tadoussac to Saint-Fulgence is a deep fjord reaching depths of 270 m bordered by steep cliffs up to 300 m creating wind channels and local variations in apparent Beaufort sea state and detection conditions.

VISUAL SURVEY DESIGN

The design over the SLE was systematic with random placement of parallel lines oriented perpendicular (130° T) to the main axis of the estuary and a spacing of 7.4 km (4 NM). Stratum areas and line lengths were estimated on a GIS (ArcView 3.2, ESRI) using a Lambert equal area azimuthal projection with central meridian -68.77°N and reference latitude of 48.22°N. The upstream stratum (5,770 km^2) was covered by 29 or 28 lines depending on the placement of the lines, and the downstream stratum (6245 km^2) was covered by 16 lines extending to Pointe-des-Monts (Figure 1). The Saguenay River was covered by two passes from Tadoussac to Saint-Fulgence and back, similar to the previous visual and photographic surveys. This design allowed each stratum to be completely surveyed in one day.

All visual surveys were flown with a Partenavia P68 Observer equipped with bubble windows. The visual surveys were flown at a target altitude of 305 m (1,000 ft) and a target speed of 185 km/h (100 knots). Position and altitude were recorded every 2 seconds on a GPS (Garmin GPS MAP 78s).

Observations were recorded by two observers each day, one on each side of the plane, but a total of four different observers participated in the surveys. The observers received line-transect sampling training on the ground prior to the surveys. Three of the observers had previous aerial survey experience, and all had field experience with marine mammals prior to their first survey.

Observations of beluga were recorded as groups, which were defined as several animals within a few body length of each other and swimming in the same general direction or showing similar behaviour. For each group of beluga, observers recorded: the species, the estimated group size, the angle below the horizontal, the time when animals were passing abeam, behaviour and reaction to plane (i.e. a change in behaviour assumed to be a reaction to the approaching plane). The perpendicular distance from the track line was estimated using the angle below the horizontal measured using an inclinometer (Suunto, PM 5/360 PC) and the GPS altitude output using the formulae by Lerczak and Hobbs (1998). The time when animals were passing abeam was synchronised with time from the GPS. The position of each observation was estimated using time and interpolation between adjacent GPS locations.

Surveys were only initiated when sea conditions were Beaufort 3 or less, and when cloud cover was above the target altitude of 305 m (1000 feet). Weather and observation conditions were recorded at the beginning of transect lines, at regular intervals along the lines or whenever changes in sighting conditions occurred. The conditions noted included sea state (Beaufort scale), subjective visibility (5 levels: 1- excellent; 2- good: some reduction of detection, 3- fair; 4- reduced: clearly missing sightings; 5- none: no visibility), sun reflection intensity (4 levels: 1- intense: when animals were certainly missed in the center of the reflection angle; 2- medium: when animals were likely missed in the center of the reflection angle, 3- low: when animals were likely detected in center of the reflection angle and 4- none: when there was no reflection), cloud cover percentage and water color (4 levels based on sediments in suspension: 1-dark: clear with no sediment in suspension, 2- green, 3- light green and 4- brown: high concentration of sediments). All the information was recorded on a digital voice recorder (Sony, IC recorder ICD-UX200), by each observer.

LINE-TRANSECT ANALYSES

Line-transect analyses were completed using Distance 6 (Thomas et al. 2009). There is a blind area under the plane and the distribution of perpendicular distances of beluga sightings was examined for left truncation, *i.e.* truncation of the closest distances within maximum probability of detection. A first step was to determine the distance where the number of sightings increased regularly, *i.e.* a new sighting every few meters and then remained constant. Fine tuning of left truncation distance was finalized by testing a range of potential left truncation distance values using both half-normal and hazard-rate to increase the goodness of fit. This was done by giving priority near the track line (*i.e.* maximizing the *p* value of the C^2 statistic of the Cramér-von Mises test with cosine weighting) while maintaining good fit on the overall distribution (*i.e.* maximizing the *p* value of the W^2 statistic of the Cramér-von Mises test with uniform weighting). The selected left truncation distance was subtracted to the measured perpendicular distances for further analyses.

A similar approach was used for right truncation of the distribution of perpendicular distances. A range of the most distant perpendicular distances where larger gaps started to appear were tested as right truncation to improve the fit near the track line while maintaining good overall fit. The most distant right truncation that maximized the *p* values of both C^2 *and* W^2 as above was retained as right truncation.

Model selection and inclusion of covariates followed the stepwise procedure of Marques and Buckland (2003). The first step is to select which between the half-normal or the hazard-rate model without adjustment term best fitted the truncated distribution of ungrouped perpendicular distances according to the lowest AIC. Using the selected half-normal or hazard-rate as the key function, or both functions if they had similar AIC, we examined, as the next step, if AIC could be reduced further by the addition of one of the following covariates: cluster size, observers (4 levels), sea state (Beaufort), glare intensity (4 levels), cloud percentage (as decimal), water color (4 levels) and visibility (5 levels). The four variables for sea state, glare intensity, cloud percentage and visibility are correlated and therefore were never combined in the same model. The covariates were also only included if they satisfied the following additional conditions after the reduction in AIC: if factor covariates only affected the scale and not the form of the detection function (*e.g.* covariate was not included if its addition created a new spike compared to key function or previous step model); if less than 5% of the estimated probabilities of detection of sightings were less than 0.2 and none were less than 0.1; if the Cramér-von Mises goodness of fit test with cosine weighting, which puts more emphasis on the fit near the track line, estimated that the model fitted the data ($p > 0.05$). Models with additional covariates were selected in subsequent steps if the addition of a covariate further reduced AIC and if the above conditions of estimated probabilities of detection of sightings were respected.

For each sighting, observers were instructed to give priority to the identification of species, followed by group size estimation, the angle below the horizontal to provide perpendicular distance and the other variables if time permitted. Therefore, some observations were lacking perpendicular distance measurement, when high densities of beluga were encountered. We can use two different approaches to deal with these missing perpendicular distance values. We can ignore the sightings in our analyses and assume that sightings further away have a higher probability of missing data; this would have the effect of reducing the estimated effective strip width and would compensate for the missing observations. A second approach is to assume that missing perpendicular distances had a similar distribution as the ones recorded and to include sightings. This second approach can be implemented in two steps in Distance. Detection function is estimated using a first run using only sighting with perpendicular distance to estimate the effective strip width and a corresponding probability of sighting detection. This probability of detection is then used as a divider of density estimated using a uniform model with no adjustment term in a second run including all sightings. During the 2014 surveys, high densities of belugas occurred on short segments of transects and for these short segments, all sightings were missing perpendicular distance measurement regardless of their distance from the track line. Therefore the second approach was used.

Observations of beluga were recorded as groups and the estimation of daily density and abundance indices require an estimation of the average group size each day. There is a possible bias in the estimation of average group size as larger groups of beluga may have a higher probability of being detected than smaller groups as perpendicular distance from the track line increases. To consider this potential bias, we used the group size bias regression method, *i.e.* we verified if the regression of the natural logarithm of group size against the detection function value [$g(x)$] was significant (p < 0.15; Buckland et al. 2001). This regression was not significant for any survey day and therefore the mean group size was used. No beluga sighting was missing cluster size estimation during the 10 days of surveys in 2014 and therefore no correction for missing group size values was required.

The encounter rate was estimated as the number of all groups detected along the transects, divided by the total length of all transects surveyed each day. The variance of the encounter rate for each day was estimated considering adjacent pairs of lines as overlapping strata (*re.* equation *O2* in Fewster et al. 2009). No beluga was detected in the stratum downstream of the recognized summering range, and to simplify the text the following methods will be specific to the upstream stratum of the SLE.

For each survey day, a density in the SLE was estimated using a uniform model with no adjustment term, the mean group size and encounter rate of all groups, with and without perpendicular distance. This density was then divided by the daily probability of detection given covariates values for that day and estimated using the Marques and Buckland (2003) method in a previous run including only the groups with perpendicular distance as described above. The surface abundance index in the Estuary was then estimated by multiplying the density index by the area of the stratum, which was 5,770 km^2 for the upstream stratum.

POPULATION INDICES

Line-transect sampling assumes that all sightings are detected at the track line. We know that this is not true for visual surveys of marine mammals as some animals are underwater for the whole time they are in visible range from the passing aircraft (*re.* availability bias) and that some that come to the surface while in visible range from the aircraft are missed by the observers (*re.* perception bias). We applied the correction factor for availability developed by Kingsley and Gauthier (2002) for the photographic surveys of SLE beluga with a probability of being detected at the surface of, P_s=0.478 (SE=0.0625, df=71) and used it as an additional divider of density in a third run in Distance. As described in the introduction, the inverse of this probability of detection is 2.09 and falls in the range of correction factors used in the Arctic (1.66 to 2.90) and Alaska (0.88 to 3.62; Frost et al. 1985, Heide-Jorgensen et al. 1998, Hobbs et al 2000b, Martin et al. 1994, Martin and Smith 1992). The correction factor applied to account for availability bias was developed for photographic surveys, and the previous factors from the literature only considered the proportion of time the animals spend at the surface and not the longer period available to observers during visual surveys to scan the surface. Therefore, the applied availability correction factor may be higher than a proper visual survey correction factor. We did not estimate a perception bias correction factor which is usually done during visual line-transect surveys using a double platform with independent observers. Studies in the North Water Polynya and in Alaska estimated that 2% to 8% of belugas could be missed by observers during visual surveys (Heide-Jorgensen et al. 2013, Hobbs et al 2000a). These values suggest small correction factors for perception bias and as the availability correction factor may already be higher than it should be for a proper correction factor for visual survey, we did not apply a perception correction to our estimates.

SAGUENAY RIVER COUNTS

The Saguenay River (Saguenay) was surveyed on the same days as the upstream stratum with the same plane and same set of observers after or before the systematic survey of the SLE was completed. The number and position of beluga were recorded on a first pass from Tadoussac to Saint-Fulgence and on a second pass in the opposite direction. For sightings or groups seen on the same location on both passes, the maximum count was used for this location. Sightings on the second pass that were not detected on the first pass, or that could not be duplicate sightings of the first pass according to distances with locations of sightings of the first pass and time lapse between sightings and a maximum velocity of 10 knots, were added. Counts in the Saguenay were not corrected for availability nor perception biases because of the narrow searching area, curves in plane trajectory which allowed observers to spend more time to search on any given location, and replicate passes (upstream and downstream).

The daily abundance indices, were obtained from the daily surface abundance index corrected for availability (third run of Distance) to which the count in the Saguenay was added without availability or perception bias correction.

To estimate the 2014 abundance index, the daily surveys in the SLE (upstream stratum) were considered replicates. The 2014 abundance index was estimated as the mean abundance of daily surveys weighted by the daily effort, *i.e.* the total number of km surveyed each day to which the average of seven Saguenay counts (no count was available for one survey day; see Results) was added. With the addition of covariates to the detection function, the variance of the daily density and abundance indices were estimated analytically, but the CV and 95% CI of the combined 2014 index were estimated using bootstrapping. Given missing perpendicular distances, the bootstrap was done in two steps. A first bootstrap (5000 resamples), using transect lines as resampling units, was performed considering only the sightings with perpendicular distances to provide the daily bootstrap estimate of the probability of detection. This probability of detection was used in a second bootstrap run (5000 resamples) as a divider of density estimated using the uniform model without adjustment term and including all sightings. For each resample, the daily abundance indices were averaged, and weighted by the daily effort. The 95% CI of the 2014 abundance estimate was the 2.5% and 97.5% quantiles of these 5000 averages of eight daily surveys to which the averages of seven Saguenay counts were added.

REPORTED DEATHS

The information on reported deaths was provided by a carcass monitoring program that has been operating since 1982 (reviewed in Lesage et al. 2014). This program collects data and tissues from beluga carcasses that are reported by the public. An evaluation of carcass freshness is made on the shore. If fresh, carcasses are transported to a veterinary laboratory for complete necropsy. If the carcass is not fresh, sampling may consist of information on location, sex, removing a tooth to determine age and a skin/blubber sample. The program is promoted each spring by a publicity campaign mainly concentrated along the St. Lawrence Estuary in Quebec.

RESULTS

Eight visual line-transect surveys were completed over the upstream stratum from the 19 August to the 10 September 2014. Another two surveys were completed over the downstream stratum on the 27 August and 9 September. However, on 19 August, the Saguenay River was not surveyed, because of the late start of the SLE survey that day. On the 24 August, the survey started with 4 lines to the east, and was delayed in Rimouski for 2 hours before the Saguenay and the remaining lines were surveyed from the west including a 30 minute stop in Charlevoix. For the other days, the survey was completed from east to west with a 30 to 58 minute stop in Charlevoix before the Saguenay was completed.

On the 27 August, 12 lines were completed in the lower stratum with a stop of 1h34 minutes in Baie-Comeau to allow winds to die down, resulting in not completing the four easternmost lines. The 16 lines of the lower stratum were completed from west to east with a 48 minute stop in Baie-Comeau on the 9 September.

An average of 105 groups (255 individuals) was detected during the visual surveys of the upstream stratum with counts widely ranging from 53 to 153 groups among survey days (145 to 389 individuals; Table 1). Some groups were missing perpendicular distances on six of those surveys, which for the last 4 surveys represented between 16% and 47% of the individual counts (Table 1). No beluga was detected during the two days of survey in the downstream stratum and the following sections only present results of the upstream stratum.

LINE-TRANSECT ANALYSES

The distribution of perpendicular distances suggests a definitive increase in probability of detection from 0 to 150 m from the track line that might still increase up to 200 m. Left truncations from 111 to 222 m were tested and within that range the half-normal model always provided the lowest AIC. Within that range, the best goodness of fit was obtained when 155 m was used as the left truncation both close to the track line (i.e. maximum $p = 0.6$ for the C^2 statistic of the Cramér-von Mises test with cosine weighting) and for the overall distribution (i.e. maximum $p = 0.7$ for the W^2 statistic of the Cramér-von Mises test with uniform weighting). Therefore, 155 m was used as left truncation.

Right truncation was tested for the most distant perpendicular distance range of 2,362 m to 3,408 m. Right truncation improved the fit of both the hazard-rate and half-normal models near the track line and for the overall distribution. From no right truncation ($p = 0.6$ for C^2 and $p = 0.7$ for W^2), the fit improved with removal of distant perpendicular distances up to 2,578 m ($p = 0.9$ for C^2 and $p = 0.9$ for W^2) which was retained as the right truncation. The left truncation distance was subtracted to the perpendicular distances for further analyses, leaving a maximum width of 2,423 m.

Following Marques and Buckland (2003) procedure, detection functions were first tested against each other without covariates and showed no difference between the hazard-rate (AIC of 10,459.65) and half-normal models (AIC of 10,461.17) according to AIC (ΔAIC = 1.52, i.e. <2; Table 2). Then, improvement of the fit by the addition of covariates was tested for both hazard-rate and half-normal functions. In the second step, only the observer as a covariate with the hazard-rate key function further reduced the AIC (10,456.42, ΔAIC = 3.23) while still maintaining the additional conditions. In a third step, the addition of visibility further reduced the AIC (10,450.91, ΔAIC = 5.51) while maintaining the additional conditions, but given its high correlation with observer, visibility was not retained. Glare intensity also reduced AIC (10,452.75, ΔAIC = 3.67) and was retained. Watercolor was the only covariate not correlated with glare intensity that could be included in a fourth step, but it did not reduce the AIC further (10,452.54, ΔAIC = 0.21<2). Therefore, the hazard-rate with observer and glare intensity as covariates was used to estimate the detection function. When applied to 688 sightings with perpendicular distances, this model provided an effective strip width of 1,199 m (CV = 0.03, df = 680). The daily effective strip widths given covariate values varied from 1,023 m to 1,377 m (Table 3).

The first step of the bootstrapping (5000 resamples) to estimate the 2014 abundance index provided daily probabilities of detection ranging from $p = 0.4282$ to $p = 0.5661$, corresponding to effective strip widths of 1,038 m to 1,372 m, respectively.

Belugas were recorded as groups, but there was no significant effect of the detection function on group size ($p > 0.15$) for daily regressions of ln(cluster size) vs detection function [g(x)] ;

therefore average cluster size was used each day and varied from 1.97 to 2.75 for sightings with perpendicular distances. We therefore used the average for all daily estimates when we included sightings without perpendicular distance, which resulted in estimated group sizes varying from 2.22 to 2.78 (Table 3).

There were 28 or 29 lines surveyed in the upstream stratum, leading to a total transect length varying from 769 km to 802 km, so a variation between daily effort of 4% or less. There was a gradient in density along the main axis of the upstream stratum, and the daily variance in encounter rate benefit from the use of the post-stratification scheme with overlapping strata (equation O2 from Fewster et al. 2009). However, the encounter rate remained the main contributor to the variance in density and abundance, contributing on average 72.1% (CV = 0.15) of the daily variance in density and abundance, ranging from 56.1% of the variance on 20 August to 86.1% of the variance on 10 September.

The Saguenay count represented up to 33% of the individuals counted during the survey on the 21 August. It represented 5% of the availability corrected abundance indices on the 21 August and 3 September.

The daily abundance indices in the SLE varied from 400 to 1,169 beluga, before adding the correction for availability and the Saguenay count. These extremes occurred between counts of two consecutive days, from the 20 August to the 21 August, representing a 66% reduction in abundance. This change in abundance was completely driven by the reduction of 70% in encounter rate, given that the effective strip width decreased and the expected group size increased, which would both have implied an increase in abundance when taken independently. Encounter rate is the important factor in the variation of density and abundance: it accounted on average for 72.1% of the variance within surveys, as mentioned above, and resulted in a CV of 0.39 between surveys. In comparison, effective strip width and average cluster size had CVs of 0.10 and 0.08 between surveys, respectively.

The 2014 visual line-transect surveys index is the second highest of the series of 7 visual line-transect survey indices obtained since 2001 (Table 4; Figure 3). The linear regression of the daily surveys from 2001 to 2014 using the average Saguenay count of 29 for 19 August 2014, showed a poor fit (adjusted $R^2 = 0.06$) and the slope was not significantly different from zero ($p = 0.08$, df = 34; Figure 6).

REPORTED DEATHS

A total of 17 and 11 carcasses, including neonate animals were reported in 2013 and 2014, respectively. The number of dead newborn calves was 5 and 6 for 2013 and 2014, respectively.

DISCUSSION

The 2014 abundance index is the second highest in the time series of comparable surveys flown since 2001, and above any of those obtained using the photographic methodology. The visual survey indices tend to be higher than the photographic survey estimates. This could be due to the fact that any given location at the surface of the water that come in visible range of the observers can be examined for a longer period in visual surveys, while it is instantaneous for photographic surveys. Specific availability correction for visual line-transect surveys will likely result in a lower correction in abundance than the 2.09 factor developed for SLE beluga photographic surveys (Kingsley and Gauthier 2002). Unfortunately, there are only two years where abundance indices were obtained using both techniques to allow direct comparison. The first visual surveys were not flown before 2001, and visual surveys have been flown more frequently since then. The series of 8 photographic surveys was used in the population model that estimated that the population had increased in the 1990s to the early 2000s and had decreased over the last decade. A regression analysis of the 36 visual line-transect survey abundance indices from the last decade does not show significant changes in abundance. This was also the case during the last assessment of the population for a regression analysis done using the 28 earlier indices from 2001 to 2009 (Gosselin et al. 2014).

Different approaches have been used to assess SLE beluga abundance since the mid-1970s (Gosselin et al. 2007, 2014; DFO 2014). Beginning in 1988, a series of standardized photographic systematic survey indices was initiated and surveys were flown following this design in 1988, 1990, 1992, 1995, 1997, 2000, 2003 and 2009 using large format 9 inch x 9 inch film (Gosselin et al. 2014). The latest evaluation of the population in 2013 was based on a model fitted to that time series of abundance indices and the proportions of calves (*i.e.* 0 to 1 year-old) estimated using the same photographic surveys from 1990 to 2009 (Mosnier et al. 2015). Our intention was to repeat the large format photographic systematic survey, in combination with the visual surveys in 2014, but with changes in technology, photographic platforms using film are getting harder to find and logistical problems did not allow to get the film in due time nor did it allow sufficient time to organize a large format digital photographic survey component to accompany the visual surveys.

The large film (Agfa, Aviphot Chrome 200 PE1) used in past surveys provided images covering 1.8 km x 1.8 km of the water surface; with a spacing of 3.7 km between lines, it provided a coverage of about 50% of the SLE. The resolution of the images on the film permitted the detection and measurement of small calves. Large format digital cameras and platforms were available, and tests were made to compare the resolution of film versus digital images for a 1.8 km strip width at the surface of the water. Images from a Vexcel, Ultracam X with a width of 14,400 pixels were used. The resolution of these images was not as good as film and did not allow for detection or measurement of calves. To get similar beluga image quality would have required changing the survey design to have more transects of narrower strip width to maintain the 50% coverage. No tests were made with the new Ultracam Eagle, with an image size of 23,010 pixels x 14,790 pixels. Improvements in digital technology may allow us to change the photographic platform from film to digital in the near future but the digital cameras available in 2014 could not be used to replace films without important changes in the design that has been used since 1988.

Visual surveys do not provide a permanent record for re-evaluation of detection or for measurement and identification of calves. However, they are usually less expensive to execute than photographic surveys and results are obtained much faster, which means that the surveys may be repeated several times within a single season. For the cost of a photographic survey using large format film or large format digital cameras, about 15 to 20 visual line-transect surveys could have been completed in 2014 using small planes, such as the Cessna 337 or Partenavia P68 observer. Although single photographic surveys have the advantage of providing images for re-evaluation, measurements and identification of calves, they are subject to the same problem of clumping of beluga, and they usually show high variability in encounter rate as single visual surveys for the estimation of density and abundance. Until we get a better understanding of the factor that might be driving the changes in distribution of beluga, replicate surveys are one solution to capture and estimate this important source of variability when assessing abundance and trend.

Bias of aerial surveys arises from two main sources: not all animals are detected by observers during visual surveys or counted on photographs (perception bias) and not all animals are available at the surface to be detected (availability bias). In photographic surveys, with a permanent image, the perception bias is reduced to very low levels, or multiple counts provide some measure of the uncertainty associated with imagery reading (Gosselin et al. 2014;

Stenson et al. 2014). A correction factor for availability has been developed specifically for the photographic aerial surveys used for SLE beluga to account for the estimated proportion of time that animals are visible at the surface from an aerial platform (Kingsley and Gauthier 2002). Therefore, photographic surveys can be considered fully corrected for these two biases. On the other hand, visual line-transect surveys have to be corrected for both perception and availability biases. The perception bias is usually corrected using a double platform and mark-recapture procedure to provide an estimation of the proportion of animals at the surface that is detected by the observers (Laake and Borchers 2004). Our visual estimates were not corrected for perception bias and consequently, considering only this bias, our final estimates will underestimate abundance by some unknown amount compared to the photographic surveys. However, perception bias corrections for beluga in other studies have generally been small (2-8%; Heide-Jorgensen et al. 2013, Hobbs et al. 2000a). Even though the correction may be small, adequate correction for perception bias will require the use of double platform in future surveys. The availability correction that we have applied to our visual line-transect survey estimates was developed for the photographic film surveys. A more appropriate availability correction factor should be developed using detailed diving behavior of SLE beluga. The correction factor should also consider that the detection is not instantaneous and should consider the duration of time that any given location at the surface of the water remains in the observer field of view while the plane passes overhead (Gómez de Segura et al. 2006, Forcada et al. 2004, Laake et al 1997, McLaren 1961). Considering only the availability correction factor applied, our abundance estimate likely overestimates abundance by an unknown amount compared to the use of a proper availability correction for visual surveys. Once adequate correction factors for both biases are available, abundance estimates obtained from photographic and visual survey methods will be comparable, and could be integrated as a single time series into the population model.

In addition to abundance, the photographic surveys provided an index of the proportion of calves in the population. Calves are recorded during visual surveys, but the number of calves was a variable that became hard to reliably collect when the density of animals was too high. Smaller format cameras were incorporated in a High Arctic Cetacean Survey in 2013 using Twin Otter aircrafts as survey platforms (Pike and Doniol-Valcroze 2015). Small format cameras will not replace large format film cameras or large format digital cameras, but they can provide permanent records of animals from which a proportion of calves could be estimated without the bias of visual surveys. The inclusion of small cameras should be considered for future surveys of SLE beluga or any other visual surveys of cetaceans using small aircraft.

Another source of uncertainty associated with the estimation of abundance of SLE beluga, is the possibility that their summer distribution extends outside of the recognized range from Île-aux-Coudres to Rimouski. Nineteen groups corresponding to 29 individuals were detected outside of this range in July and August 2007, of which 17 groups (27 individuals) were detected between Rimouski and Pointe-des-Monts on 22 July 2007. This is roughly a month earlier than the dedicated SLE beluga surveys to estimate abundance of the population that are usually conducted from mid-August to early September. Two surveys covered the downstream stratum (i.e., between Rimouski and Pointe-des-Monts) in August-September of 2009 and 2014; they led to the sighting of only one animal on 25 August 2009 (Gosselin et al 2014). VHF tracking of 44 animals tagged in the center of the summer range from 2001 to 2005, and visual tracking of 465 herds from 1989 to 2005 did not reveal movements outside of the recognized summer range (Lemieux Lefebvre 2009). Although some effort should be maintained to evaluate this possible bias, it is unlikely that movement outside of the summer range could explain the variation between daily surveys and it is more likely that uneven distribution within the summer range may have a greater impact on the variance of abundance indices.

The observations were examined for possible double counting between adjacent transects that represent a potential positive bias. For this, we verified the geographic locations of observations for which perpendicular distance exceeded 3,700 m or the half-way distance between transects. There was only one observation with a perpendicular distance of 4,410 m that exceeded this distance in 2014 (3 September, line 9). Another 7 sightings had a perpendicular distance exceeding 3,200 m (one on line 17 on 21 August; 4 on lines 7, 8, 9 and 9 on 3 September; 1 on line 17 on 8 September; 2 on lines 13 and 14 on 10 September), but only two groups were close between adjacent lines. One group of 15 to 20 individuals was seen on line 8 on 3 September at 10:47:05. It was estimated to have been seen again and estimated again to include 15 to 20 individuals on line 9 at 10:55:40 at an estimated position that was 1,076 m away from the previous one. Direct movement, would correspond to a speed of 2.09 m/s or 7.5 km/h, a plausible swimming speed for beluga (Lemieux Lefebvre et al. 2012). However, the swimming direction on the first sighting was reported at 270° relative to the heading which would have lead them in the opposite direction from the second sighting's location. The swimming direction of the second sighting was 0° relative to heading, a 90° difference from the swimming direction of the previous sighting. This was the only account of possible double counting in 2014, but the right truncation eliminated the possibility of double counting animals at the same location. Some perpendicular distances exceeded 3,700 m in surveys conducted in 2005 but none exceeded the half way distance in 2001, 2003, 2007, 2008 and 2009. There are only a limited number of sightings that occur far enough to be possible double counts if they remain in the same position and the verification made here illustrate that if it does occur, it is not a frequent occurrence. Furthermore, in the absence of obvious directional movements of the animals, movements towards a following transect that could allow double counting are likely to be compensated by movements towards the previous track line that would compensate for double counting and it reduces the possibility that it is a constant positive bias.

A better understanding of animal movements within the summer range could also be useful to improve the precision of abundance estimates. The correction factor for availability developed by Kingsley and Gauthier (2002) considered the variability of detection along the axis of the estuary where there is an important turbidity gradient. Correction factors could consider this factor more specific to the locations of detected groups within each survey. Tide cycle may affect the distribution of beluga within the summer range. If we can estimate how tide cycle influences the distribution of beluga, surveys could be planned to cover the population when it is in water of lower turbidity to increase the number of sightings. Given the wide variation in bathymetry between regions (*e.g.* Laurentian Channel vs the south shore or the area upstream of the Saguenay), we could also examine variation in diving depth with sectors as this is likely to affect availability. The aggregation of belugas and behaviour may also vary according to the tide cycle, and surveys should preferably be conducted when the distribution is more uniform to get more reliable estimates of density and abundance and reduce the encounter rate variance based on the difference in counts between adjacent lines. We could also examine if shipping influences their horizontal distribution or their diving behavior. Shipping is more intense in the northern part of the beluga summer range and we could examine if the distribution of detected beluga changed with variation in the intensity of traffic throughout their range.

The addition of small cameras, as indicated above, may provide a means of obtaining estimates of the proportion of calves in the population, which will also influence population trend estimated from the population model. Alternatively, the use of new technology such as drones may provide a means of obtaining and improving this information independently of the standard aerial surveys. Independent field programs could be developed to improve the information that is integrated in the population model (Mosnier et al. 2015).

The number of dead beluga reports is another source of information that is integrated into the population model. There is considerable year-to-year variation, but no trend in the number of adult beluga carcasses (male and female) reported over the period from 1983 to 2014 with a median of 15 whales annually (Figure 7). Since the last status review, the total number of carcasses reported in 2013 and 2014 were near this median with 17 and 11, respectively. The number of young-of-the-year reported dead varied annually from 0 to 3 between 1983 and 2007 with a median of 1. However, unusually high numbers were recorded in 2008, 2010, and 2012 with 8, 8 and 16 carcasses respectively (Lesage et al. 2014). In other years, the number of dead newborn calves reported was outside of the range reported prior to 2008, with 4 cases in 2011, five cases in 2013 and six cases in 2014.

The population model that integrates information on the proportion of 0 and 1 year old calves , abundance from the survey program, and information on reported deaths from the carcass monitoring program represents the most reliable tool to estimate the trend of SLE beluga population (Mosnier et al. 2015). As outlined above, estimates from photographic and visual surveys are not directly comparable owing to specific correction factors needed for each method to adjust for perception and availability biases. Until such factors can be developed it is not possible to incorporate estimates from both methods into a single time series for use in the population model. The population model also requires an update of the proportion of 0 and 1 year old calves. Until these updates become available, the review completed in 2013 remains the most recent and most reliable assessment of this population (Mosnier et al. 2015).

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TABLES

Table 1. Survey effort and number of belugas detected during 10 line-transect surveys in the main summering area (Upstream) and the lower marine estuary (Downstream) in summer 2014. The number retained for effective strip width estimation after left truncation at 155 m and right truncation at 2578 m are also provided.

Stratum Date	Stratum area (km^2)	Number of lines	Total track length (km)	Number of groups	Number of individuals	Groups (individuals) without distance	Groups with distance after truncations
Upstream	5770						
19 Aug		29	802	107	241	0	100
20 Aug		28	779	153	389	0	151
21 Aug		29	775	53	145	1 (4)	44
24 Aug		29	801	74	165	1 (3)	69
29 Aug		28	769	144	321	48 (107)	95
3 Sep		29	800	67	173	6 (27)	58
8 Sep		28	769	124	301	25 (70)	96
10 Sep		29	801	118	302	41 (143)	75
Downstream	6245						
27 Aug		16	830	0	0	0	0
9 Sep		16	851	0	0	0	0
Total		229	6,295	840	2037	122 (354)	688

Table 2. Summary of the model selection for the estimation of the effective strip width using covariates that followed the stepwise procedure of Marques and Buckland (2003) applied to 688 sightings after truncations.

Model	AIC	Delta AIC	Cramér-von Mises (cos) p	Effective Strip Width (m)	ESW CV
HR+Observer+Glare intensity	10,452.75	0.00	0.6	1,199	0.03
HR+Observer+Water color	10,453.94	1.19	1.0	1,273	0.03
HR+Observer	10,456.42	3.67	0.5	1,209	0.03
HR+Observer+Beaufort	10,457.03	4.28	0.6	1,218	0.03
HN+Glare intensity	10,457.76	5.01	0.3	1,289	0.03
HN+Water color	10,457.83	5.08	0.4	1,289	0.03
HR+Cloud percentage	10,458.59	5.84	0.6	1,205	0.03
HR+Glare intensity	10,458.74	5.99	0.6	1,204	0.03
HR	10,459.65	6.90	0.9	1,284	0.05
HN	10,461.17	8.42	0.3	1,299	0.03

Table 3. Density and abundance indices of St Lawrence Estuary belugas from 8 line-transect surveys of upstream stratum, or the main summering areas, flown in 2014. Coefficient of variation are shown in parenthesis. The corrected abundance indices include a correction for availability and then the Saguenay count was added. The average Saguenay count was added to the overall 2014 estimate.

Date	Effective strip width (m)	Estimated group size	Encounter rate (groups/km)	Density index in the Estuary (Ind./km^2)	Surface abundance index in Estuary	Saguenay count	Corrected abundance index	95% CI
19 Aug	1,077 (0.08)	2.27 (0.09)	0.1247 (0.25)	0.1314 (0.28)	758	n/a	1,586 (0.31)	869-2,895
20 Aug	1,219 (0.06)	2.55 (0.07)	0.1937 (0.18)	0.2027 (0.20)	1,169	17	2,463 (0.24)	1,539-3,943
21 Aug	1,163 (0.11)	2.78 (0.18)	0.0581 (0.36)	0.0694 (0.41)	400	48	885 (0.41)	398-1,966
24 Aug	1,023 (0.10)	2.26 (0.09)	0.0874 (0.39)	0.0964 (0.41)	556	38	1,202 (0.42)	527-2,744
29 Aug	1,183 (0.08)	2.22 (0.07)	0.1860 (0.38)	0.1748 (0.40)	1,009	26	2,136 (0.41)	948-4,810
3 Sep	1,377 (0.09)	2.44 (0.16)	0.0800 (0.34)	0.0785 (0.39)	409	49	904 (0.39)	423-1,932
8 Sep	1,343 (0.07)	2.41 (0.08)	0.1574 (0.24)	0.1410 (0.26)	813	22	1,724 (0.29)	974-3,052
10 Sep	1,301 (0.08)	2.51 (0.10)	0.1448 (0.46)	0.1396 (0.48)	805	0	1,685 (0.50)	651-4,360
2014					738	29	1,574 (0.13)	1,189-2,021

Table 4. Yearly surface abundance indices of St Lawrence Estuary beluga from photographic and visual survey from 1988 to 2014. Corrected abundance indices are corrected for availability and include the addition of the Saguenay counts (from Gosselin et al. 2014).

Year	Method	Number of surveys	Surface abundance index in Estuary	Saguenay count	Corrected abundance index (CV)	95% CI
1988	Photo	1	417	22	893 (0.20)	751-1,062
1990	Photo	1	527	28	1,129 (0.50)	446-2,860
1992	Photo	1	454	3	952 (0.16)	702-1,291
1995	Photo	1	568	52	1,239 (0.18)	881-1,742
1997	Photo	1	575	20	1,222 (0.16)	903-1,654
2000	Photo	1	453	6	953 (0.14)	724-1,254
2001	Visual	1	529	15	1,122 (0.28)	555-1,675
2003	Photo	1	630	2	1,319 (0.20)	896-1,942
2003	Visual	5	658	7	1,378 (0.14)	1,039-1,828
2005	Visual	14	492	39	1,068 (0.09)	891-1280
2007	Visual	1	822	29	1,746 (0.23)	1,047-2,583
2008	Visual	1	502	11	1,053 (0.26)	636-1,744
2009	Photo	1	319	10	676 (0.16)	499-915
2009	Visual	6	460	17	979 (0.14)	750-1,277
2014	Visual	8	738	29	1,574 (0.13)	1,189-2,021

FIGURES

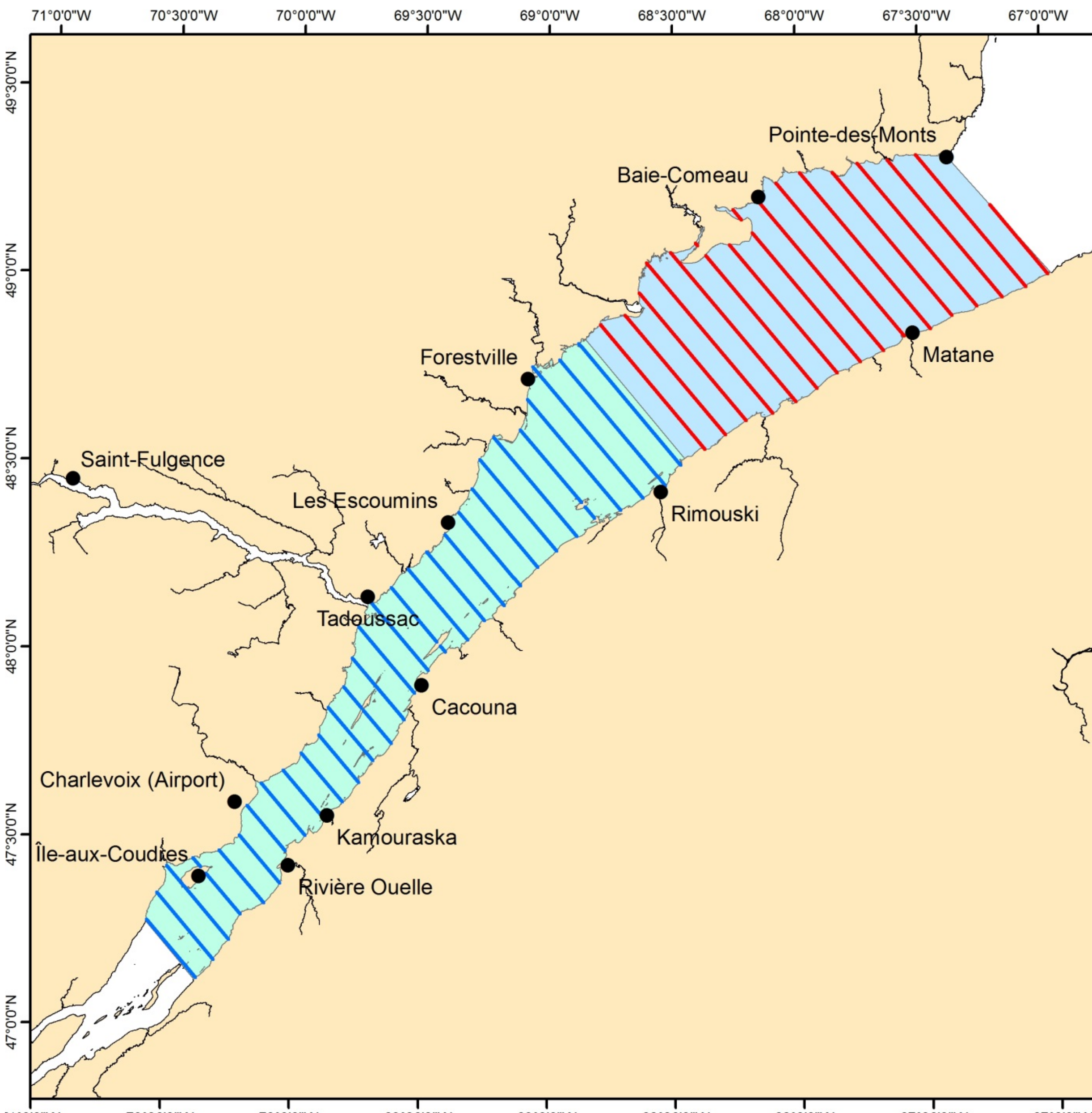

Figure 1. An example of the systematic survey design with random placement used for 8 line-transect surveys conducted in the upstream stratum and 2 line-transect surveys conducted in the downstream stratum. The figure only shows one set of lines for each stratum, but the number of lines varied from 28 to 29 in the upstream stratum and there were 16 lines in both downstream surveys.

Figure 2. Satellite image of the St Lawrence River Estuary taken on the 29 August 2014, showing the water turbidity gradient from high turbidity in the upper estuary to clear water in the lower estuary and the Laurentian channel. The image comes from Rapid Response imagery, LANCE/NASA/GSFC/Earth Science Data and Information System (ESDIS),.

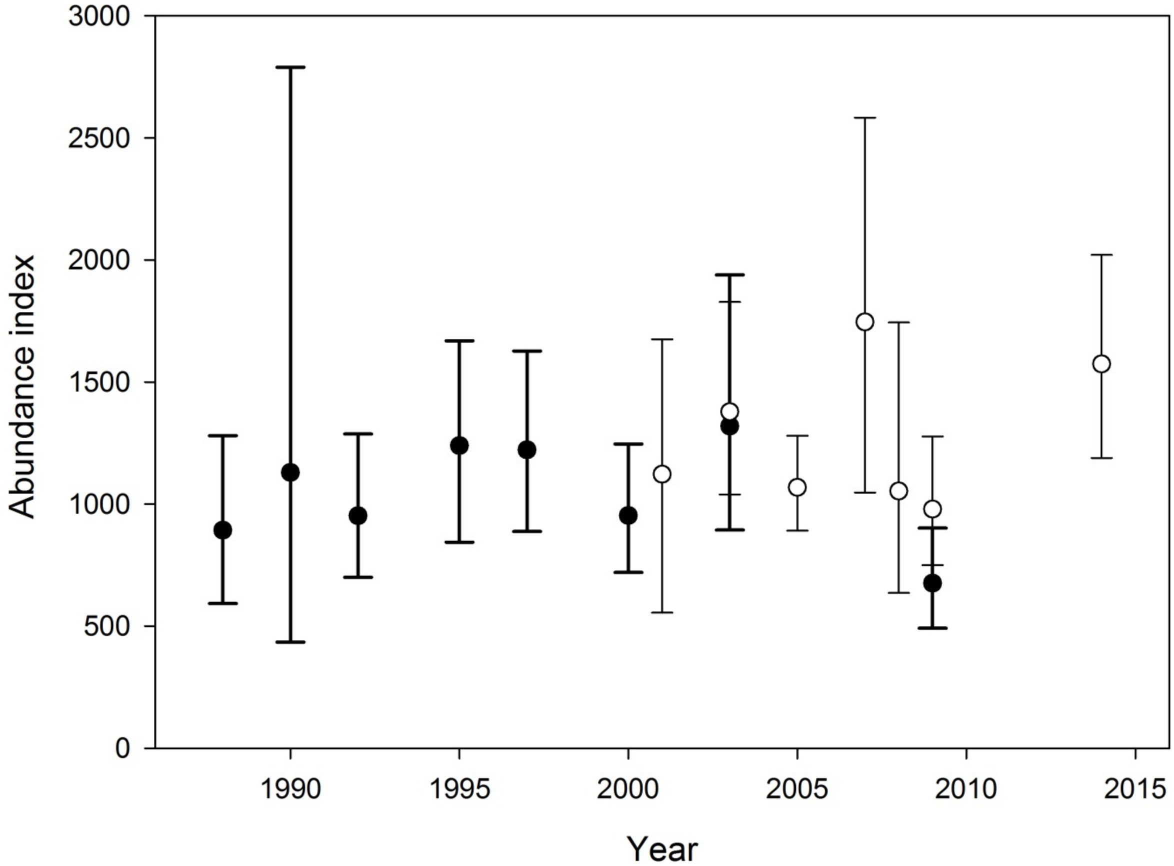

Figure 3. Abundance indices of St Lawrence Estuary beluga from eight photographic surveys (close circles) and from the yearly average of 36 visual line-transect surveys (open circles) from 1988 to 2014. The yearly average of visual line-transect survey were based on 1 survey in 2001, 5 in 2003, 14 in 2005, 1 in 2007, 1 in 2008, 6 in 2009 and 8 in 2014.

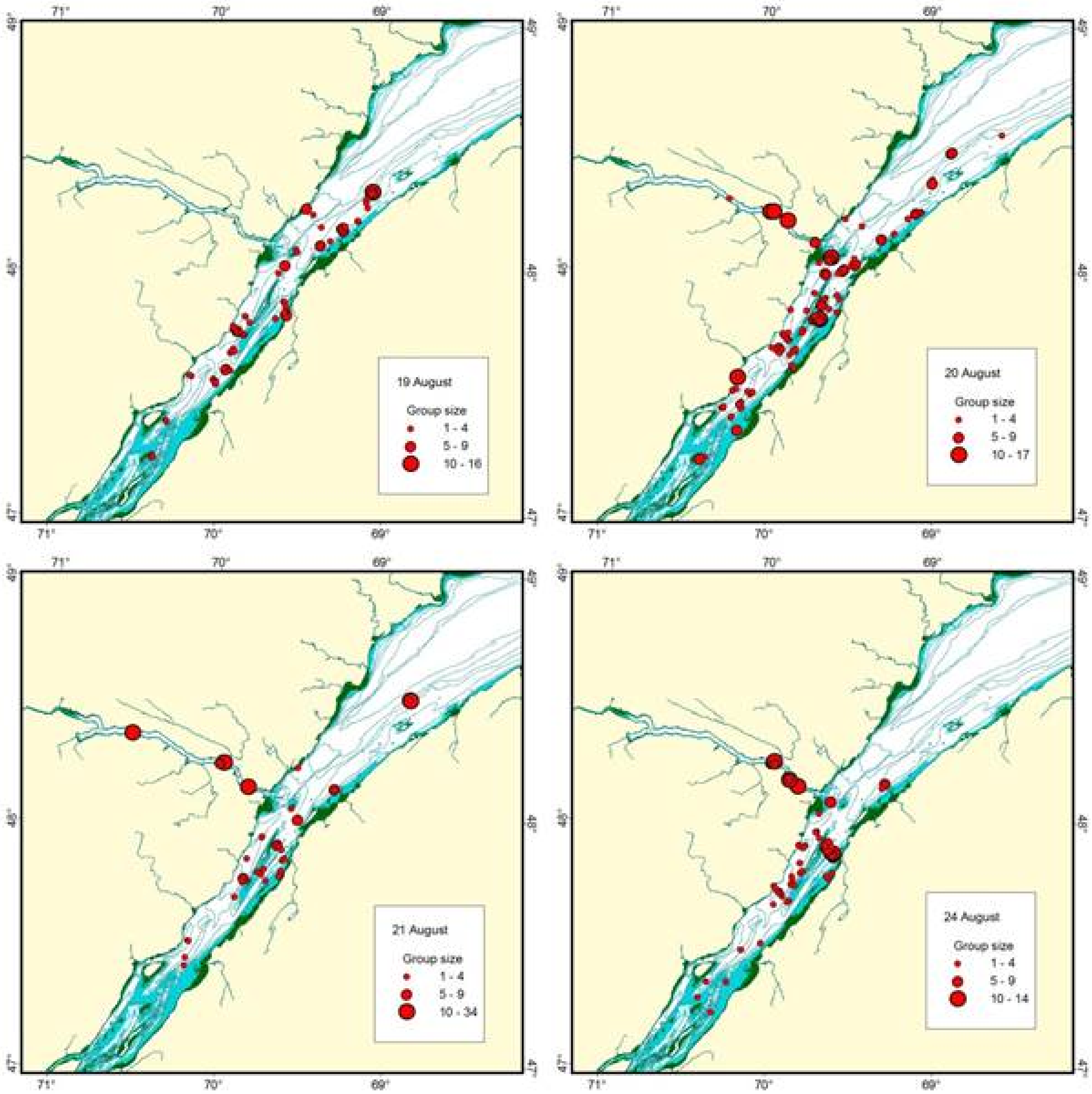

Figure 4. Locations and group sizes of beluga detected along transect lines flown in the St Lawrence Estuary and the Saguenay River from 19 August to 10 September 2014. The Saguenay River was not surveyed on the 19 August.

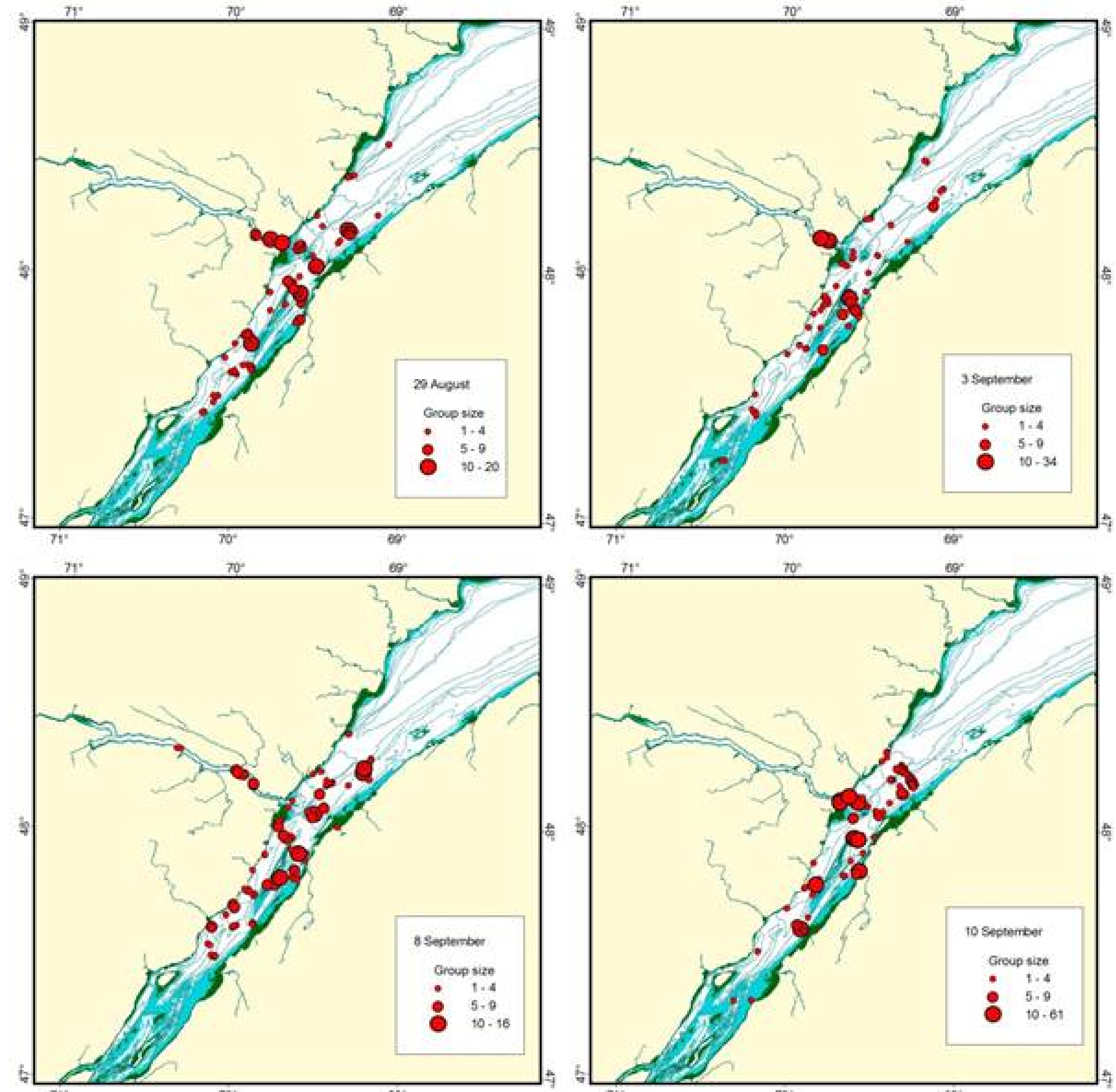

Figure 4 cont'd. Locations and group sizes of beluga detected along transect lines flown in the St Lawrence Estuary and the Saguenay River from 19 August to 10 September 2014.

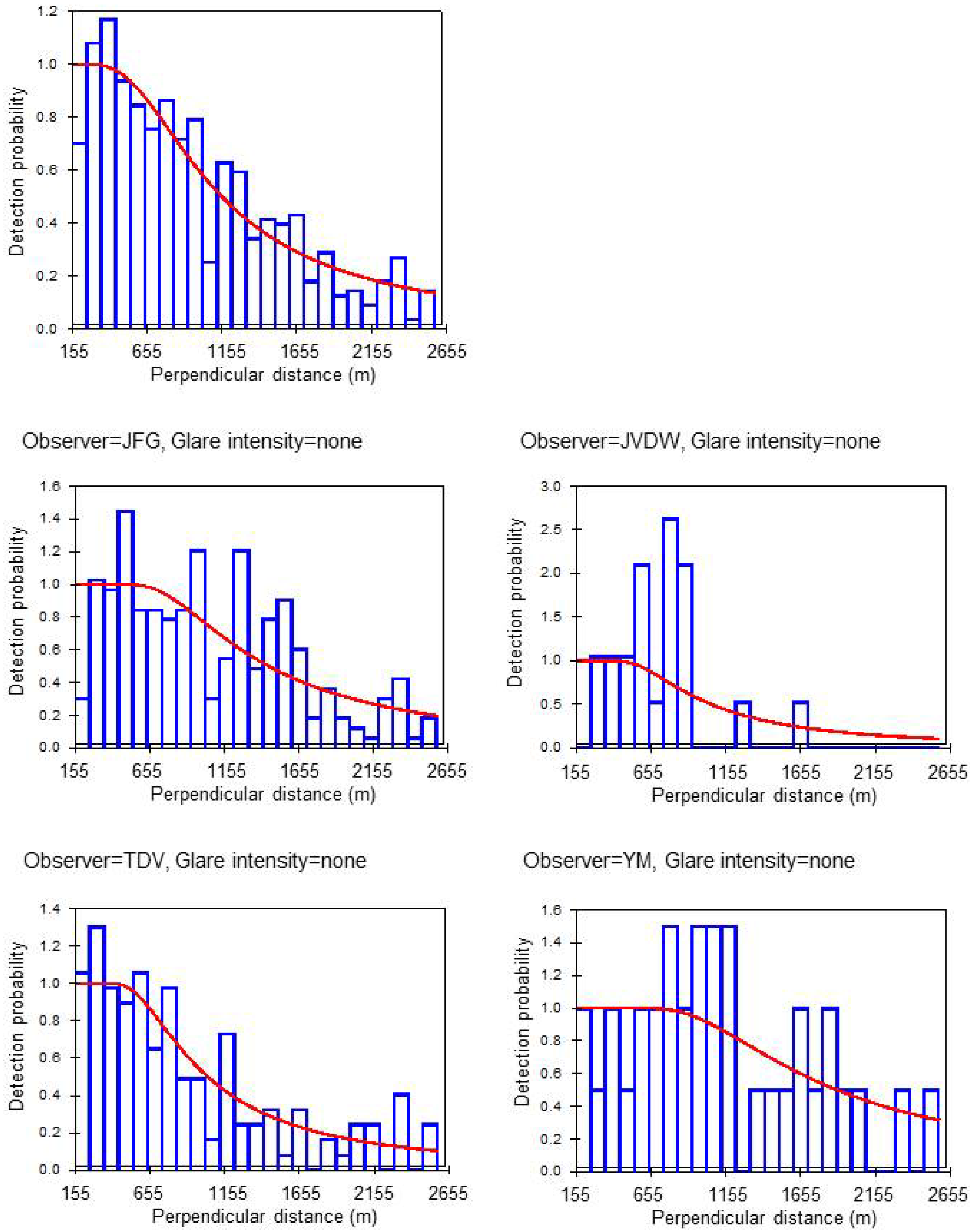

Figure 5. Distribution after truncations (155 m to 2578 m) of 688 perpendicular distances of groups of belugas detected during 8 line-transect surveys from 19 August to 10 September 2014. The first graph shows the overall fit and the following graphs show the 13 combinations of the observer and glare intensity covariates.

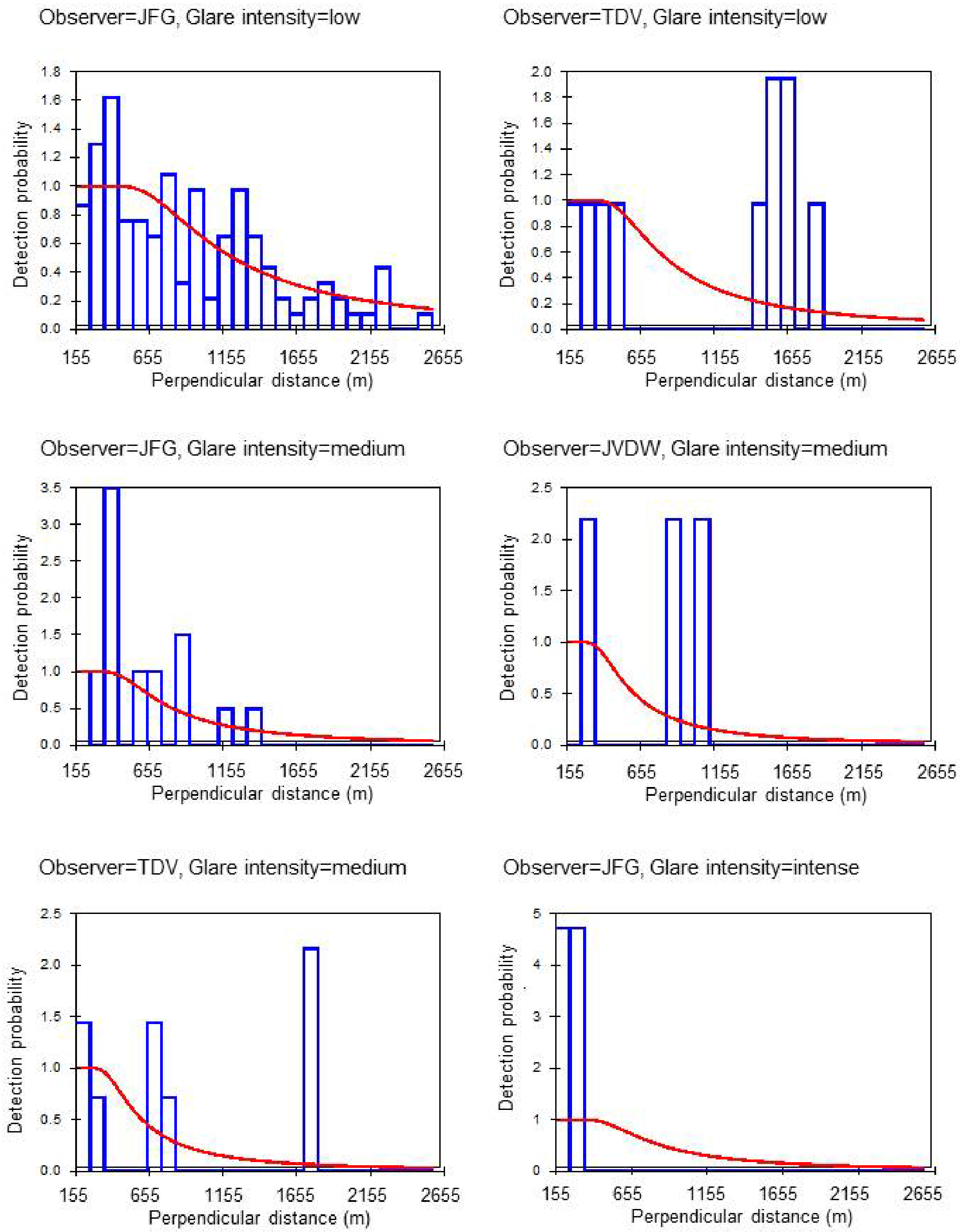

Figure 5 cont'd. Distribution after truncations (155 m to 2578 m) of 688 perpendicular distances of groups of belugas detected during 8 line-transect surveys from 19 August to 10 September 2014. The first graph shows the overall fit and the following graphs show the 13 combinations of the observer and glare intensity covariates

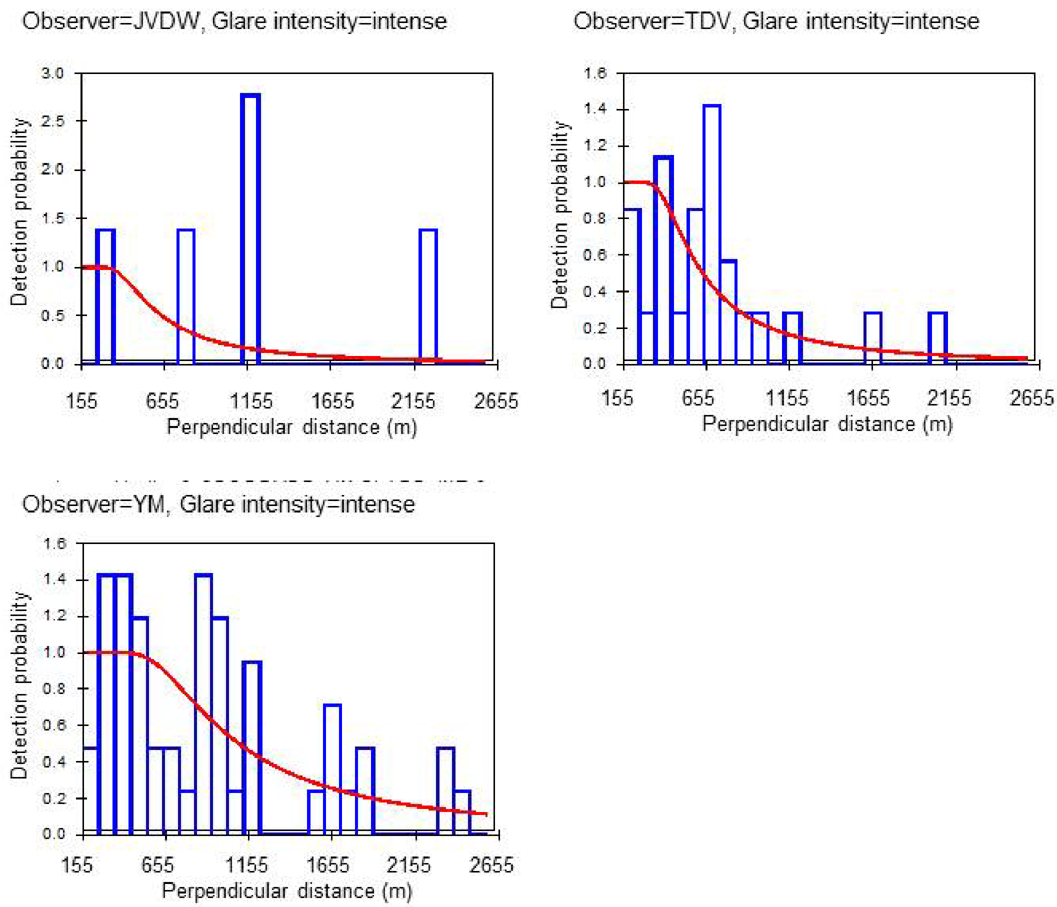

Figure 5 cont'd. Distribution after truncations (155 m to 2578 m) of 688 perpendicular distances of groups of belugas detected during 8 line-transect surveys from 19 August to 10 September 2014. The first graph shows the overall fit and the following graphs show the 13 combinations of the observer and glare intensity covariates.

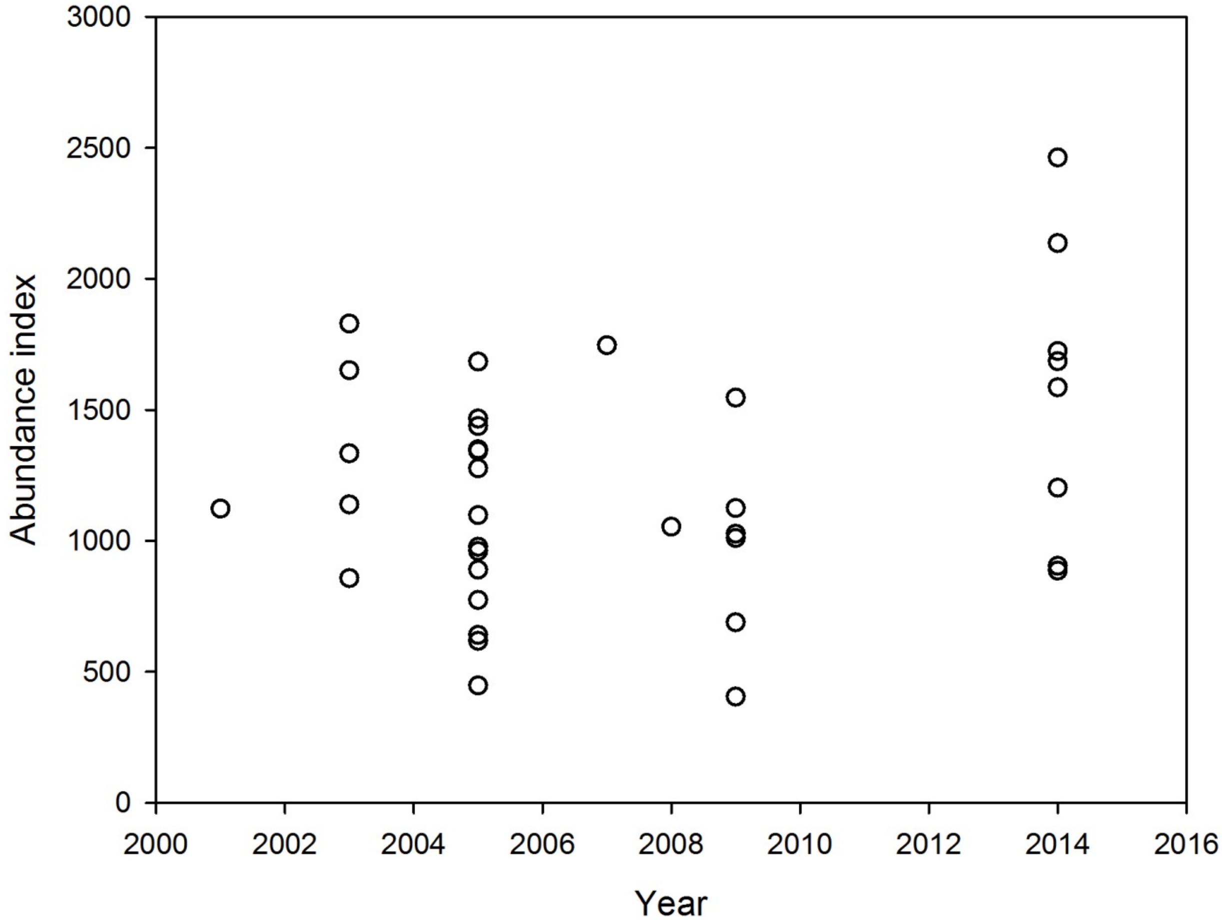

Figure 6. Regression of the 36 visual line-transect survey abundance indices corrected for availability in the Estuary (factor 2.09, Kingsley and Gauthier 2002) and adding the Saguenay count from 2001 to 2014. The regression showed a poor fit (adjusted $R^2 = 0.06$) and the slope was not significantly different from zero ($p = 0.08$, $df = 34$).

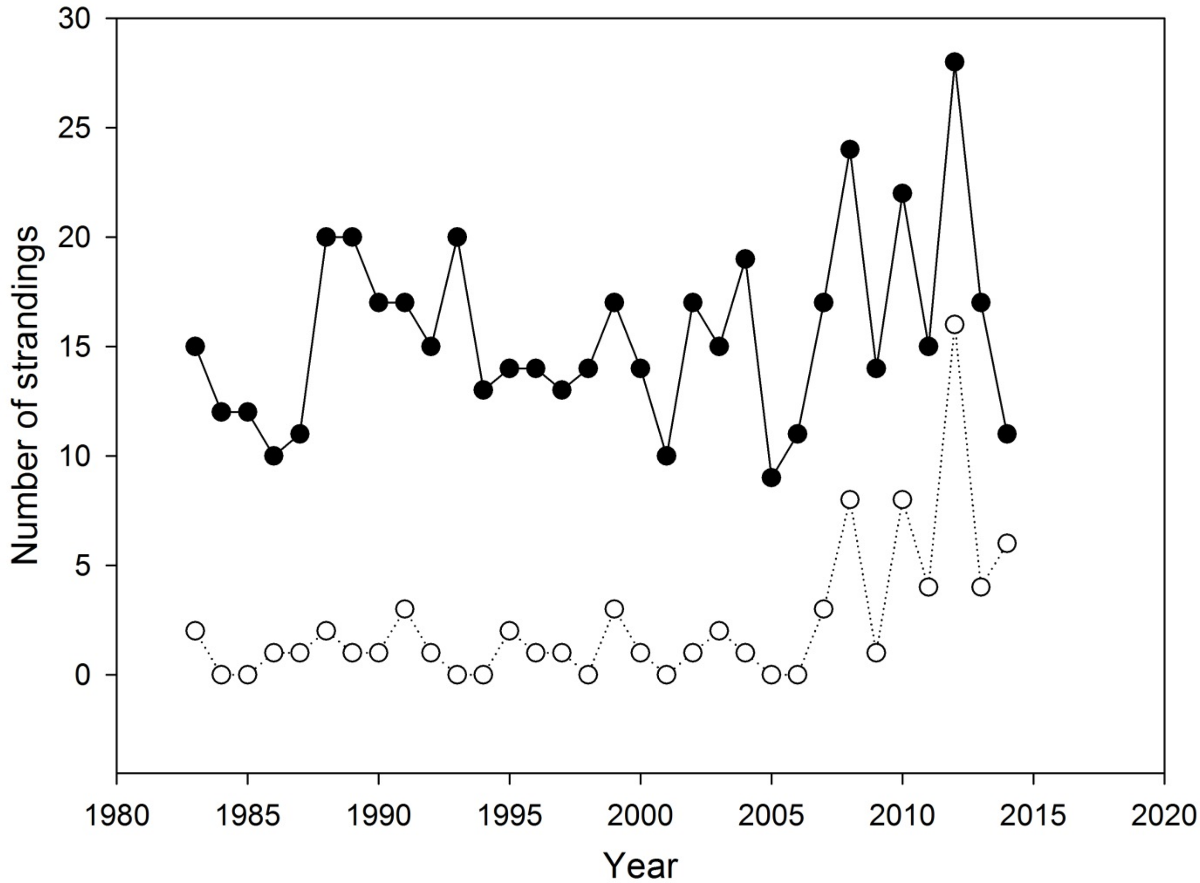

Figure 7. Total number of reported dead beluga (solid dots) and the number of reported dead young-of-the-year calves (open dots) in the Estuary and Gulf of St Lawrence from 1983 to 2014. The overall average is 15.5 for total number and 2.3 for young-of-the-year calves.