# Monitoring Beluga Harvests in the Mackenzie Delta and Near Paulatuk, NT, Canada: Harvest Efficiency and Trend, Size and Sex of Landed Whales, and Reproduction, 1970-2009

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# MONITORING BELUGA HARVESTS IN THE MACKENZIE DELTA AND NEAR PAULATUK, NT, CANADA: HARVEST EFFICIENCY AND TREND, SIZE AND SEX OF LANDED WHALES, AND REPRODUCTION, 1970-2009

by

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Standardized, hunter-based monitoring of the annual subsistence harvest of beluga whales in the Mackenzie River delta was initiated in 1980, and here we extend and expand analyses to include reproductive data and standardized sampling from 2000-2009. Harvest monitoring has continued annually without interruption in the three main harvesting areas of the Mackenzie River delta since 1980 (Shallow Bay, Kendall Island, and Kugmallit Bay, collectively ‘the Delta’), and near Paulatuk, NT, since 1989. The program has provided three decades of data on the timing of the harvest and biological data on whales landed, and four decades of data on the size and efficiency of the hunt. Standard length, gender, age, colour, and presence/absence of stomach contents have been recorded from 90-110 belugas each year since 1980. The number of belugas landed has declined by 28% since the 1970s, with the most recent (2000-2009) annual take averaging 97.4 belugas (SD 19.6). Annual struck-and-lost rates have also declined, and currently average 5.4% of the total harvest. There has not been a detectable change in the start and end times of the annual beluga harvest in the Delta, with the exception of Kugmallit Bay where there has been a tendency for the last whale of the whaling season to be landed up to 10 days later than in the 1980s ($p<0.05$). Hunters selected larger and older belugas, males outnumbering females 2.0 to 1 between 1980 and 1989; 3.0 to 1 between 1990 and 1999 and 3.6 to 1 between 2000 and 2009. Reconciled dentinal growth layer group (GLG) counts were used to calculate asymptotic lengths for 839 males and 225 females sampled over 16 seasons (1989, 1993-2008). Asymptotic lengths were 435.3 cm (SE 2.0) for males and 380.1 cm (SE 1.8) for females, males being 14.5% longer than females. Age classes younger than 10 GLG were essentially absent from harvests in both the Delta and Paulatuk. Belugas landed in Paulatuk were also mature adults, but were younger and shorter than Delta-harvested adult whales. Harvested belugas had mainly empty stomachs (Delta, 94%; Paulatuk, 87%). Reproductive tracts from 56 females sampled from the Delta harvests during 2000 to 2005 indicated a crude birth rate of 0.59 and a pregnancy rate of 0.32, equivalent to a three-year calving interval. All but one male (n=89) had testes mass, size and/or age indicative of sexual maturity. The harvest-based approach of this program has actively included Inuvialuit hunters as participants in the collection of biological and harvest data that are used for assessment of status of the Eastern Beaufort Sea beluga stock.

Key Words: Beaufort Sea beluga; Mackenzie Delta; Paulatuk; harvest; harvest efficiency; condition; pregnancy rate; GLG.

## RÉSUMÉ


Harwood, L.A., Kingsley, M.C.S., and Pokiak, F. 2015. Monitoring beluga harvests in the Mackenzie Delta and near Paulatuk, NT, Canada: harvest efficiency and trend, size and sex of landed whales, and reproduction, 1970-2009. Can. Manuscr. Rep. Fish. Aquat. Sci. 3059: vi + 32 p.

Le programme de surveillance par les chasseurs de la récolte de subsistance annuelle de bélugas dans le delta du fleuve Mackenzie a été lancé en 1980. Dans le présent document, nous allons étendre l'analyse en y ajoutant des données de reproduction et un échantillonnage normalisé pour la période de 2000 à 2009. Le processus de surveillance de la récolte s'est poursuivi sans interruption sur une base annuelle dans les trois principales zones de récolte du delta du fleuve Mackenzie depuis 1980 (baie Shallow, île Kendall, et baie Kugmallit), et près de Paulatuk, dans les Territoires du Nord-Ouest, depuis 1989. Ce programme a fourni, pendant trois décennies, des données sur les périodes de récolte et des données biologiques sur les baleines débarquées, de même que, pendant quatre décennies, des données sur l'ampleur et l'efficacité de la chasse. La longueur standard, le sexe, l'âge, la couleur, et la présence ou l'absence des contenus stomacaux des baleines débarquées ont été enregistrés dans le cas de 90 à 110 bélugas par année depuis 1980. Le nombre de bélugas débarqués a diminué de 28 % depuis les années 1970. Le plus récent relevé (2000 à 2009) correspond à une capture moyenne annuelle de 97,4 bélugas (écart-type de 19,6). Les taux annuels d'abattage et de perte ont également diminué (moyenne de 5,4 % de la récolte totale). Il n'y a pas eu de changement détectable dans les périodes de début et de fin de la récolte annuelle de bélugas dans le delta, sauf pour la baie Kugmallit, où l'on a remarqué une tendance indiquant que le débarquement de la dernière baleine de la saison de chasse s'est produit jusqu'à dix jours plus tard que dans les années 1980 ($p < 0,05$). Les chasseurs ont choisi des bélugas plus gros et plus âgés. Le nombre de mâles a dépassé le nombre de femelles dans une mesure de 2,0 contre 1 entre 1980 et 1989, de 3,0 contre 1 entre 1990 et 1999, et de 3,6 contre 1 entre 2000 et 2009. Les longueurs asymptotiques ont été calculées au moyen des dénombrements de GCA à partir des dents de 839 mâles et de 225 femelles échantillonnés au cours de 16 saisons (1989, 1993-2008). Ces longueurs asymptotiques étaient de 435,3 cm (ET de 2,0) chez les mâles et de 380,1 cm (ET de 1,8) chez les femelles. Les mâles étaient plus longs que les femelles dans une mesure de 14,5 %. Les classes d'âge plus jeunes que dix groupes de couches d'accroissement (GCA) étaient pour ainsi dire absentes des récoltes du delta et de Paulatuk. Les bélugas adultes débarqués par les chasseurs de Paulatuk étaient plus jeunes et moins longs que ceux capturés dans le delta. Les bélugas capturés avaient essentiellement l'estomac vide (94 % pour le delta et 87 % pour Paulatuk). Entre 2005 et 2008, l'échantillonnage du système reproducteur de 56 femelles a indiqué un taux de natalité brute de 0,59 % et un taux de gestation de 0,32, ce qui correspond à une période de mise bas de trois ans. Tous les mâles sauf un (n=89) possédaient une masse testiculaire, une taille ou un âge indiquant la maturité sexuelle. L'approche fondée sur les récoltes de ce programme a inclus les chasseurs inuvialuits à titre de participants à la collecte des données biologiques et des données sur les récoltes qui servent à l'évaluation de l'état des stocks de bélugas dans la mer de Beaufort.


Mots-clés: Bélugas de la mer de Beaufort; delta du fleuve Mackenzie; Paulatuk; récolte; efficacité de la récolte; condition; taux de gestation; CGA.

## INTRODUCTION

The Eastern Beaufort Sea stock of beluga whales (*Delphinapterus leucas*) winters in the Bering Sea, and each spring migrates along the north coast of Alaska to known summering areas in the Mackenzie Estuary, the offshore Beaufort Sea, and Amundsen Gulf (Fig. 1) (Fraker 1979; Richard et al. 2001). This stock of belugas, shared with Alaska and Russia, is the second largest in Canada, and has been assessed as stable or increasing (DFO 2000). Hill and DeMaster (1999) estimated stock size as 39,258 (CV=0.229), based on a correction of aerial survey data from late July, 1992 (Harwood et al. 1996). Harwood and Kingsley (2013) documented an increased number of surfaced beluga in the offshore Beaufort Sea in late August of the 2000s, compared with the 1980s. The most plausible explanation for this increase is that beluga distribution has changed in response to changes in prey . There has also been an emerging pattern of declining growth rates in belugas of the Beaufort Sea between 1989-2008 (Harwood et al. 2014), likely underpinned by shifts in their prey base (Harwood et al. in press). There is also recent evidence from West Greenland of changes in beluga distribution in relation to changes in sea-ice cover (Heide-Jørgensen et al. 2010).

The Inuvialuit of the western Arctic have a long history of hunting belugas for food (McGhee 1988; Day 2002; Harwood and Smith 2002), however there is little information available about the size of beluga harvests prior to European contact (ca. 1888), during the commercial whaling period (1888-1907) (Bockstoce 1986), and up until the 1950s. The first written records about Inuvialuit harvests of Beaufort Sea belugas in Canada appear in Royal Canadian Mounted Police (RCMP) and Northwest Territories game officer reports made in 1954, which reported that 210 belugas were landed (Smith and Taylor 1977). Smith and Taylor (1977) reported an average annual harvest of 120 belugas between 1960-1963, while Strong (1989) reported an average annual harvest of 146 belugas between 1960-1966. Most sources indicate beluga harvests are lower now than they were in the 1970s and earlier (Table 1; Nuligak 1966; Smith and Taylor 1977; McGhee 1988; Strong 1989; Friesen and Arnold 1995; Day 2002). Harvests from 1970 to 1999 were assessed as sustainable (Innes 1996; Cosens et al. 1998; DFO 2000).

Present-day harvesters from the communities of Inuvik, Aklavik, and Tuktoyaktuk travel by small boat to seasonal whaling camps clustered on the coast of the Mackenzie River delta (hereafter called ‘the Delta’), mainly on the shores of Kugmallit Bay, Kendall Island, and Shallow Bay (Fig. 2). Beluga hunting occurs mainly during a four-week interval in July, when belugas aggregate in the shallow estuarine waters of the Mackenzie River (Fraker et al. 1979; Norton and Harwood 1986;

Harwood et al. 2002). Harvesters from Paulatuk, Ulukhaktok (formerly Holman) and Sachs Harbour (Fig. 1) also hunt belugas opportunistically near their communities, usually in late July or early August (Norton and Harwood 1985; Richard et al. 2001).

Here we extend by a decade, the existing series of hunter-based beluga whale monitoring from the 1970s through 1990s (Fraker 1977; Fraker 1978; Fraker and Fraker 1979; Hunt 1979; Fraker et al. 1979; Fraker 1980; Norton Fraker 1983; Fraker and Fraker 1981; Strong 1989, 1990; Weaver 1991; Harwood et al. 2002). Collectively, the annual monitoring programs summarized here have produced the longest and largest database on beluga harvesting in Canada, spanning four decades.

Standardized monitoring has continued with the same protocols for nearly three decades, with the same two main objectives. The first objective is to document the size, efficiency, and timing of the Beaufort/Mackenzie beluga subsistence harvest. This is important because documenting the size and efficiency of the harvest contributes information for stock management and conservation (Adams et al. 1993; Bell and Harwood 2012; FJMC 2013). Long term records of the timing of the harvest serve as a general indicator of changes in spatial and temporal patterns of beluga distribution and possibly the factors influencing these changes. Such information is relevant for harvesters, regulators and for industry. In the Delta, this information has already been used to establish terms and conditions for industry activities, to ensure undisturbed beluga whale access to the Mackenzie Estuary in spring and no subsequent disturbance to belugas (or to subsistence hunters) during the summer aggregation period.

The second objective was to compile hunter-collected data from beluga harvests in the Delta and in Paulatuk (i.e., gender, length, age, colour, reproductive status, and presence/absence of stomach contents of landed whales). When collected in a consistent manner over the long term, these data can be useful indices to monitor and evaluate changes relevant to stock trend, and in some cases, provide clues as to the factors causing change. In 2000-2005, monitoring also included determination of pregnancy rate and crude birth rate in a sample of 56 mature females, and maturity in 89 males.

# METHODS

## FIELD SAMPLING

Since 1972, hunters at the seasonal whaling camps have provided data on the number of whales struck, landed and lost, and on the size and timing of the harvest. Starting in 1980, the collection of biological data from landed whales was standardized, and has continued throughout the monitoring period with the same approach. From 1981-2009, at least six beluga hunters were hired as seasonal monitors for the duration of the annual whaling season. The “beluga monitors” received pre-season training either individually or as a group, from the head monitor and the project biologist. Then, throughout the whaling season, they documented their own and near-neighbours’ harvests by collecting hunt related information and biological data. Since 1981, beluga monitors have documented catches from each of the six main whaling areas within the Delta and, since 1989, beluga hunts in the Paulatuk area (Fig. 2).

As soon as possible after each hunt, beluga monitors interviewed each hunt captain and recorded hunt related information (e.g., the number of whales that were struck, landed, and lost, the hunting date, weather and ice observations, and a confidential identifier for each hunter participating in the hunt). Local monitors also examined as many landed whales as possible. They determined the sex of the landed whale, recorded skin colour as one of four categories (dark gray, gray, gray-white, white), and used a cloth tape measure to record standard length and fluke width (American Society of Mammalogists 1961). The monitors also checked for and recorded presence/absence of lactation, collected lower jaws for later age estimation, and the presence/absence of stomach contents, including identification of contents if possible, for each landed whale.

In addition to the data collected from the regular monitor’s work, in 2000-2005, reproductive organs from belugas harvested in the Kendall Island and Kugmallit Bay hunting areas were collected (Fig. 2). This included intact, whole uteri and ovaries from 56 landed females and paired testis from 89 males. All reproductive material was labelled and fixed in 10% buffered formalin in the field, then shipped to the laboratory in Inuvik where they remained in formalin, indoors, for up to four weeks. Samples were drained of formalin just prior to shipping, and then were shipped without freezing to laboratories in Winnipeg, MB and Abbotsford, BC.

## LABORATORY ANALYSIS

In the laboratory, lower jaws were boiled gently to allow extraction of two mandibular teeth, usually the second and fifth from the left side, for age estimation (Wainwright and Walker 1988; Stewart 2012). A growth layer group (GLG) consists of two adjacent growth layers, one light and one dark (Perrin and Myrick 1980). There is disagreement in the literature whether one or two GLGs are deposited annually (Brodie 1982; Goren et al. 1987; Stewart et al. 2006; Brodie et al. 2013). Age determination can sometimes be further confounded by the loss of GLGs through normal tooth wear, especially in older animals (Suydam 2009). Here we interpret one GLG as the equivalent of one year of 'age'.

Extracted teeth were embedded in clear casting resin and longitudinally thin-sectioned at roughly 3 mm intervals using a diamond wafering blade. Sections were stored wet in 70% ethanol (Wainwright and Walker 1988), in vials labeled with the specimen number and tooth number. The most suitable section for use in age estimations was selected from available material and labeled appropriately. The tooth section was viewed wet, under transmitted light, using a variable power Nikon dissecting microscope. Each section was read three to five times, and the numbers of GLGs present in the dentine and cementum was recorded.

Upon arrival in the laboratory, the reproductive tracts were kept cool and formalin refreshed until the time of analysis. The ovaries were weighed (formalin fixed weight) then cross-sectioned at approximately 3 mm intervals. Corpora with a diameter in excess of 5 mm were measured for height and width (mm), and classified according to the proportion of luteal material present: corpus luteum (CL) (100% yellow, 0% white), regressing corpus (75% yellow/25% white, 50% yellow/50% white, and 25% yellow/75% white) and corpus albicans (CA) (0% yellow, 100% white). Uteri were measured for horn length (cm) and horn diameter (cm). Horns were then dissected and visually inspected for signs of pregnancy, including nidation chambers, foetuses, changes of vascularisation, and changes in the endothelium structure.

Each testis was weighed (fresh weight, g) and then formalin fixed. As the testis mass greatly exceeded the mass of mature testis (see Stewart and Stewart 1989), no formalin fixed weights were taken. Tissues gain 1-5% of fresh weight during formalin fixation. This increment would not alter the interpretation of maturity for these animals.

## DATA ANALYSIS

We merged the harvest information collected at the three main beluga hunting areas in the Mackenzie Delta into a single "Delta" dataset, for comparison with harvest data from belugas landed in Paulatuk, which is geographically separate (Fig. 2).

### *Harvest Level, Efficiency, and Timing*

We obtained the numbers of whales for each year from 2000-2009 which were landed, and struck but lost, through direct observation, and post-hunt interviews with harvesters and monitors participating in the Fisheries Joint Management Committee's (FJMC) beluga monitoring program. We used published sources to calculate the mean decadal harvest and sex ratio of the harvest for 1970-1979 (Smith and Taylor 1977; Fraker 1980), 1980-1989 (Strong,1990; Weaver 1991), 1990-1999 (Harwood et al. 2002).

From the entire database, and for each year, we calculated the days of the year when 5%, 50%, and 95% of the total harvest had been landed in the three Delta hunting areas (Shallow Bay, Kendall Island, and Kugmallit Bay) hunting areas, in order to standardize and examine the start, midpoint, and end dates of their respective harvests. To evaluate temporal trends for the Kugmallit Bay and Kendall Island areas, we used Mann-Kendall trend tests (2-tailed) in XLStat-TIME. Missing data and small sample sizes precluded running trend tests on the standardized harvest dates from Shallow Bay and Paulatuk.

### *Gender, Age, and Size of Landed Whales*

The proportions of landed male and female belugas overall, and by each of four colour categories, were tallied for the Delta and Paulatuk hunting areas, as were the percentages of beluga stomachs that were empty or not empty at the time of butchering. Estimated ages for 1064 beluga sampled over 16 seasons (1989, 1993-2008) were obtained from reconciled counts of GLGs visible in longitudinal tooth sections (see Harwood et al. 2014). Box-whisker plots were used to examine the mean, median, and range of GLGs of the landed whales, by sex and year. Temporal trends in the age structure of the landed catch were examined using Mann-Kendall trend tests in XLStat TIME. For the Delta and Paulatuk harvest locations, we constructed cumulative frequency distributions of standard lengths (cm) and age (GLG).

Asymptotic size-at-age curves were fitted to the von Bertalanffy model, parameterised in terms of standard length and growth rate at age zero, and asymptotic length calculated for each sex, as follows:

$$l(t) = l(\infty)\left(1-\left(1-\frac{l(0)}{l(\infty)}\right)\exp\left(\frac{-kt}{l(\infty)-l(0)}\right)\right)$$

where the observed length $l_i$ was assumed related to the predicted length $\hat{l}_i$ by:

$$l_i = \hat{l}_i + \varepsilon_i$$

and the scatter terms $\varepsilon_i$ were considered to have independent normal distributions with zero mean and variance:

$$\sigma_i^2 = a^2 \cdot l_\infty^2 \cdot \left(\frac{\hat{l}_i}{l_\infty}\right)^{2b} .$$

This defines a power-law relationship between predicted length and the scatter about the fitted relationship, with the parameter *a* specifying the coefficient of variation at asymptotic length and the parameter *b* specifying the relationship between the CV and length. In particular, *b*=0 specifies a standard deviation about the line, and *b*=1 a coefficient of variation, that is independent of length.

To examine the ages when female belugas were reproductively active, we compared the number of CAs and CLs vs. GLGs using a scatterplot, for females for which we had been able to obtain ovaries. The reproductive status of the sampled females was examined on a scatterplot of standard length vs. GLG, distinguishing between females with first term foetuses, full term foetuses and females with no evidence of pregnancy or recent parturition. For adult males, testis weight and standard length, and testis weight and GLG, were compared using a scatterplot.

# RESULTS

## HARVEST LEVEL, EFFICIENCY, AND TIMING

The mean annual landed harvest from the Mackenzie Delta and Paulatuk harvesting areas (combined) was 133.7 (SD 26.0) during 1970-1979, 124.0 (SD 23.3) during 1980-1989, 111.0 (SD 19.0) during 1990-1999, and 97.4 (SD 19.6) during 2000-2009 (Table 1). The number of belugas struck and lost was lowest in the 2000s (5.4% of strikes), higher in the 1990s (averaged 11.2%) and highest in the 1970s (estimated 15.9%) and 1980s (averaged 17.7%; Table 1).

Of the landed catch in the Mackenzie Delta from 1980-2009, the majority (64.5%) came from Kugmallit Bay, 21% from the Kendall Island area, and 14.5% from Shallow Bay (Fig. 2). Overall, 89.2% of the catch was landed in July, with 2.6% in June, 8.2% in August, and 0.1% in September–October. The earliest known landed catch occurred on 20 June, and the latest on 3 October. Median harvest date in the Delta for 1980-2009 was July 16. All whales taken by Paulatuk harvesters (n=194 in total) were landed in July and August, most in the last 15 days of July (100% in the 1980s, 57% in the 1990s, and 87% in the 2000s).

The days of the year when 5%, 50%, and 95% of the harvest had been landed in the Delta, by year, are plotted for the three Delta hunting areas: Shallow Bay, Kugmallit Bay, and Kendall Island (Fig. 3). Mann-Kendall trend tests did not reveal any significant changes (p>0.05) in the timing of the start (5%) or median (50%) harvest dates for either the Kendall Island or the Kugmallit Bay areas, or for the end (95%) date for Kendall Island. However, the end date at Kugmallit Bay became progressively later in the season over time (Kendall's tau 0.309, p=0.020) (Fig. 3) ($R^2$=0.1793), eventually 10 days later in the season in the 2000s compared with the 1970s.

## GENDER, AGE, AND SIZE OF LANDED WHALES

Sex was determined for 95.2% (3026/3179) of the belugas landed in the Delta and Paulatuk harvests between 1980 and 2009. The harvest has been, and continues to be, strongly biased toward males over the past three decades: in 1980-1989 males outnumbered females in the harvest 2.0 to 1.0; in 1990-1999, 3.0 to 1.0 (Harwood et al. 2002), and in 2000-2009, 3.6 to 1.0. Trend tests revealed that this diminishing proportion of harvested females was statistically significant over the time series (Kendall's tau=0.281, p=0.033). Over the study period, the proportion of females landed ranged from a low of 19.6% in Paulatuk, to 32.4% in the Kendall Island area (Fig. 4).

Ages estimated by two reconciled readers were included in the analyses, producing a dataset of 1064 GLG readings (225 females, 839 males). Overall, females in the sample ranged from 10-63 GLGs, and males from 8-67 GLGs. The mean, median and range of GLG values for both sexes were variable over the time series (Fig. 5). There was no statistical trend toward increasing or decreasing GLGs over the 1989-2008 time series for Delta females (Kendall's tau=0.007, p=0.892), and only a slight trend of decreasing GLGs in Delta males (Kendall's tau=-0.101, p<0.05, n=668) (Fig. 5), attributed to fewer older whales being landed in the 2004-2008 period (Fig. 5). There were too few whales from the Paulatuk sample to examine temporal trends in GLGs for either sex.

Delta females were on average older than males (Fig. 6), with median GLG counts of 34 and 28, respectively. The maximum difference in cumulative proportion between males and females was 14.7% (p<0.01), this at 34 GLGs. Male belugas from Paulatuk were on average younger than Delta males (Fig. 6), with a median GLG count of 22; the maximum difference in cumulative proportion was 31.5% (p<0.001) at 20 GLGs.

Belugas of both sexes landed in Paulatuk were shorter than those taken in the Delta (Fig. 7). Median length for females was 356 cm at Paulatuk and 368 cm in the Delta; for males, 398.5 cm and 420 cm. The maximum difference in cumulative proportion was 22% (p>0.05) for females, at 360 cm length. For males, the maximum difference was 26% (p<0.001) for males, at 400 cm.

Both standard length and a colour-class assignment were available for a combined total of 994 landed belugas (Table 2). Overall, 78% of the whales were white (adults), 21% were gray or gray-white (maturing), and <1% were dark gray (neonates or yearlings).

Both an accepted GLG estimate and colour class were available for 153 females in two of the colour classes (gray and white), and for 611 males in the gray, gray-white, and white colour classes. For both males and females, 75% of the gray animals were in the 18-26 GLG range. For females, 75% of the white animals were in the 25-44 GLG range, and for males, 75% of the white animals were slightly younger, in the 23-38 GLG range.

Reconciled dentinal growth layer group (GLG) counts were used to calculate asymptotic lengths for 839 males and 225 females sampled over 16 seasons (1989, 1993-2008) (Table 3). Asymptotic lengths were 435.3 cm (SE 2.0) for males and 380.1 cm (SE 1.8) for females, males being 14.5% longer than females (Fig. 8). The model estimated length at zero age (cm) as 154.9 cm (SE 14.9), and growth at age zero (cm/GLG) as 30.2 cm (SE 2.8).

Of 634 beluga stomachs that were examined, in the Delta harvests, 94.5% were empty. At Paulatuk, 86.5% of 89 stomachs examined were empty.

**REPRODUCTION**

We collected intact, whole uteri and ovaries from 56 landed females between 2000 and 2005. Of these, 29 were from the Kendall Island area, and 27 were from Kugmallit Bay. All females in the sample were sexually mature, with 53% having corpora lutea, and 100% having regressing corpora lutea and corpora albicantia (Fig. 9). These mature females ranged in age from 10 to 58 GLGs (n=51), and in size from 323 cm (41 GLG) to 439 cm (49 GLG). CAs and CLs were most common in females aged 20-40 GLG (Fig. 9). The numbers of visible corpora appeared to decrease in later years of life, although the sample size of females older than 40 GLG was small. The same pattern was apparent in with CLs, also lower in females over 40 GLG.

The two youngest females in the sample (10 and 17 GLGs) were neither pregnant nor lactating, but ovarian corpora were present in both (Fig. 8). The two oldest females in the sample (56 and 58 GLGs) were both lactating. Twenty-three of 56 females (41%) were lactating, 8 of these had also recently ovulated. Twenty-three of 56 (41%) had no evidence of lactation or ovulation, 18 (32%) carried a first-term foetus (i.e. conceived that spring), and 15 (27%) carried a full-term foetus or were postpartum (Fig. 10). The pregnancy rate for females with first-term foetuses was 0.32, indicative of a calving interval of three years. Crude birth rate (percent of sexually mature females that were pregnant) was 0.59.

Fourteen first-term foetuses were examined in the laboratory; their mean wet weight was 109.7 g (SD 63.8, range: 14-219 g); mean cranial to caudal length was 15.9 cm (SD 5.0; range 8.5-22 cm); and mean thoracic diameter was 3.1 cm (SD 0.8, range 1.8-4.5 cm). These were collected from females landed at Kendall Island (n=7) and Kugmallit Bay (n=7) between 9 and 23 July, a span of 14 days.

All but one of the 89 male belugas sampled were mature, based on testis mass, body size, and/or age (Fig. 11). Sexual maturation is attained when sperm production occurs, usually in a testis that weighs >200 g (Sergeant 1973). Testis mass increases from 50 g to 300 g at body lengths between 290-330 cm, and at age 7-9 y (see Stewart and Stewart 1989). Therefore, testis mass, age, and/or body length for all males sampled exceeded the minimal criteria for designation as mature, except for one.

## DISCUSSION

### HARVEST LEVEL, EFFICIENCY, AND TIMING

The Eastern Beaufort Sea (EBS) beluga stock has a wide geographic range, much of which is located far from hunting areas in either Canada or Alaska (Harwood et al. 1996; DFO 2000; Richard et al. 2001). Although we do not have absolute abundance estimates for the EBS beluga stock, the available data continue to suggest that the catch is small in comparison to the size of the stock (DFO 2000; this study).

Since the 1970s, the size of the beluga subsistence harvest has declined by 28%. Waning interest and dependence on traditional hunting pursuits, along with the high cost of hunting equipment and fuel, are likely the main contributing factors to the harvest declining over time (Day 2002; Harwood et al. 2002). Local sea ice conditions, particularly the timing of breakup of the fast ice in spring, are affected by the changing climate (Barber et al. 2008). This in turn influences the timing of entry and the distribution of belugas in the various bays of the Mackenzie Estuary (Hornby et al. 2014), and their availability to harvesters (Norton and Harwood 1986). Between the 1970s and 2000s, the annual beluga hunting season in Kugmallit Bay has lengthened, on average, by about 10 days. Hunters report that environmental factors, particularly the apparent increase in frequency and intensity of winds, are becoming increasingly challenging for boating and hunting. This is the most common local explanation for the extended Kugmallit Bay hunting season, where the number of weather days suitable for whale hunting on the ocean from small boats are fewer and farther between (F. Pokiak, personal observation).

Loss rates have declined from 15.9% in the 1970s to 5.4% in the 2000s. This trend in the harvest data reflects an improvement in hunting efficiency, with decreased loss rates since the 1970s (Table 1). This was fostered through the establishment of local hunting by-laws, where hunters are required to first secure their belugas by ‘harpooning first' before shooting (FJMC 2013). This measure, one of the main recommendations in the Beaufort Sea Beluga Management Plan (FJMC 2013), appears to have had a positive influence on reducing the number of whales struck-but-lost (unable to retrieve). In addition to the establishment of local hunting rules, there has also been funding made available for harvesters to monitor their catches, to work closely with biologists on field projects in the whaling camps, to hold local user meetings to discuss study results and stock trends, and to ratify hunting by-laws (FJMC 2013). All of these aspects of co-management have fostered stock stewardship.

There are several benefits of the on-site approach used in this study, where the harvest monitors personally observe and count each and all whales landed, for the entire six week monitoring period. The monitor interviews each hunter, and this essentially eliminates the potential for double counting of landed whales by multiple hunters on the same hunt. We believe the data are representative as they were collected immediately after the hunt and in person by the monitor who is a peer and a fellow beluga hunter.

**GENDER, AGE, AND SIZE OF LANDED WHALES**

Hunters selected larger and older belugas, males outnumbering females 2.0 to 1 between 1980 and 1989, 3.0 to 1 between 1990 and 1999, and 3.6 to 1 between 2000 and 2009. More than 99% of the whales taken in this harvest were older than 10 GLGs in 1993-2009. In particular, Delta hunters have continued to select adult male belugas, as has been the case in the past (Strong 1989; Weaver 1991; Harwood et al. 2002). The difference in cumulative proportion of males and females in the harvest, between 20 and 40 GLGs, most likely reflects the local hunting practice of not taking adult females with calves.

Hunters from Paulatuk also direct their harvests to adult male beluga, although somewhat younger males are landed than in the Delta. Belugas landed in Paulatuk do not have a different size-at-age relationship from those taken in the Delta (Harwood et al. 2014). Also, information from satellite tracking (Richard et al. 2001) showed the younger adult males and the adult females (tagged in the Delta in late July) spent the post-estuary period in Amundsen Gulf. It is there where they would be available to beluga hunters from Paulatuk (Richard et al. 2001), harvested mainly from Brown’s Harbour on the Parry Peninsula. The largest males tagged in the Delta ultimately travelled to distant summer feeding areas (e.g., Viscount Melville Sound), and did not make any migrations into Amundsen Gulf or to areas where they would be accessible to hunters from Paulatuk.

While it is usually possible to discriminate stocks of belugas on the basis of molecular genetics (O'Corry-Crowe et al. 1997; de March and Postma 2003), it can also be possible to discriminate putative stocks using size-at-age relationships given that both environment and genotype are reflected in growth rates (Stewart 1994). For Beaufort Sea beluga, asymptotic sizes calculated by Luque and Ferguson (2006) and in this study, were essentially equivalent to those calculated for the Chukchi Sea (Suydam 2009) and Kotzebue Sound (Burns and Seaman 1986) stocks in Alaska. All of these stocks share a common wintering area, and collectively make up the Bering Sea beluga population.

Asymptotic sizes calculated for Beaufort Sea beluga were also similar to those for at least two stocks in the eastern Canadian Arctic: Jones Sound and Cumberland Sound (Stewart 1994). This makes differentiation on the basis of asymptotic lengths impossible. However, individuals of each of these northern stocks were collectively and on average longer and thus distinguishable from more southerly stocks in east and west Hudson Bay (Doidge 1990; Stewart 1994) and the St. Lawrence Estuary (Kingsley 1996). Belugas from west Greenland were the longest on average (Heide-Jørgensen and Teilmann 1994). Size-at-age differences among stocks may be a reflection of the availability of food during winter (Sergeant and Brodie 1969), although this remains largely untested (Stewart 1994).

## REPRODUCTION

Since the beluga harvest is strongly biased toward males and older animals, obtaining data to establish age of maturity, or assess temporal changes in reproductive rates, is constrained by the paucity of adult females that can be sampled in any given season. Age-specific mortality and reproductive rates are not available for this stock, and because of hunter selection for adult males, it is not likely that newborn and juvenile mortality rates will ever be available (DFO 2000). From a limited sample of reproductive tracts obtained from 56 mature females between 2000 and 2005, we were able to calculate a pregnancy rate of 0.32. This indicates a three-year calving interval, which agrees well with rates published for other stocks (DFO 2000), and with those for two beluga stocks that share a common a overwintering area with Beaufort Sea beluga: 0.34 for Kotzebue beluga (Burns and Seaman 1986) and 0.41 for Eastern Chukchi beluga (Suydam 2009). We also calculated a crude pregnancy rate of 0.59 for Beaufort Sea beluga, which also agrees with the 0.56 rate calculated for eastern Chukchi beluga calculated by Suydam (2009). All but one of the males that were sampled were mature.

**OUTLOOK**

There is no compelling evidence from the results presented here or previously that the Beaufort Sea beluga stock has increased or decreased in size over the monitoring period (DFO 2000; Harwood et al. 2002; Luque and Ferguson 2006; this study). This stock was last assessed in 1999 as stable or increasing (DFO 2000), and plans are in place for reassessment in 2015. Harwood and Kingsley (2013) documented an increase in the number of surfaced beluga in the offshore Beaufort Sea in late August of the 2000s, with the most plausible explanation for the increased whale counts being a change in beluga distribution relating to changes in their prey. There is recent evidence from West Greenland of changes in beluga distribution in relation to changes in sea-ice cover (Heide-Jørgensen et al. 2010). Monitoring also revealed a subtle but sustained decrease in the growth rate of these beluga over the past decade, which also suggests there may have been a prey shift (Harwood et al. 2014). Finally, a concurrent decline in the mercury concentrations in the liver of the harvested belugas in the last decade (Loseto et al. 2014) provides a third line of evidence implicating dietary shifts have occurred over the last decade. Although the proximate causes of these changes in beluga growth rates are unknown, they are likely mediated by a down trend in the availability of forage fish, especially Arctic cod (*Boreogadus saida*).

The harvest-based approach of this program has provided a means by which the Inuvialuit hunters have been able to actively participate in the collection of hunting and biological data, all of which are necessary for on-going assessment of the well-being of the Beaufort Sea beluga stock. Future studies, including continued harvest-based monitoring, coupled with diet studies using fatty acid and stable isotope analyses, would be prudent to determine feeding strategies and provide a quantitative assessment of the availability and condition of the resources used by belugas in the Beaufort Sea (e.g., Loseto et al. 2009). Such studies are now possible, given the well-established co-management approaches with DFO and the FJMC.

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Table 1. Decadal comparison of beluga hunting efficiency (whales struck, landed, and lost) in the Beaufort Sea/Delta region, 1970-2009. Data from Strong (1990), Weaver (1991), and Harwood et al. (2002).

| Decade | | No. of belugas | | | % |
|---|---|---|---|---|---|
| | | Struck | Landed | Lost | Lost |
| 1970-1979 | mean | 164.5 | 133.7 | 26.0 | 15.9 |
| | SD | | 26.0 | | |
| 1980-1989 | mean | 146.0 | 124.0 | 27.5 | 17.7 |
| | SD | | 23.3 | | |
| 1990-1999 | mean | 124.9 | 111.0 | 13.9 | 11.2 |
| | SD | 19.5 | 19.0 | | |
| 2000-2009* | mean | 109.3 | 97.4 | 5.9 | 5.4 |
| | SD | 23.1 | 19.6 | | |

*includes three belugas in 2004 and one beluga in 2005 landed at Ulukhaktok (formerly Holman) and two beluga landed at Sachs Harbour in 2008.

Table 2. Mean standard length (cm) of landed belugas by colour category and sex, 1990-2009.

| Sex | | Colour category | | | |
|---|---|---|---|---|---|
| | | Dark gray | Gray | Gray-white | White |
| Males | n | 5 | 110 | 24 | 1065 |
| | mean | 240.2 | 367.0 | 382.7 | 422.0 |
| | SD | 62.2 | 40.6 | 35.4 | 28.5 |
| Females | n | 3 | 69 | 7 | 250 |
| | mean | 297.2 | 352.7 | 377.0 | 382.4 |
| | SD | 90.3 | 21.8 | 30.8 | 27.9 |

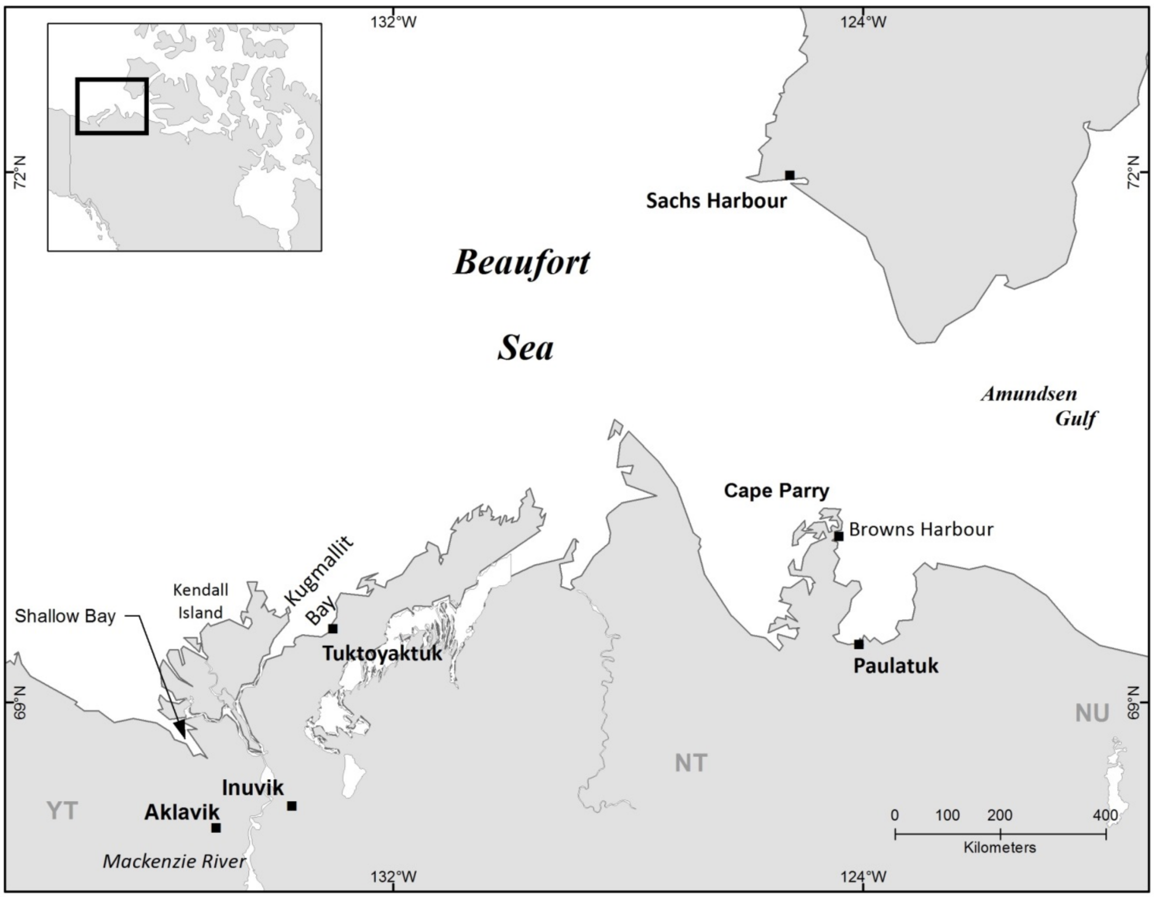



Figure 1. Southeast Beaufort Sea, Mackenzie River estuary, Amundsen Gulf, and locations mentioned in text.

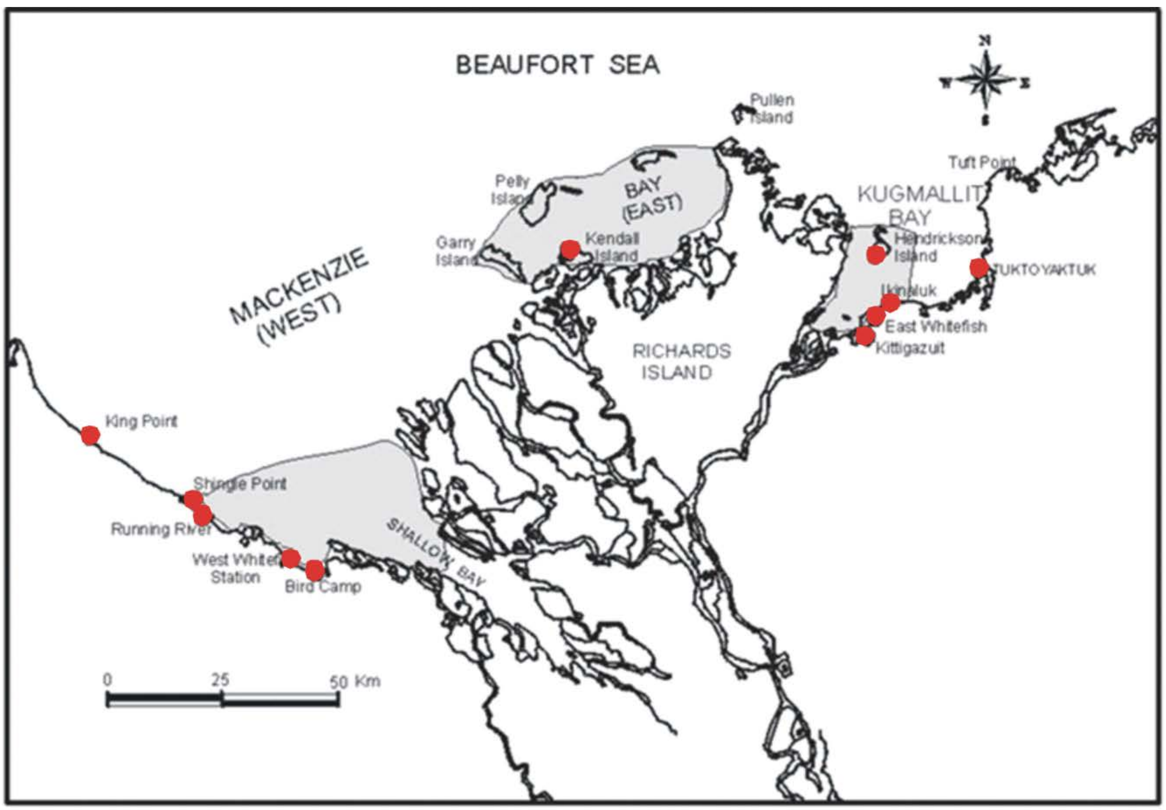



Figure 2. Seasonal whaling camps (red dots) and main harvesting areas (shaded) in the Mackenzie River estuary ('the Delta'), NT, Canada.

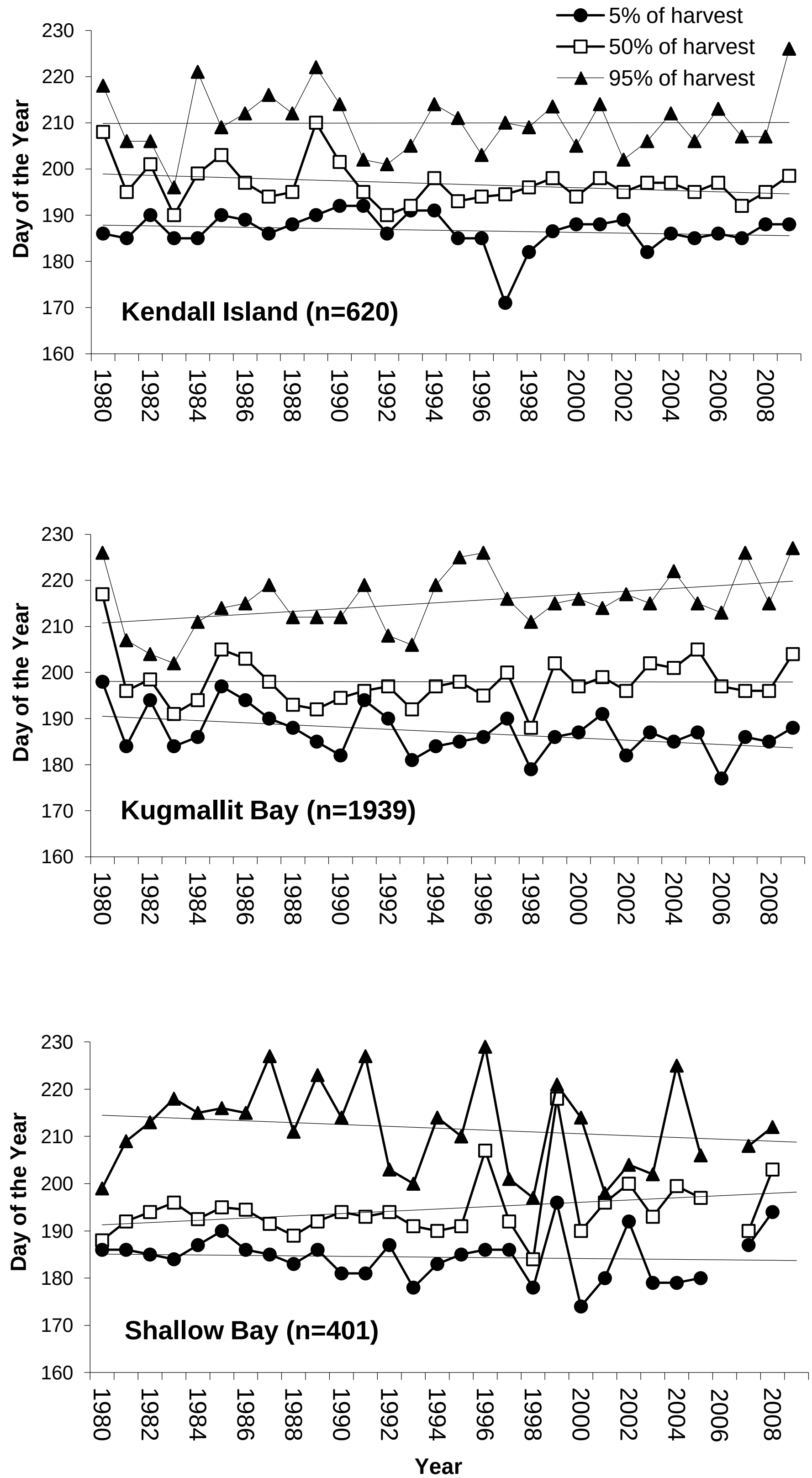



Figure 3. Day of the year by when 5%, 50%, and 95% of the year's harvested belugas were landed in Kendall Island, Kugmallit Bay, and Shallow Bay, 1980-2009.

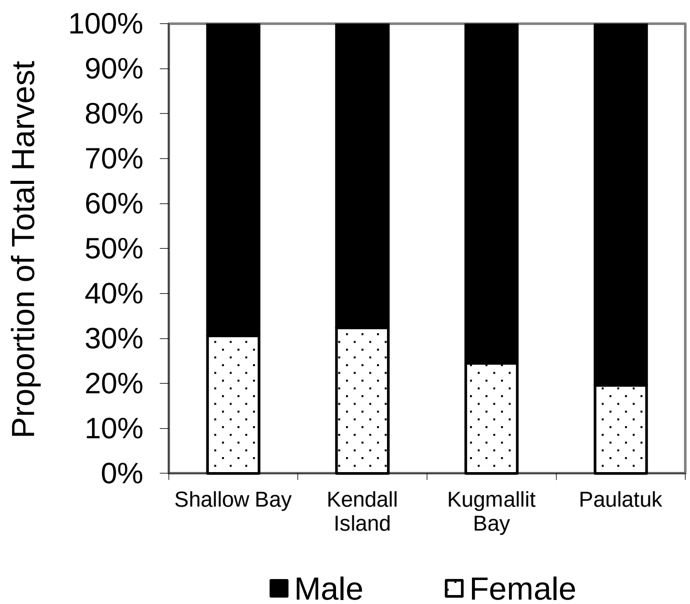



Figure 4. Proportion of males and females landed in the beluga whale subsistence harvest by Delta whaling camp area and near Paulatuk, 1980-2009.

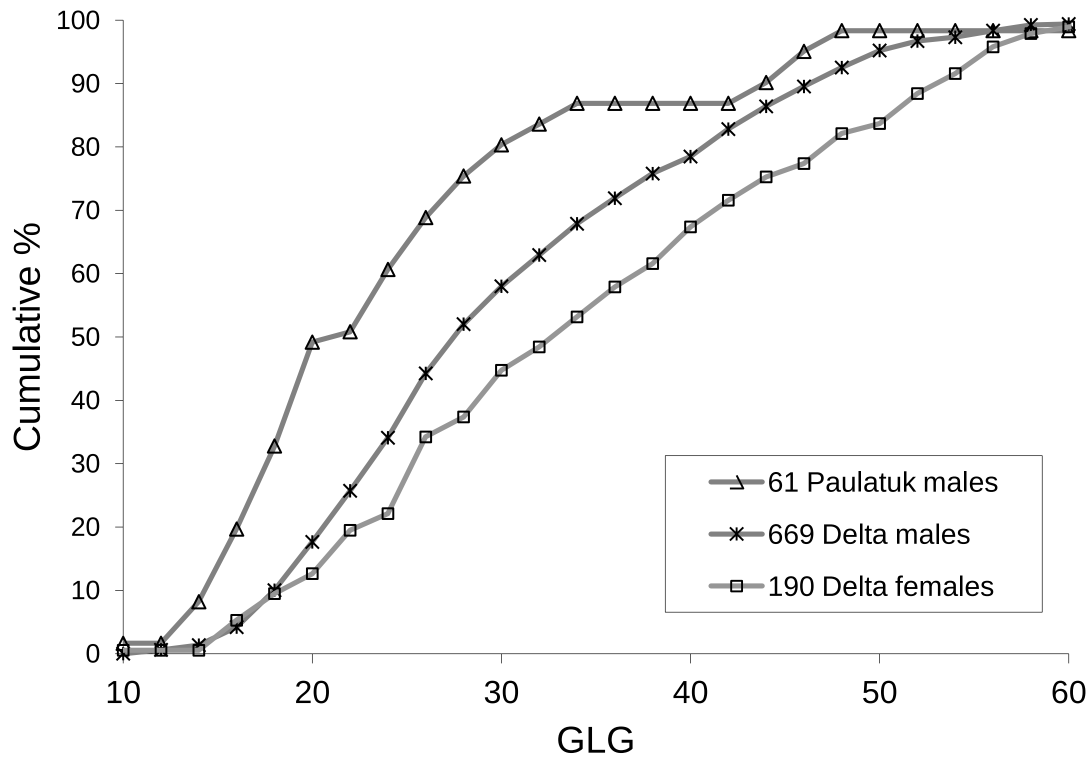



Figure 5. Cumulative frequency distribution of GLGs estimated for male and female belugas landed in the Delta and for male belugas landed in Paulatuk, 1993-2008 (adapted from Harwood et al. 2014).

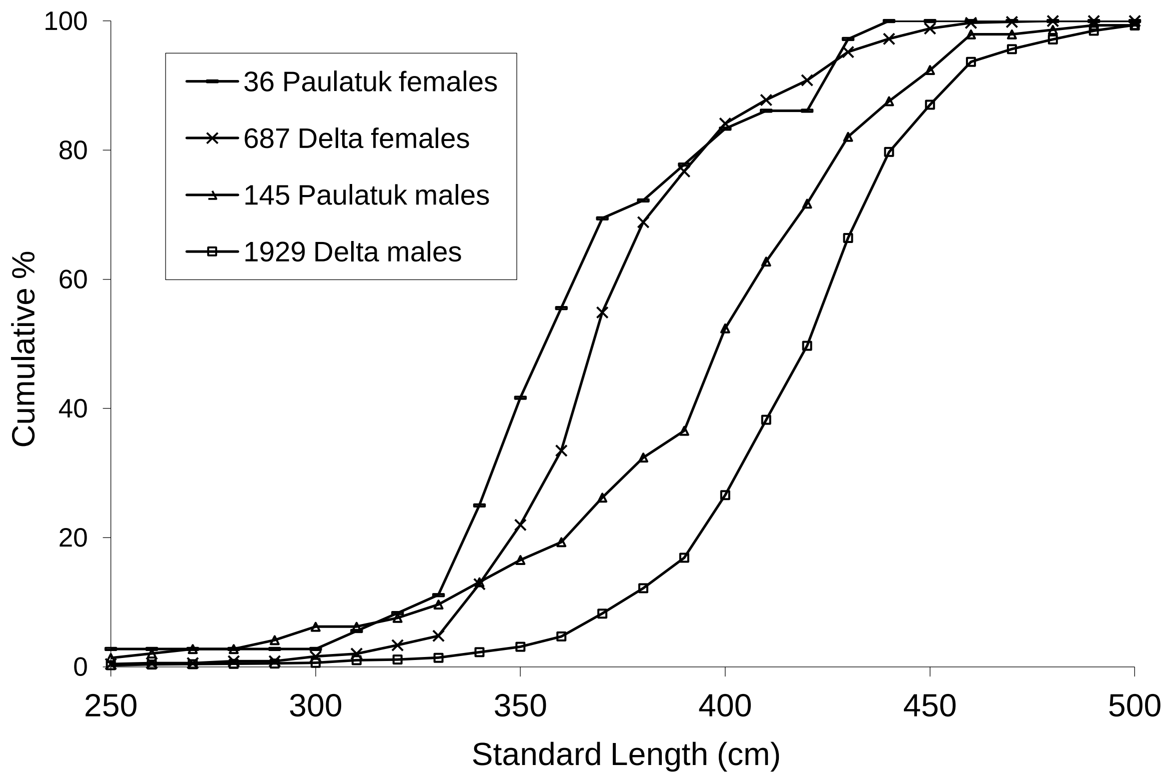
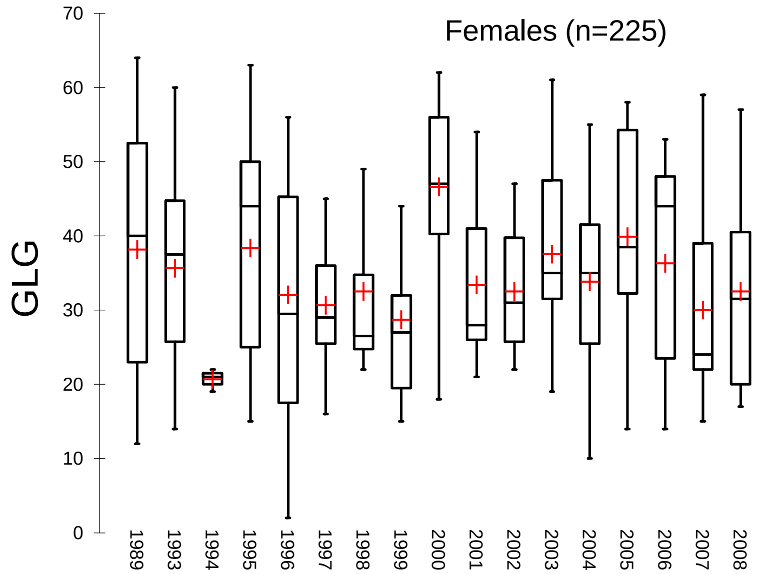



Figure 6. Cumulative frequency distribution of standard lengths of male and female belugas landed in the Delta and Paulatuk harvesting areas, 1993-2008 (adapted from Harwood et al. 2014).



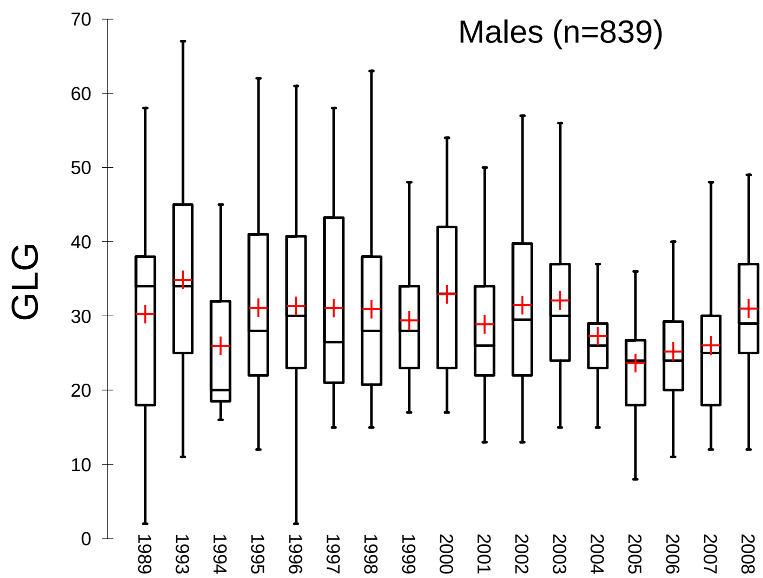




Figure 7. Whisker-box plots of distribution of GLGs for all female (n=225) (top) and male (n=839) (bottom) belugas for Mackenzie Delta and Paulatuk that were read by readers 1 and 3, 1989-2008 (boxes = 75% of observations; + = mean; — = median).

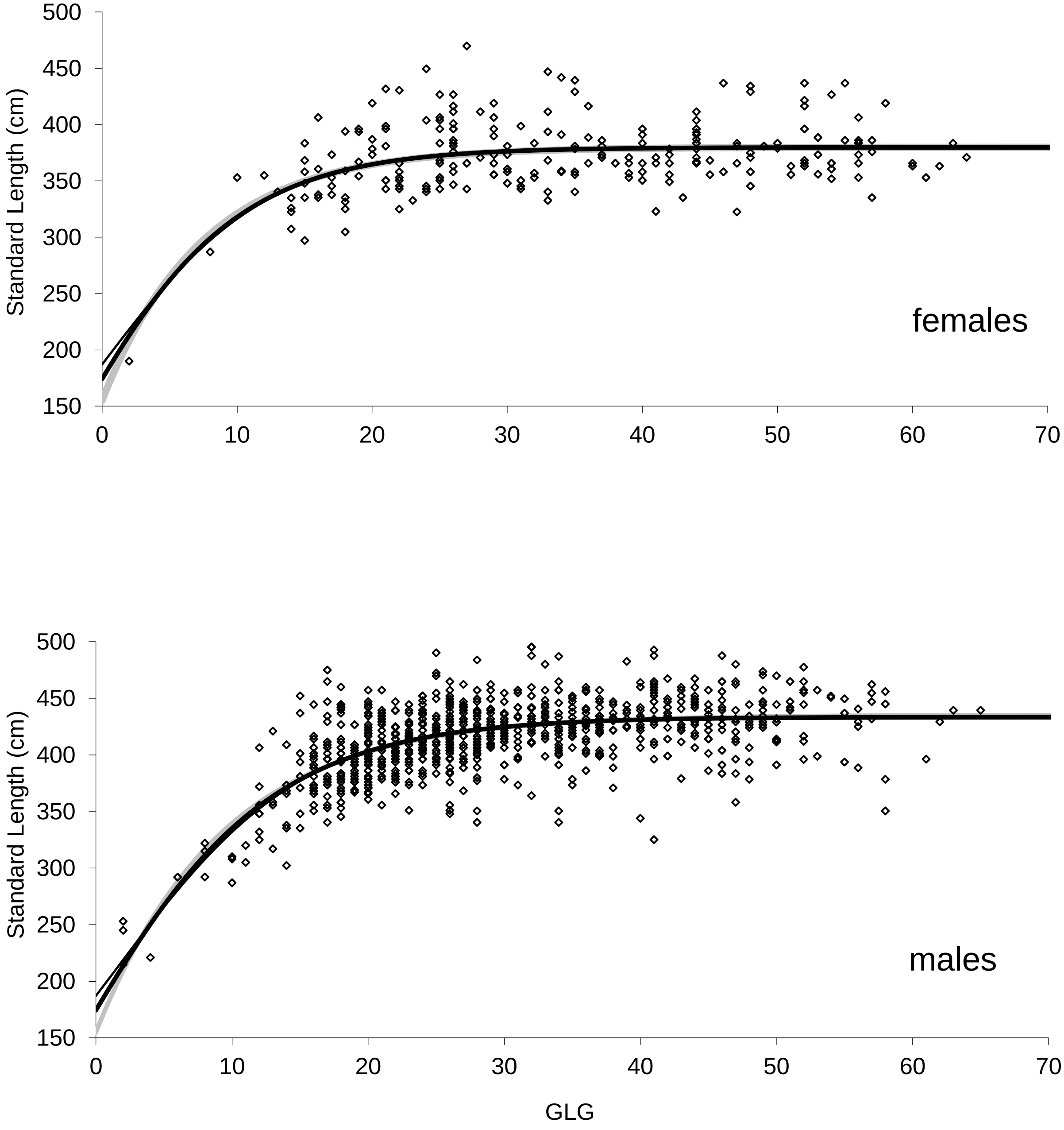



Figure 8. The von Bertalanffy growth model for female (top) and male (bottom) belugas landed in in the Delta and Paulatuk subsistence harvests, 1989 and 1993-2008 (adapted from Harwood et al. 2014).

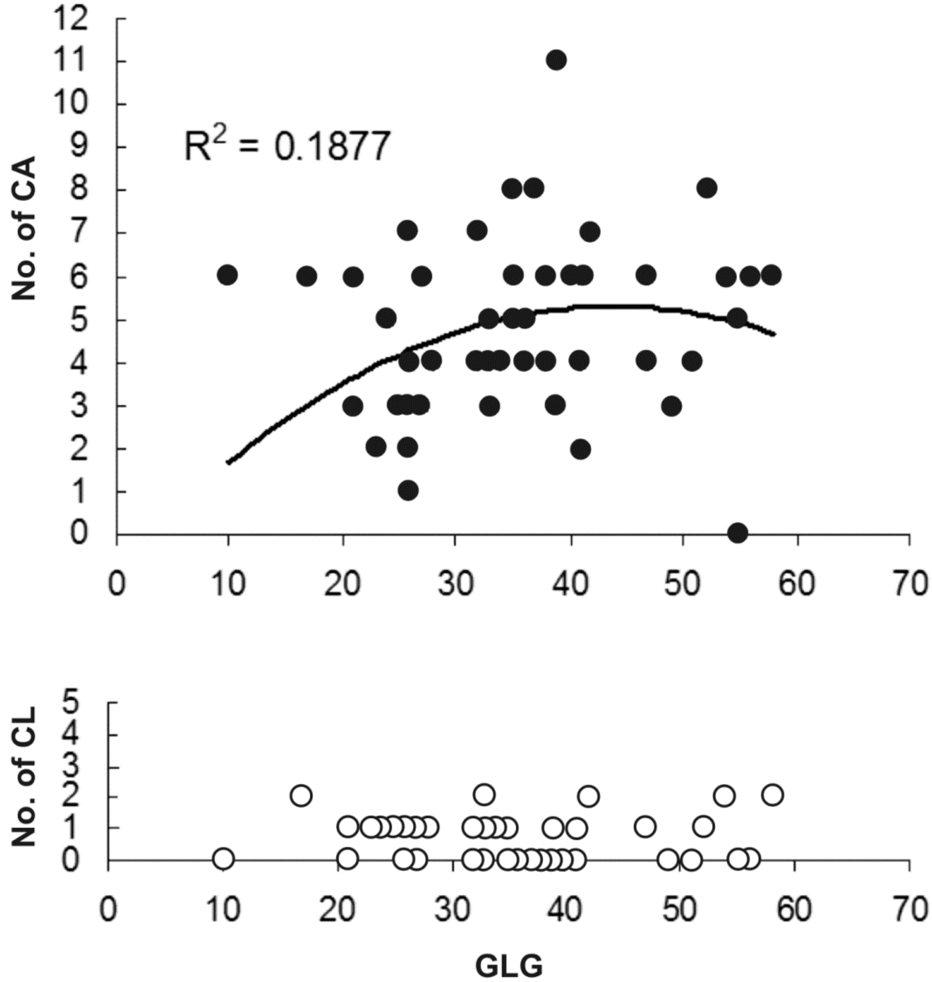



Figure 9. Number of corpora albicantia (CA) (top) and corpora lutea (CL) (bottom), by GLG, observed in ovaries of belugas landed in subsistence harvests at Kugmallit Bay and Kendall Island, 2000-2005.

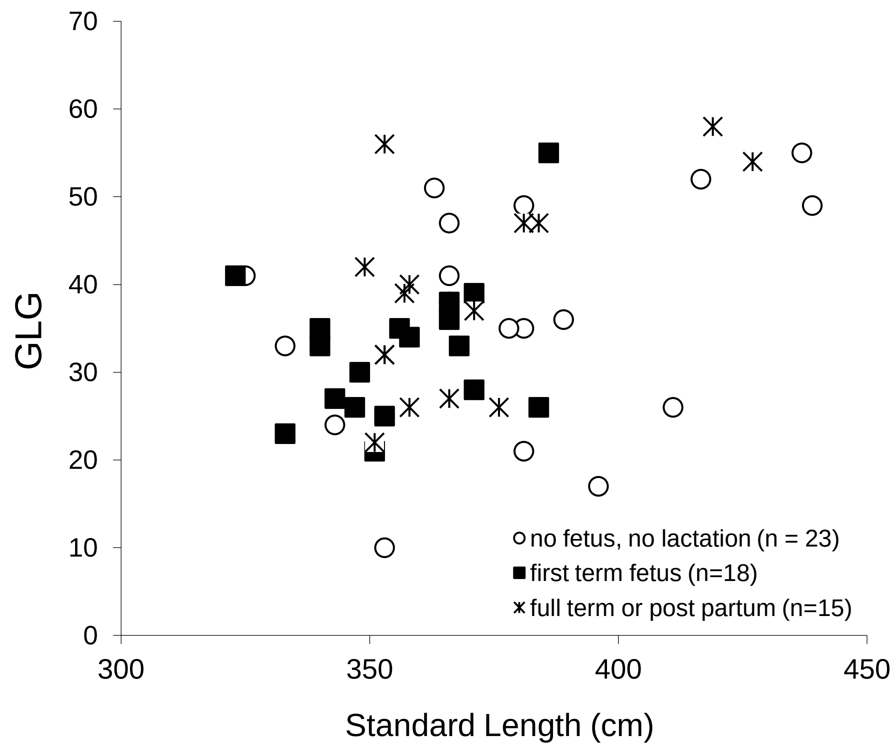



Figure 10. GLG and standard length of 56 adult female belugas examined from Kugmallit Bay and Kendall Island subsistence harvests, by reproductive status, 2000-2005.

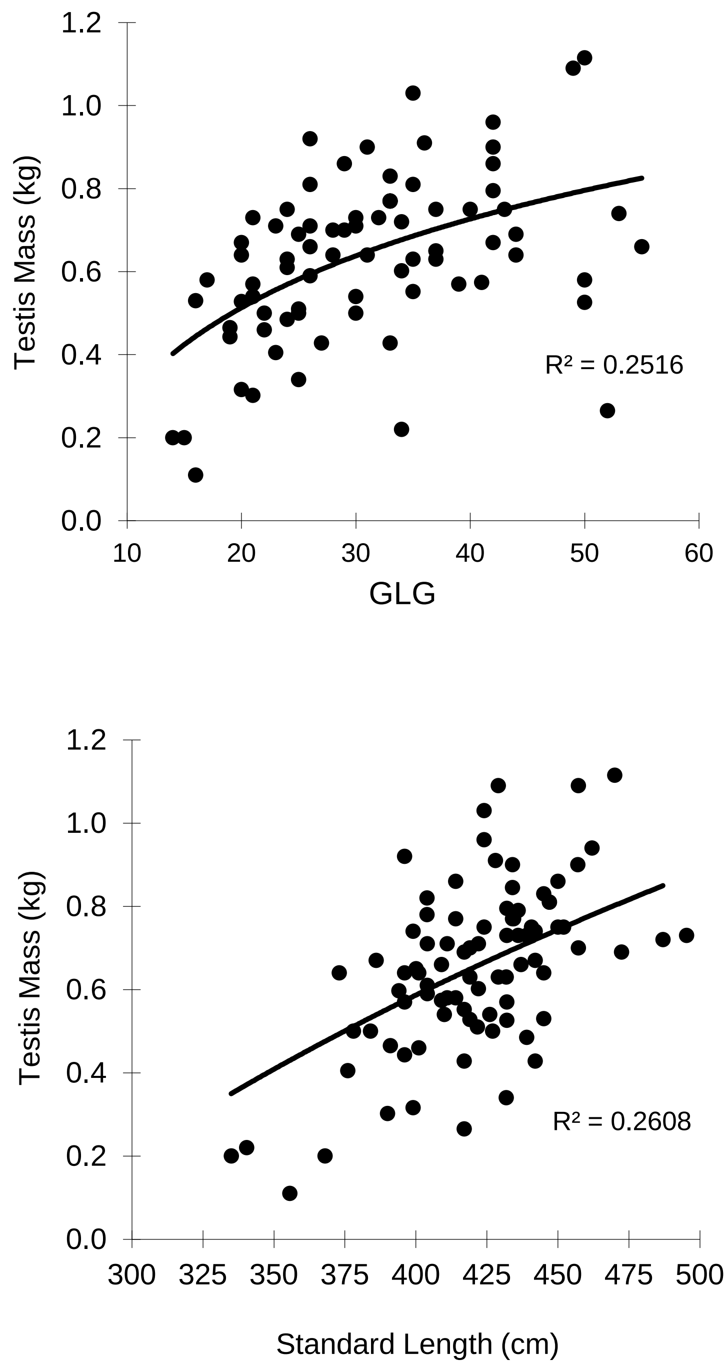



Figure 11. Testis mass vs. GLG (top) and standard length (bottom) of 89 male belugas examined from the Kugmallit Bay and Kendall Island subsistence harvests, 2000-2005.