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The Harvest of Beluga Whales in Canada's Western Arctic: Hunter-Based Monitoring of the Size and Composition of the Catch

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ABSTRACT. Hunter-based beluga monitoring programs, in place in the Mackenzie Delta since 1973 and in the Paulatuk, Northwest Territories, area since 1989, have resulted in collection of data on the number of whales harvested and on the efficiency of the hunts. Since 1980, data on the standard length, fluke width, sex, and age of the landed whales have also been collected. The number of belugas landed each year averaged 131.8 (SD 26.5, n = 1337) between 1970 and 1979, 124.0 (SD 23.3, n = 1240) between 1980 and 1989, and 111.0 (SD 19.0, n = 1110) between 1990 and 1999. The human population increased during this same period. Removal of belugas from the Beaufort Sea stock, including landed whales taken in the Alaskan harvests, is estimated at 189 per year. The sex ratio of landed belugas from the Mackenzie Estuary was 2.3 males:1 female. Median ages were 23.5 yr (47 growth layer groups [GLG]) for females (n = 80) and 24 yr (48 GLG) for males (n = 286). More than 92% of an aged sample (n = 368) from the harvest consisted of whales 10 or more years old (20 GLG). The rate of removal is small in relation to the expected maximum net productivity rate of this stock. The continued availability of large, old individuals after centuries of harvesting and the apparent lack of change in the size and age structure of the catch in recent years also support a conclusion that the present level of harvest is sustainable.

Key words: beluga, Mackenzie Estuary, Paulatuk, hunt monitoring, Beaufort Sea, catch composition, age, growth, standard length

RÉSUMÉ. Des programmes de surveillance du bélouga gérés par les chasseurs et mis en oeuvre dans le delta du Mackenzie depuis 1973 et dans la région de Paulatuk (Territoires du Nord-Ouest) depuis 1989, ont abouti à la collecte de données sur le nombre de baleines blanches prélevées et sur l'efficacité des expéditions de chasse. Depuis 1980, on a également collecté des données sur la longueur standard, la largeur de la nageoire caudale, le sexe et l'âge des bélougas ramenés à terre. Le nombre moyen de bélougas ramenés à terre chaque année était de 131,8 (écart-type 26,5, n = 1337) entre 1970 et 1979, de 124,0 (écart-type 23,3, n = 1240) entre 1980 et 1989, et de 111,0 (écart-type 19,0, n = 1110) entre 1990 et 1999. La population humaine s'est accrue durant cette même période. On estime à 189 le nombre annuel de bélougas prélevés sur le stock de la mer de Beaufort, y compris ceux ramenés à terre qui font partie des récoltes de l'Alaska. Le rapport des sexes des bélougas ramenés à terre depuis l'estuaire du Mackenzie était de 2,3 mâles pour 1 femelle. La moyenne d'âge était de 23,5 (47 groupes de couches de croissance [GCC]) pour les femelles (n = 80) et 24 (48 GCC) pour les mâles (n = 286). Plus de 92 p. cent d'un échantillonnage (n = 368) prélevé sur la récolte et dont l'âge avait été déterminé, consistait en des baleines blanches de 10 ans ou plus (20 GCC). Le taux de retrait est faible par rapport à la productivité maximale nette à laquelle on peut s'attendre de ce stock particulier. La présence continue d'individus âgés et de grande taille après des siècles de prélèvements, et le manque apparent de changements dans le nombre des prises et leur distribution d'âge au cours des dernières années permettent de conclure que le niveau actuel des prélèvements est durable.

Mots clés: bélouga, estuaire du Mackenzie, Paulatuk, surveillance de la chasse, mer de Beaufort, composition des prises, âge, croissance, longueur standard

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INTRODUCTION

The belugas (*Delphinapterus leucas*) that occur in the Beaufort Sea during summer migrate to spend the winter in the Bering Sea. Each spring, they travel along the north coast of Alaska to their summer range in the Mackenzie River estuary, Beaufort Sea, and Amundsen Gulf (Fraker, 1979; Richard et al., 2001). They share the Bering Sea wintering areas with at least three other stocks of belugas: those that summer in Bristol Bay, Norton Sound, and the eastern Chukchi Sea (Brennin et al., 1997; O'Corry-Crowe and Lowry, 1997; O'Corry-Crowe et al., 1997). Together these four stocks, as well as stocks that summer in Russian waters, make up the Bering Sea beluga population (Burns and Seaman, 1985).

The hunting of belugas by Inuit, for use as human and dog food, has a long history. For 500 or more years, the

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aboriginal people of the Western Arctic have successfully hunted the beluga whale in the Mackenzie River estuary (McGhee, 1988). Limited information is available on the size of the beluga harvest during the pre-contact (prior to 1888) and commercial whaling (1888–1907) periods (Bockstoce, 1986), or from the end of the commercial bowhead whaling era up until the 1950s. Available data suggest that harvests in those times were likely higher than at present (Nuligak, 1966; Smith and Taylor, 1977; McGhee, 1988; Strong, 1989; Friesen and Arnold, 1995; Billy Day, unpubl. data).

Each summer, contemporary hunters and their families from Inuvik, Aklavik, and Tuktoyaktuk, Northwest Territories (Fig. 1) travel to traditional whaling camps along the eastern Beaufort Sea coast (Fig. 2). The hunt has always been conducted mainly during the month of July. It lasts for four to six weeks, while the belugas are aggregated in three main areas of the Mackenzie River estuary: Kugmallit Bay, Beluga Bay, and Shallow Bay (Fraker et al., 1979; Norton and Harwood, 1986).

The Inuvialuit of Holman and Paulatuk, Northwest Territories (Fig. 1) also have a history of hunting the beluga. Hunting takes place when the whales travel close to shore near these communities, after they have left the Mackenzie River estuary, usually in late July and August (Norton and Harwood, 1985). Results from recent satellite telemetry studies have shown that belugas taken by hunters from Paulatuk are likely from the same stock as those taken in the Mackenzie River estuary, but are taken later in the season, once the whales have moved to offshore feeding areas (Richard et al., 2001).

During their spring and fall migrations, the belugas of the Beaufort Sea stock are also hunted by Inuit of Alaskan villages (i.e., Little Diomede, Kivalina, Point Hope, Barrow, Wainwright, and Kaktovik; Lowry et al., 1988). Residents of the Chukotskiy Peninsula, Russia, probably also take whales from this stock. Harvests in Russian waters since 1990 have been low, probably not exceeding 20–30 animals per year (Melnikov et al., 1998; Belikov, 1999). The origin of the small number of belugas being taken in Russia at the present time is not entirely known and may include more than one stock.

The first written records about harvesting of belugas from the Beaufort Sea stock in Canada are found in Royal Canadian Mounted Police (RCMP) and territorial game officer reports from 1954, which reported that 210 belugas had been landed (Smith and Taylor, 1977). Smith and Taylor (1977) report that the harvest averaged 120 per year between 1960 and 1963, while Strong (1989) reports an average harvest of 146 per year between 1960 and 1966.

A formal harvest-monitoring program was conducted from 1973 to 1975 by the Fisheries and Marine Service of the Government of Canada (Hunt, 1979). Monitoring was continued from 1977 through 1982 by an oil and gas industry–sponsored program (Fraker, 1977, 1978; Fraker and Fraker, 1979, 1981; Norton Fraker, 1983) and from 1981 through 1986 by a program led by Fisheries and Oceans Canada (DFO) (Strong, 1990; Weaver, 1991). Finally, the Fisheries Joint Management Committee (FJMC) has conducted programs annually from 1987 to the present.

In all years, data were collected from hunters at the seasonal whaling camps on the size and timing of the harvest and the number of whales struck, landed, and lost. From 1980 onward, the landed whales were measured and sexed, and biological samples were taken. This information was collected to document the magnitude and trend of the harvest and to obtain data necessary to assess stock status and the impact of the harvest on that stock. This series of programs has produced the longest and largest database on harvested beluga whales in Canada.

The main objective of the beluga harvest-monitoring programs was to detect changes in the harvest and the beluga stock over time through measurement of certain parameters. In this paper, we collate and summarize the available data on the number of whales struck, landed, and lost from the Beaufort Sea stock during the last four decades. We also provide a summary of the biological data collected from the monitoring programs for the 20 yr period between 1980 and 1999.

METHODS

Sampling Landed Whales

Before 1980, appropriate biological data were collected on an opportunistic basis, when an independent contractor and a local hunter were present in a whaling camp. During these visits, which usually took place every 5–7 days, the hunters were interviewed as to how many whales had been struck since the previous visit. The contractors would also sample any whales that happened to be landed during the course of the camp visit (Fraker, 1977, 1978; Fraker and Fraker, 1979, 1981; Fraker et al., 1979; Norton Fraker, 1983).

In 1980, sampling was intensified, with as many as six local hunters hired each season. Within the Mackenzie Delta, one hunter was assigned to each of the six core whaling areas: 1) Shingle Point/Running River, 2) West Whitefish/Bird Camp, 3) Kendall Island/Garry Island, 4) Hendrickson Island, 5) Tuktoyaktuk, and 6) East Whitefish. These hunters, termed "beluga monitors," collected hunt-related and biological data at their own and neighbouring (usually extended family) whaling camps throughout the whaling season. The monitors received pre-season training from a biologist, either individually or as a group. Often the same hunter held the beluga monitor position in a given camp year after year. Billy Day worked at the same site for all but one year between 1977 and 1999.

After each hunt, the monitor interviewed each hunt captain to obtain information on how many whales were struck, landed, and lost. The benefit of this approach is that the monitor personally observes and counts each landed

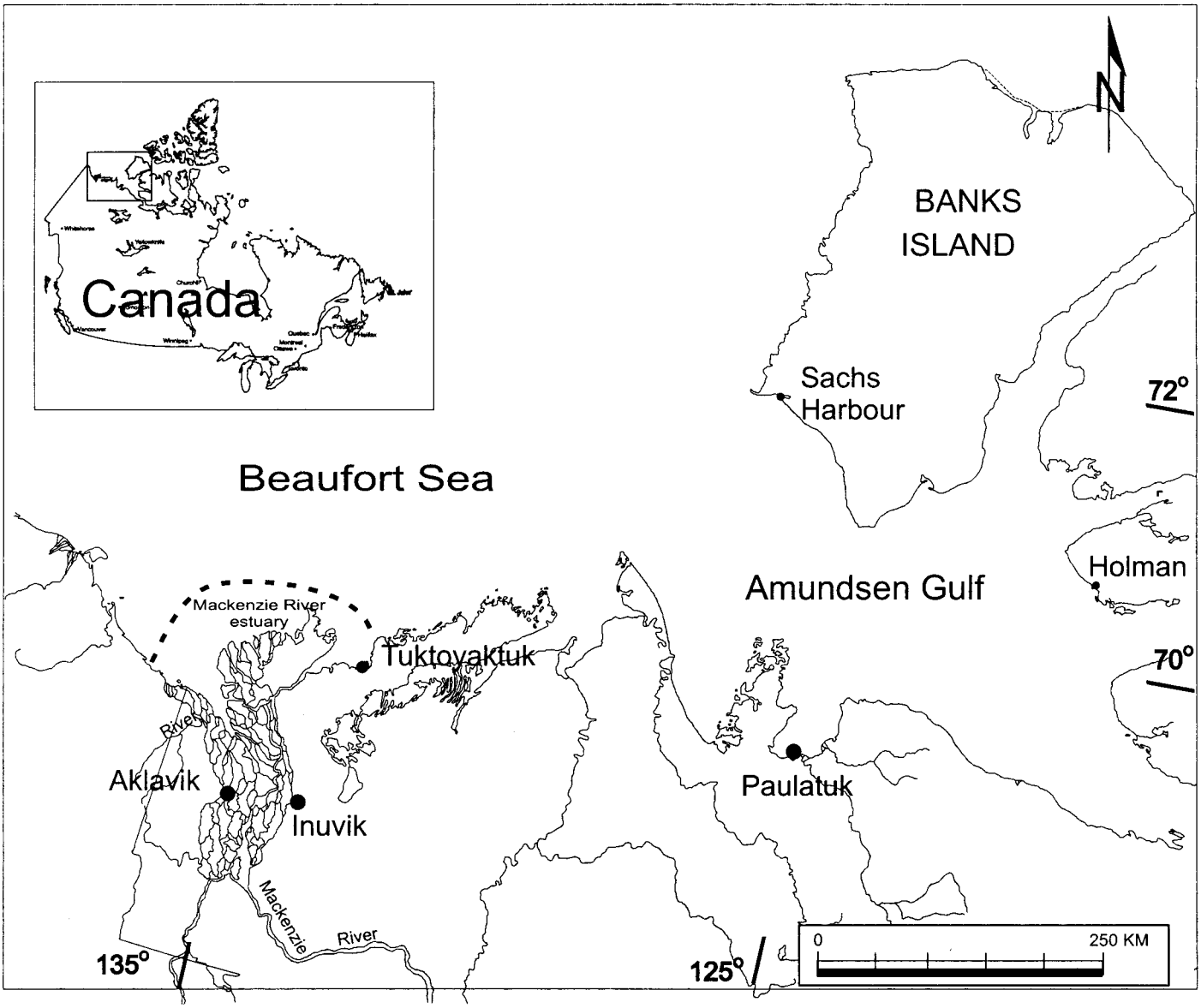

FIG. 1. Map showing location of the Mackenzie River estuary and the Inuvialuit communities that hunt belugas in Canada's Western Arctic.

whale. The monitor also sees and records the names of the different hunters on the hunt, which thus rules out the potential for double counting of a landed whale by more than one hunter on the same hunt. The monitors also collect samples, determine the sex of the landed whales, and measure the standard length of as many whales as possible, according to a standard protocol (American Society of Mammalogists, 1961). Other measurements include fluke and flipper widths (E. McLean, FJMC, unpubl. data, 1988–2000).

Lower mandibles were collected, labelled, and air-dried in the field and were later separated into left and right dentaries. These were trimmed by cutting transversely through the bone, posterior to the tooth row. Teeth were prepared following methods described by Wainwright and Walker (1988). Dentaries were boiled gently to facilitate extraction of two mandibular teeth, usually the second and fifth, for age estimation. These were embedded in clear casting resin and longitudinally thin-sectioned at ~0.3 mm intervals, using a diamond wafering blade. Finished thin sections were stored in 70% ethanol.

Thin sections were examined wet, using a dissecting microscope and reflected light. A single "reader" made the age estimates using counts of dentinal growth layer groups (GLGs) to estimate minimum age. A growth layer group consists of two adjacent growth layers, one light and one dark (Perrin and Myrick, 1980). For each tooth, the mean of three individual counts became the final GLG estimate. Chronological age, based on the assumption that belugas deposit two GLGs annually (Goren et al., 1987), was rounded upward to the next integer. However, recent studies have challenged this assumption (Hohn and Lockyer, 1999), so we have also provided the number of GLGs beside each age estimate.

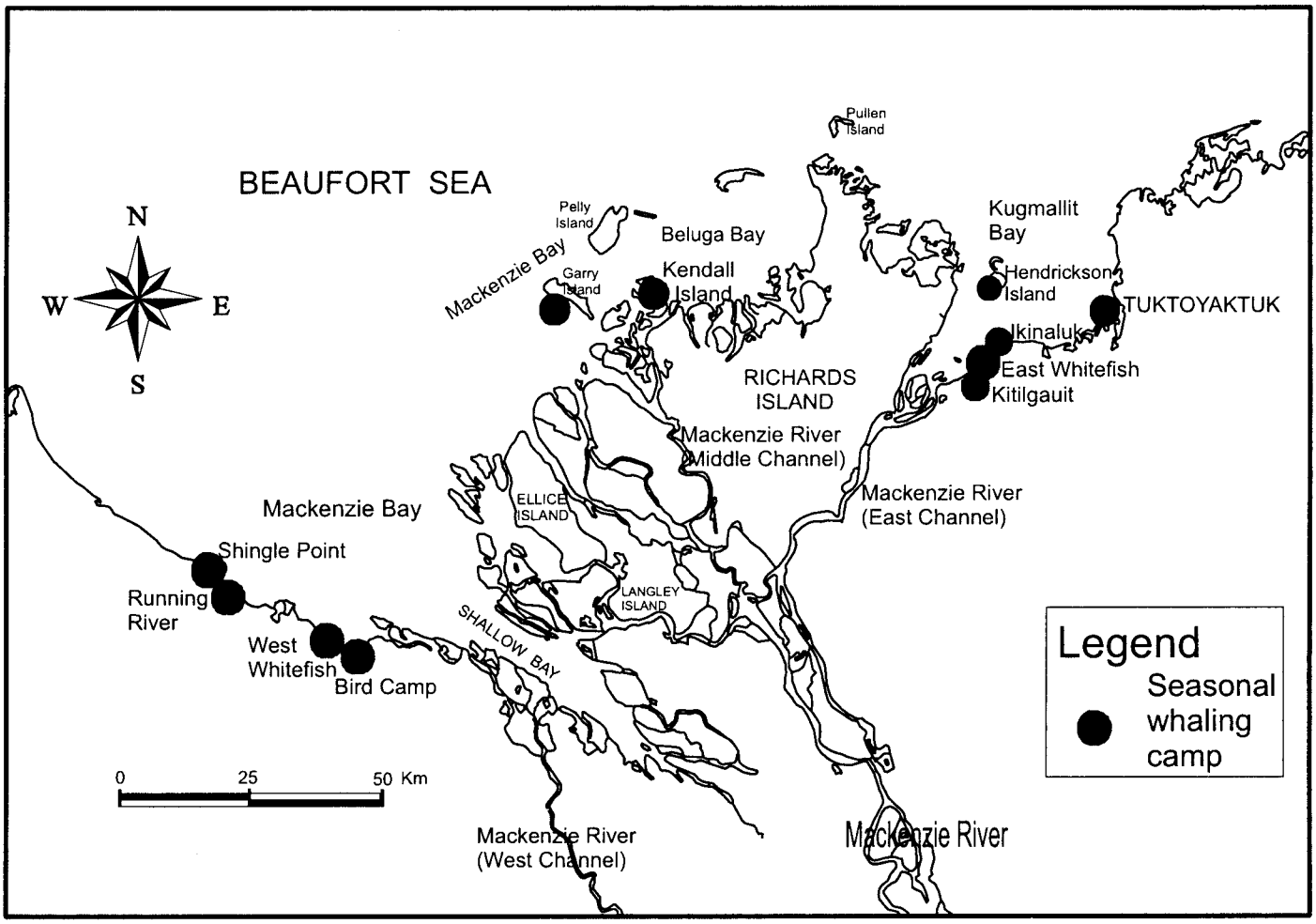

FIG. 2. Locations of seasonal whale camps used by Inuvialuit beluga hunters from Aklavik, Inuvik, and Tuktoyaktuk, Northwest Territories.

Analysis

A database of all whales sampled from 1974 to 1999 was prepared from the original data sheets and published reports. These data are now archived as Lotus 123 files at the FJMC office in Inuvik.

The number of whales struck and the number landed were tabulated from the literature for the 1960s and 1970s (Smith and Taylor, 1977; Strong, 1989) and from the database for subsequent years. Spearman's correlation (Sokal and Rohlf, 1995) was used to determine whether the number of whales landed per year was related to the size of the human population in a given community. Human population data, provided by Statistics Canada, represent all ages and ethnic groups. Data from the 1981, 1986, 1991, and 1996 national censuses (Statistics Canada, 1994, 1998) were examined. In addition, we obtained from the Inuvialuit Regional Corporation (IRC) data for 1988 through 1996 on the number of beneficiaries aged 18 years and older, by community, living in the Inuvialuit Settlement Region (M. Tingmiak, IRC, unpubl. data, 1998).

The annual harvest-related removal of belugas from the Beaufort Sea stock was set as the number of whales struck in a given year. No independent data are available with which to assess the completeness of the reporting of struck and lost whales. Like the landed whale data, however, the struck data were collected immediately after the hunt by the monitor, himself a peer and a beluga hunter.

Recorded annual removal of belugas from the Beaufort Sea stock was calculated by summing Inuvialuit strikes and the reported number of whales struck from this same stock in Alaska.

Biological Measurements

The proportion of the catch from the Mackenzie River estuary that was measured each year for standard length, sex, age, and colour was tabulated from the database. In 1977–79, the proportion of the landed whales that was sampled was low (e.g., on average, only 24% were measured for standard length, and sex was determined for only 36%). From 1980 onward, monitors were tasked with sampling as many of the landed whales in their monitoring area as possible. We have limited our analyses of basic biological parameters to the years 1980–99, when sample size was large (588 females, 1428 males) and more complete (90.8% for standard length, 92.5% for sex, 86.2% for colour).

A Kolmogorov-Smirnov 2-sample test (Kiefer, 1959) was used to compare the length frequency distribution of males and females from the Mackenzie River estuary harvest. A one-way analysis of variance (SAS, 1996) was then used to test for differences in the mean length of harvested belugas between years, separately for males and females. The Duncan Multiple Range test (Zar, 1974) was used to rank and compare the mean annual standard lengths of belugas, separately for each sex, using SAS (1996).

Estimated ages of 368 belugas were available for the years 1988 –1994. Median ages were determined separately for each sex. Age-frequency histograms were prepared for each sex and compared using a Kolmogorov-Smirnov 2-sample test (Kiefer, 1959).

Gompertz growth curves for standard length (cm) were fitted to the data using a non-linear regression available in SAS (1996), according to Stewart (1994) and the equation [1]:

$$L_s = A(e^{(-e-k \bullet age + k \bullet t_o)}) \qquad [1]$$

where A is the asymptote (cm), k and t_o are fitted constants, *e* is the base of the natural logarithm (approximately 2.7183), age is the estimated age of the whale (yr) and L_s is the standard length (in cm) that is predicted from the equation. Annual differences in the asymptotic length of male belugas were examined by comparing predicted values and the associated 95% confidence intervals.

For the other years in the database, teeth were not collected or estimated ages are not yet available. For this reason, the monitors' colour category assignments of white (includes white with yellow, or moulting, skin), white with gray, gray, and dark gray were used to estimate the relative age of landed whales. The mean standard lengths of whales (by sex) in each colour category were compared using an analysis of variance and the Duncan Multiple Range test (Zar, 1974) to reveal specific differences between categories. The proportions of harvested whales in each colour category were tallied, and the relative age of whales in those category assignments were estimated from age and colour data available for 335 whales sampled between 1988 and 1992.

RESULTS

The Landed Harvest

Inuvialuit hunters travel from the communities of Inuvik, Aklavik, and Tuktoyaktuk to whaling camps along the Beaufort Sea coast. The seasonal camps are located on the shores of Kugmallit Bay, Beluga Bay, Mackenzie Bay, and Shallow Bay within the Mackenzie River estuary, and along the northern Yukon coast as far west as King Point (Fig. 2). Beluga hunting has also been conducted approximately 350 km east of Tuktoyaktuk, at Paulatuk, Northwest Territories, by residents of that community. The annual landed harvest from both the Mackenzie estuary and Paulatuk areas averaged 131.8 (SD 26.5, n = 1337) from 1970 to 1979, 124.0 (SD 23.3, n = 1240) from 1980 to 1989, and 111.0 (SD 19.0, n = 1110) from 1990 to 1999 (Table 1). Most (91.8%) of the belugas were landed in the Mackenzie River estuary by hunters from Aklavik (17.0%), Inuvik (34.7%), and Tuktoyaktuk (40.1%) areas. The remaining were landed near Holman and Paulatuk. Residents of Holman reported one beluga landed in 1973, seven in 1975, and two in 1978 (Strong, 1989). Hunters at Paulatuk landed four belugas in 1966, three in 1985, and one in 1987 (Strong, 1989), and they report a "regular" annual harvest since 1989 (a total of 91 whales landed between 1990 and 1999; mean = 9.1 whales/yr).

The average number of belugas harvested has declined over the last three decades, while the number of Inuvialuit beneficiaries has increased. Between 1988 and 1996, the number of beneficiaries aged 18 years and older living in the Inuvialuit Settlement Region increased by 14% (M. Tingmiak, IRC, unpubl. data, 1998).

Statistics Canada reports an overall increase in the aboriginal population of 26.4% for Inuvik, Tuktoyaktuk, Aklavik, and Paulatuk between 1981 and 1996. There were no positive correlations between the size of the human population and the size of the beluga harvest for the 1981, 1986, 1991, and 1996 census data (Inuvik: $|r| = 0.62$, $p = 0.3789$; Tuktoyaktuk: $|r| = 0.46$, $p = 0.5403$; Aklavik: $|r| = 0.74$, $p = 0.2611$). The same was true for comparisons between the number of Inuvialuit beneficiaries and the size of the beluga harvest (Inuvik: $|r| = 0.12$, $p = 0.7523$; Tuktoyaktuk: $|r| = 0.08$, $p = 0.8428$; Aklavik: $|r| = 0.23$, $p = 0.5517$).

Total Removal

The average number of belugas struck but lost, expressed as a percentage of the total number struck, was lower in the 1990s (mean = 11.2%), than in the 1970s (estimated mean = 15.9%) or the 1980s (mean = 17.7%; Table 1). The past and present efficiency of this hunt, and the factors that affect it, are relevant here for the calculation of the total number of belugas removed from the stock by the harvest. Including strikes by all Inuvialuit hunters, the number of belugas struck averaged 124.9 per year (SD 19.5, n = 1249) during the period from 1990 to 1999 (Table 1).

Inupiat, living along the northern coast of Alaska, struck an estimated 64 belugas per year (range 42 – 117) during the period from 1995 through 2000, from this same stock (Suydam and Frost, 2001). Struck and loss rates are just becoming available for this harvest, as programs are in place to address this data gap (Adams et al., 1993).

Combining what is known about Alaskan harvests from this stock with data on removals by the Inuvialuit indicates a total removal of approximately 189 belugas per year (not including any that may be taken in Russian waters).

The latest aerial surveys, conducted in 1992, gave an index of abundance of 19 629 belugas in the southeast Beaufort Sea and western Amundsen Gulf (95% confidence

TABLE 1. Number of beluga whales struck, landed, and lost in the Mackenzie River estuary and Paulatuk hunting areas, 1970–99 (data from Strong, 1989; Weaver, 1991; FJMC, unpubl. data).

Year	No. of Belugas			
	Struck	Landed	Lost	Percent Lost
1970	nr[1]	115	nr	nr
1971	nr	79	nr	nr
1972	nr	113	nr	nr
1973	nr	178	nr	nr
1974	nr	128	nr	nr
1975	nr	149	nr	nr
1976	nr	154	nr	nr
1977	172	148	24	14.0
1978	157	129	28	17.8
1979	nr	144	nr	nr
Mean	164.5	133.7	26.0	15.9
SD		26.0		
1980	85	85	nr	nr
1981	155	155	nr	nr
1982	146	126	20	13.7
1983	102	86	16	15.7
1984	156	141	15	9.6
1985	148	120	28	18.9
1986	199	150	49	24.6
1987	174	144	30	17.2
1988	139	116	23	16.5
1989	156	117	39	25.0
Mean	146.0	124.0	27.5	17.7
SD		23.3		
1990	106	87	19	17.9
1991	144	116	28	19.4
1992	130	121	9	6.9
1993	120	110	10	8.3
1994	149	141	8	5.4
1995	143	129	14	9.8
1996	139	120	19	13.7
1997	123	114	9	7.3
1998	93	86	7	7.5
1999	102	86	16	15.7
Mean	124.9	111.0	13.9	11.2
SD	19.5	19.0		

[1] nr = no record.

interval = 15 134–24 125; Harwood et al., 1996). It is now known that the total area occupied by Beaufort Sea belugas during summer was not covered, and that a considerable but as yet undetermined number of whales remained underwater during aerial counts. Thus, the index is undoubtedly lower than the actual stock size, which remains unknown. The present removal of an average of 189 belugas per year is less than 1% of even this most minimal index of stock size. If a hypothetical take in Russia of an additional 25 belugas was included in the calculation, the removal rate would still only be 1.1%.

Composition of the Mackenzie River Estuary Beluga Harvest

Sex was determined for 92.5% (2016/2192) of the belugas that were landed between 1980 and 1999 (Table 2), with males outnumbering females in the harvest 2.3:1 (mean = 29.3% females per year, range = 15.3–48.3%). The proportion of males and females in the harvest each year was calculated and plotted as a frequency histogram. The sex ratio remained consistent in the 20 consecutive years examined here (Fig. 3). In the 1980s, the average number of females landed per year was 34.7, while in the 1990s, the average was 24.1 per year.

The ages of 368 belugas harvested between 1988 and 1994 were available for 80 females and 286 males, representing 48.5% of the total landings (n = 758) during that period. The age-frequency histogram (Fig. 4) shows a wide range of ages in the sampled harvest, with 92.9% (351/368) being 10 or more years old (20 GLG). Females sampled from 1988 to 1994, for which age estimates are available, ranged from 0 to 49 yr (0–98 GLG), with a median of 23.5 yr (47 GLG). Males ranged from 3 to 57 yr (6–114 GLG), with a median of 24 yr (48 GLG). The age-frequency distributions of males and females were not statistically different (Kiefer, 1959; Kolmogorov-Smirnov test, $KS_a = 1.233$, n = 366, $p > KS_a = 0.1003$).

Colour was recorded for 1873/2192 or 86.2% of the belugas landed in the Mackenzie River estuary between 1980 and 1999 (Table 2). The proportion of the catch in each colour category was tallied. For both males and females, the mean standard lengths of the "white" and "white with gray" belugas were not different from each other, but they were different from that of the more variable but generally smaller "gray" category (females, $F = 39.92$, df = 2, 449, $p > F < 0.001$; males, $F = 116.22$, df = 2, 1190, $p > F < 0.0001$). Focusing on a seven-year subset of data for which age, colour, and standard length data were all available (1988–94), the mean ages corresponding to each colour category were 27.1 yr for "white" (SD 10.8, n = 274); 20.4 yr for "white with gray" (SD 8.0, n = 25); and 17.3 yr for "gray" (SD = 9.8, n = 35). The age of our one "dark gray" beluga was estimated at 3 yr (6 GLGs). The data reflect the fact that during the 20 years of monitoring in which colour category assignments were made, the hunters actively selected for older whales. Most (88.7%, or 1662/1873) were in the white/white-with-gray category). The data from 1988–94 indicate that the average age of belugas in this white/white-with-gray category was 24.5 yr (49 GLG) for females (n = 55) and 27.0 yr (54 GLG) for males (n = 243).

A length-frequency histogram was prepared for male and female belugas landed in the Mackenzie River estuary during 1980–99 (Fig. 5). Standard length was determined for 82.5% (1809/2192) of the landed whales. The length-frequency distribution shows the modal 10 cm size class for females (370–380 cm) to be 60 cm less than the modal size class for males (430–440 cm). The length-frequency distributions for males and females were significantly different from each other ($KS_a = 11.62$, $p > KS_a < 0.0001$, n = 1809).

Asymptotic lengths, predicted by the Gompertz curves (Stewart, 1994) for our 1988–94 sample of aged belugas, were 432.0 cm (SD 2.47, n = 3282; 95% CI = 427.1–436.8 cm) for males and 386.2 cm (SD 4.39, n = 379; 95% CI =

TABLE 2. Proportion of beluga whales landed that were measured, aged, sexed, and assessed for colour in the Mackenzie River estuary beluga monitoring programs during 1977–99.[1]

Year of Harvest	Total Landed	Number Measured	% Measured	Number Aged	% Aged	Number Sexed	% Sexed	No. With Colour Recorded	% Colour Recorded
1977	98	15	15.3	–	–	21	21.4	2	2.0
1978	114	24	21.1	–	–	44	38.6	3	2.6
1979	121	42	34.7	–	–	59	48.8	0	0.0
1980	82	77	93.9	–	–	77	93.9	75	91.5
1981	146	107	73.3	–	–	116	79.5	62	42.5
1982	107	96	89.7	–	–	98	91.6	99	92.5
1983	86	74	86.0	–	–	83	96.5	81	94.2
1984	141	99	70.2	–	–	111	78.7	112	79.4
1985	118	101	85.6	–	–	102	86.4	106	89.8
1986	131	109	83.2	–	–	121	92.4	118	90.1
1987	134	94	70.1	–	–	122	91.0	119	88.8
1988	114	94	82.5	62	54.4	111	97.4	95	83.3
1989	114	78	68.4	51	44.7	101	88.6	107	93.9
1990	87	63	72.4	53	60.9	78	89.7	75	86.2
1991	100	75	75.0	60	60.0	99	99.0	90	90.0
1992	103	89	86.4	73	70.9	103	100.0	94	91.3
1993	107	96	89.7	26	24.3	99	92.5	83	77.6
1994	133	117	88.0	43	32.3	128	96.2	127	95.5
1995	118	108	91.5	–	–	114	96.6	109	92.4
1996	95	90	94.7	–	–	93	97.9	86	90.5
1997	107	104	97.2	–	–	102	95.3	97	90.7
1998	84	67	79.8	–	–	82	97.6	74	88.1
1999	85	77	90.6	–	–	76	89.4	64	75.3

[1] Does not include Paulatuk harvests.

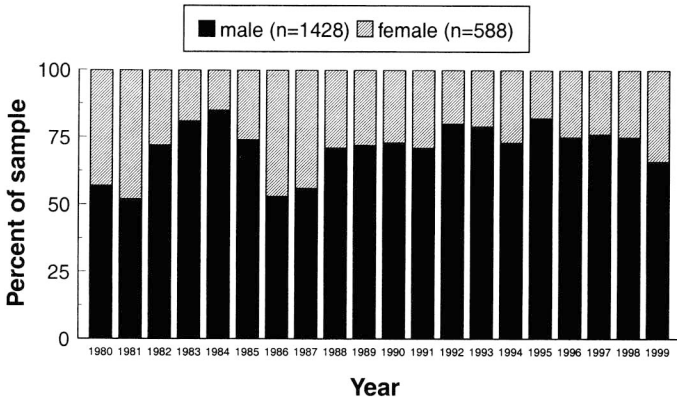

FIG. 3. Sex composition of the landed catch of beluga whales from the Mackenzie River estuary, 1980–99.

377.4–394.9 cm) for females. Between-year differences in the asymptotic lengths were not apparent for males (Table 3). Sample size was not sufficient to make this comparison for females.

The mean standard length of all males taken in the Mackenzie River estuary varied among years ($F = 2.69$, df = 19, 1297; $p > F = 0.0001$). The mean standard length of all females taken in the same area also varied among years ($F = 1.86$, df = 19, 510, $p > F = 0.0148$). There were no trends toward increasing or decreasing size for either sex over the 20 years for which data are available (Fig. 6).

Composition of the Paulatuk Harvest

Hunters from Paulatuk, located 350 km northeast of the Mackenzie River estuary, landed 95 belugas between 1989 and 1999. The annual take during this time averaged 9.5 belugas per year and ranged from 0 (1990) to 25 (1996). The sex ratio of belugas landed by Paulatuk hunters (3.7 males:1 female) showed the same strong bias toward males as was the case for the Mackenzie River estuary harvest.

The average age of belugas taken by Paulatuk hunters between 1991 and 1993 was 15.1 years (30.2 GLG) for females (n = 8, range = 7–32 yr) and 15.1 years (30.2 GLG) for males (n = 7, range = 12–20 yr). In contrast, males taken from the Mackenzie River estuary averaged 26.9 yr, while females averaged 24.6 yr, for the same period. These differences were statistically significant (for males, $F = 14.72$, df = 239, 6, $p > F = 0.0025$, $T_{unequal} = 8.80$, df = 12.2, $p > t < 0.001$; for females, $F = 1.18$, df = 63, 7, $p > F = 0.8981$; $T_{equal} = 3.01$, df = 70, $p > t = 0.0037$). Despite this difference in average age at these hunting locations, hunting effort in both locations was directed toward males.

Further work on the size and age structure of the Paulatuk harvest is warranted, as data were available for only three of eleven years of recent hunting. Although belugas taken by Paulatuk hunters were on average younger than those taken in the Mackenzie River estuary, the size of the whales taken in these two areas was similar. The mean standard lengths of the pooled white/white with gray belugas, by sex, from Paulatuk harvests (males, 429.7 cm, n = 49; females, 383.3, n = 10) were not different from those of belugas taken in the Mackenzie River estuary during the corresponding period (1989–99; males = 425.5 cm, n = 607, females, 385.0, n = 153; comparing males, $F = 1.17$, df = 606, 48, $p > F = 0.5168$; $T_{equal} = 1.00$, df =

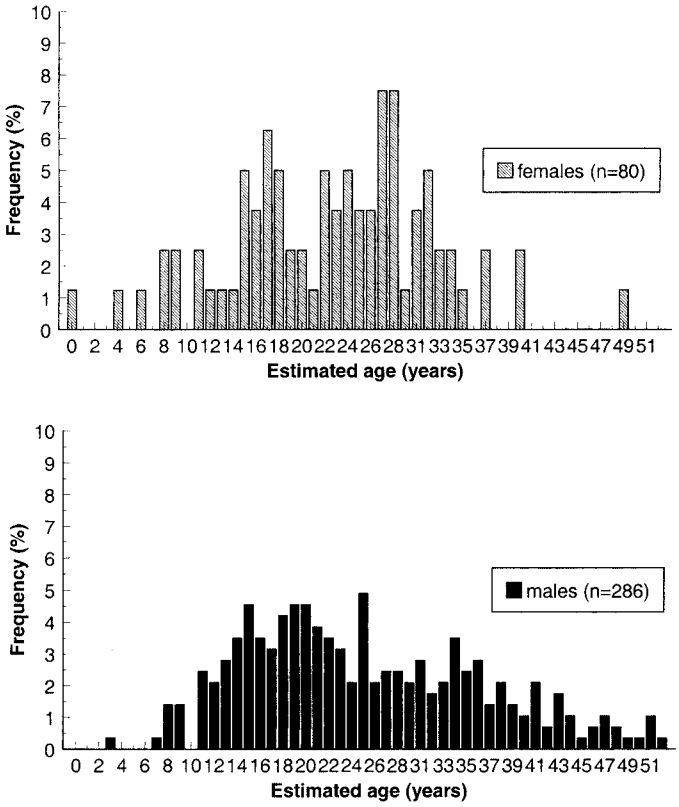

FIG. 4. Age-frequency distribution of male and female belugas landed in the Mackenzie River estuary, 1988–94.

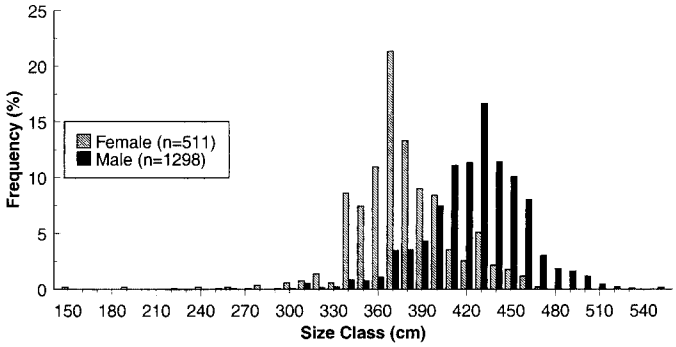

FIG. 5. Length-frequency distribution of male and female belugas landed in the Mackenzie River estuary, 1980–99.

TABLE 3. Asymptotic lengths of male belugas harvested from the Mackenzie River estuary, 1988–94.

Year	Asymptotic length (cm)	SD	df	95% confidence interval	
				lower	upper
1988	450.6	12.5	42	425.2	475.9
1989	446.9	13.8	37	418.9	474.8
1990	437.2	5.6	39	425.9	448.5
1991	433.1	3.4	47	426.2	440.0
1992	429.0	6.8	63	415.4	442.6
1993	443.2	14.7	20	412.3	474.1
1994	422.2	17.2	35	387.3	457.2
Years Pooled	432.6	2.6	289	427.5	437.6

654, $p > T = 0.3192$; comparing females, $F = 1.67$, df = 9, 152, $p > F = 0.2020$, $T_{equal} = 0.16$, $p > T = 0.8463$).

DISCUSSION

The Inuvialuit and their ancestors of the Western Arctic have a long history of hunting belugas. The size of the present-day harvest, averaging 111.0 belugas per year over the last decade, appears to be smaller than that of past harvests. Present-day harvests are lower than the estimated takes before commercial whaling (Nuligak, 1966) and those for the several decades since then for which harvest data exist (1960s, 1970s, and 1980s). In the late 1800s, the annual take of whales may have been upwards of 300 whales per summer (Nuligak, 1966). Nuligak recalls a communal drive hunt that took place in Kugmallit Bay when he was a small boy, which landed 150 belugas in a single day.

Between 1981 and 1996, the human population increased by more than 26%, yet there was not a corresponding increase in the average catch of belugas landed by the Inuvialuit. Billy Day considers this to be the result of recent trends toward a reduction in the consumption of traditional food, in particular for items requiring special equipment and knowledge to hunt and process, such as the beluga.

Although there has been an overall downward trend in the mean harvest level, annual harvests varied among years, fluctuating by as much as a factor of two between the extreme low and high harvest years in a given decade. The reasons for these variations have not been quantified, but likely include a variety of factors. For example, changes in local subsistence needs (i.e., during periods of increased wage employment in the oil and gas industry in the late 1970s and early 1980s) or in the requirement for beluga products for trade, barter, and sale to other Inuvialuit communities (i.e., when such opportunities increased after the signing of the Inuvialuit Final Agreement in 1984) would have influenced the level of the harvest in any given year. As well, environmental factors such as wind, weather, and ice conditions are known to affect the local distribution and availability of whales in a given whaling season. During 1985, for example, whales did not come into Kugmallit Bay until late in the season because of the late breakup of the ice (Norton and Harwood, 1986).

Fabijan et al. (1995) compared the beluga harvest data from the Inuvialuit Harvest Study (IHS, interview of all Inuvialuit hunters in the Inuvialuit Settlement Region monthly, using the hunter-recall interview as the method of data collection) and the number of landed beluga whales reported by the beluga monitors. Although the data collection methods were not the same, this is the only available independent data set with which to compare harvest totals. Between 1988 and 1992, the IHS reported a combined total of 494 belugas landed by hunters from Tuktoyaktuk, Aklavik, Inuvik, and Paulatuk (Fabijan et al., 1995). The FJMC program recorded 557 belugas for the same period (Table 1), 12.7% higher than the IHS data. This prompted

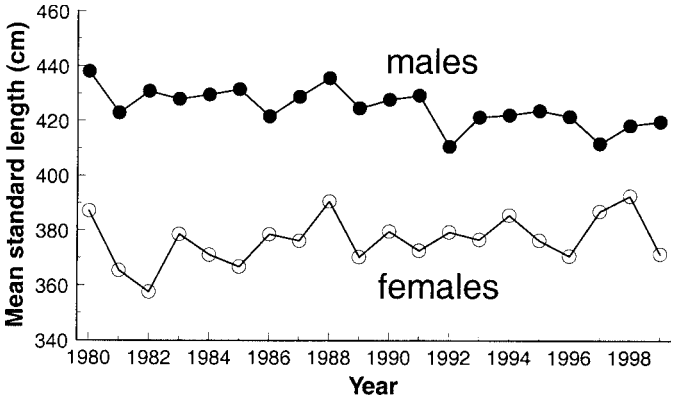

FIG. 6. Mean standard length of male and female belugas landed in the Mackenzie River estuary, 1980–99.

a matching of individual records for landed whales recorded by each study (Fabijan et al., 1995). This comparison revealed that the beluga monitors' records were more complete, because hunters and hunts were not missed by the "on-the-beach" method used by the monitors, as opposed to the IHS method of hunter recall interviews in the month following hunting.

Data from the monitoring programs indicate that hunters direct their effort toward adult males. This practice has the benefit of conserving adult females. The majority of whales (92.9%) taken in this harvest were older than 10 yr (20 GLG), and thus had contributed offspring to the stock before they were removed through the harvest. In other areas of the Canadian Arctic, belugas tend to be harvested at a younger age. For example, the mean ages of belugas sampled from the hunt in Nunavut Territory were 8.3 yr (n = 52) for females and 11.5 yr (n = 70) for males at Arviat; 8.5 yr (n = 7) for females and 7.0 yr (n = 25) for males at Pangnirtung, and 5.6 yr (n = 12) for females and 5.2 yr (n = 18) for males at Grise Fiord (Stewart, 1994).

Hunters from Paulatuk also direct their harvests to adult male belugas; however, these appeared to be younger than the adult males taken in the Mackenzie. This is consistent with information gained from satellite tagging efforts, which have shown that the largest males are the most likely to travel to distant summer feeding areas (e.g., Viscount Melville Sound). It is the smaller males and the females that tend to spend the summer in Amundsen Gulf, where they are accessible to Paulatuk hunters (Richard et al., 2001), and thus appear in the Paulatuk harvests.

The Eastern Beaufort Sea beluga stock is harvested at a rate well below the 2.0–3.85% annual rate of increase expected for beluga stocks reported by Kingsley (1996, 1998) and Cosens et al. (1998). The proportion removed is not known in relation to the actual size of the stock. Actual stock size is much larger than the index of abundance (19 629 belugas, Harwood et al., 1996). It is expected that the population size is above the maximum net productivity level and that the present level of harvest is sustainable (Innes, 1996; Cosens et al., 1998; Hill and DeMaster, 1999; DFO, 2000).

The number of whales lost due to orphaning of calves by removal of adult females (in Alaskan and Canadian waters), is still to be determined. To illustrate how this aspect could contribute to the total removal, a hypothetical example is instructive. If orphaned calves are included at a rate of one calf lost per every three adult females landed (L. Harwood, unpubl. data), then the estimate of total removal would increase by a further 9 whales in the Inuvialuit Settlement Region and a further 11 in Alaska. This assumes a sex ratio of 1:1 in the Alaskan harvest. Adding these whales to the removal estimate of 189 described above yields a removal of 209 belugas, still well below the expected rate of increase of a beluga stock.

Results from the hunter-based sampling programs reported here indicate that the harvest of southeastern Beaufort Sea belugas is sustainable. The low rate of removal, the continued availability of large and old individuals after centuries of harvest, and the apparent lack of change in the size and age structure of the catch in recent years all suggest that the present harvest is not causing a decline in stock size.

Hunter-based sampling through the FJMC beluga monitoring program is ongoing. It would be fruitful in the future if the monitors were trained to perform a basic on-site examination of female reproductive tracts. This information, together with the results of ovarian analyses, would be used to determine the reproductive status and history of individual females. Data on other reproductive parameters, including age of maturation, age at first birth, and age-specific calving interval, which at the present time are not documented for this stock, would also be obtained (Harwood and Smith, in press; DFO, 2000).

The hunter-based nature of this program has provided a mechanism for the Inuvialuit to be active partners in the collection of biological data used to assess the well-being of the beluga stock on which they depend. The Inuvialuit have been partners in other beluga research projects, including capture and handling for satellite telemetry studies (Richard et al., 2001) and the conduct of aerial surveys to examine the distribution and size of the stock (Harwood et al., 1996). These projects have elevated awareness and ownership of Beaufort Sea beluga management issues and initiatives at the levels of the hunter, the user, and the community.

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REFERENCES

ADAMS, M., FROST, K.J., and HARWOOD, L.A. 1993. Alaska and Inuvialuit Beluga Whale Committee (AIBWC) – An initiative in "at home management." Arctic 46(2):134–137.

AMERICAN SOCIETY OF MAMMALOGISTS. 1961. Standardized methods for measuring and recording data on the smaller cetaceans. Journal of Mammalogy 42(4):471–476.

BELIKOV, S. 1999. The status of the white whale population (*Delphinapterus leucas*) inhabiting the Russian Arctic. International Whaling Commission SC/51/SM21. 19 p.

BOCKSTOCE, J.R. 1986. Whales, ice and men: The history of whaling in the Western Arctic. Seattle: University of Washington Press. 400 p.

BRENNIN, R., MURRAY, B.W., FRIESEN, M.K., MAIERS, D., CLAYTON, J.W., and WHITE, B.N. 1997. Population genetic structure of beluga whales (*Delphinapterus leucas*): Mitochondrial DNA sequence variation within and among North American populations. Canadian Journal of Zoology 75: 795–802.

BURNS, J.J., and SEAMAN, G.A. 1985. Investigations of belukha whales in coastal waters of western and northern Alaska. II. Biology and ecology. Final Report submitted to NOAA, Outer Continental Shelf Environmental Assessment Program, Alaska Department of Fish and Game, 1300 College Road, Fairbanks, Alaska 99701, U.S.A. 129 p.

COSENS, S.E., de MARCH, B.G.E., INNES, S., MATHIAS, J., and SHORTT, T.A. 1998. Report of the Arctic Fisheries Scientific Advisory Committee for 1993/94, 1994/95 and 1995/96. Canadian Manuscript Report of Fisheries and Aquatic Sciences No. 2473. Winnipeg: Western Region, DFO.

DFO (DEPARTMENT OF FISHERIES AND OCEANS CANADA). 2000. Eastern Beaufort Sea beluga. DFO Science Stock Status Report E5-38 (2000). Available at www.dfo-mpo.gc.ca/csas.

FABIJAN, M., SNOW, N., NAGY, J., and FERGUSON, M. 1995. Evaluation of the Inuvialuit Harvest Study data for the years 1988–1992. Unpubl. report available from the Joint Secretariat, Box 2120, Inuvik, Northwest Territories X0E 0T0, Canada. 133 p.

FRAKER, M.A. 1977. The 1977 whale monitoring program, Mackenzie Estuary, N.W.T. Report by F.F. Slaney and Company, Limited, Vancouver, British Columbia. Available at Fisheries and Oceans Canada, Box 1871, Inuvik, Northwest Territories X0E 0T0, Canada. 53 p.

———. 1978. The 1978 whale monitoring program, Mackenzie Estuary, N.W.T. Report by F.F. Slaney and Company, Limited, Vancouver, BC. Available at Fisheries and Oceans Canada, Box 1871, Inuvik, Northwest Territories X0E 0T0, Canada. 28 p.

———. 1979. Spring migration of bowhead (*Balaena mysticetus*) and white whales (*Delphinapterus leucas*) in the Beaufort Sea. Fisheries and Marine Service Technical Report 859. Winnipeg: Dept. of Fisheries and Environment. 36 p.

FRAKER, M.A., and FRAKER, P.N. 1979. The 1979 whale monitoring program, Mackenzie Estuary. Report by LGL Ltd., Sidney, BC. Available at Fisheries and Oceans Canada, Box 1871, Inuvik, Northwest Territories X0E 0T0, Canada. 51 p.

FRAKER, M.A., GORDON, C.D., McDONALD, J.W., FORD, J.K.B., and CAMBERS, G. 1979. White whale (*Delphinapterus leucas*) distribution and abundance and the relationship to physical and chemical characteristics of the Mackenzie Estuary. Fisheries and Marine Service Technical Report 863. Winnipeg: Dept. of Fisheries and Environment. 56 p.

FRAKER, P.N., and FRAKER, M.A. 1981. The 1980 whale monitoring program, Mackenzie Estuary. Report by LGL Ltd., Sidney, BC. Available at Fisheries and Oceans Canada, Box 1871, Inuvik, Northwest Territories X0E 0T0, Canada. 98 p.

FRIESEN, T.M., and ARNOLD, C.D. 1995. Zooarchaeology of a focal resource: Dietary importance of beluga whales to pre-contact Mackenzie Inuit. Arctic 48(1):22–30.

GOREN, A.D., BRODIE, P.F., SPOTTE, S., RAY, G.C., KAUFMAN, H.W., GWINNETT, A.J., SCIUBBA, J.J., and BUCK, J.D. 1987. Growth layer groups (GLGs) in the teeth of an adult belukha whale (*Delphinapterus leucas*) of known age: Evidence for two annual layers. Marine Mammal Science 3:14–21.

HARWOOD, L.A., and SMITH, T.G. In press. Whales of the Inuvialuit Settlement Region in Canada's Western Arctic: An overview and outlook. Arctic.

HARWOOD, L.A., INNES, S., NORTON, P., and KINGSLEY, M.C.S. 1996. Distribution and abundance of beluga whales in the Mackenzie Estuary, south-east Beaufort Sea, and west Amundsen Gulf during late July 1992. Canadian Journal of Fisheries and Aquatic Sciences 53:2262–2273.

HILL, P.S., and DeMASTER, D.P. 1999. Alaska marine mammal stock assessments 1999. U.S. Department of Commerce, NOAA-TM-NMFS-AFSC-110. 166 p. Available from the National Marine Mammal Laboratory, Alaska Fisheries Science Center, 7600 Sand Point Way NE, Seattle, Washington 98115, U.S.A.

HOHN, A.A., and LOCKYER, C. 1999. Growth layer patterns in teeth from two known-history beluga whales: Reconsideration of deposition rates. International Whaling Commission Scientific Committee Report No. SC/51/SM14.

HUNT, W.J. 1979. Domestic whaling in the Mackenzie Estuary, Northwest Territories. Canadian Fisheries and Marine Service

Technical Report 769. Winnipeg: Dept. of Fisheries and Environment. 14 p.

INNES, S. 1996. Report of the National Peer Review Committee, Winnipeg, Manitoba, February 7–8, 1996. Appendix 3. Eastern Beaufort Sea beluga (1996 update) for AFSAC. Available at Fisheries and Oceans Canada, 501 University Crescent, Winnipeg, Manitoba R3T 2N6, Canada. 15–20.

KIEFER, J. 1959. K-sample analogues of the Kolmogorov-Smirnov and Cramér-von Mises tests. Annals of Mathematical Statistics 30:420–447.

KINGSLEY, M.C.S. 1996. Population index estimate for the belugas of the St. Lawrence in 1995. Canadian Technical Report of Fisheries and Aquatic Sciences 2117. Winnipeg: Western Region, DFO. 38 p.

———. 1998. Population index estimates for the St. Lawrence belugas, 1973-1995. Marine Mammal Science 14:503–530.

LOWRY, L.F., BURNS, J.J., and FROST, K.J. 1988. Recent harvests of belukha whales in western and northern Alaska and their potential impact on provisional management stocks. International Whaling Commission Scientific Committee Report No. SC\40\SM4.

MELNIKOV, V.V., ZELENSKY, M.A., and AINANA, L.I. 1998. Distribution and migrations of the belukha (*Delphinapterus leucas*) in the Chukchi Sea and northern Bering Sea. International Whaling Commission Scientific Committee Report No. SC/50/SM4. 12 p.

McGHEE, R. 1988. Beluga hunters: An archaeological reconstruction of the history and culture of the Mackenzie Delta Kittegaryumiut. Newfoundland Social and Economic Series No. 13. St. John's: Institute of Social and Economic Research, Memorial University of Newfoundland. 124 p.

NORTON FRAKER, P. 1983. The 1982 white whale monitoring program, Mackenzie Estuary. Prepared by LGL Ltd., Sidney, B.C., for Esso Resources, Dome Petroleum, and Gulf Canada, Calgary, Alberta. Available at Fisheries and Oceans Canada, Box 1871, Inuvik, Northwest Territories X0E 0T0, Canada. 53 p.

NORTON, P., and HARWOOD, L.A. 1985. White whale use of the southeastern Beaufort Sea, July-September 1984. Canadian Technical Report of Fisheries and Aquatic Sciences 1401. Winnipeg: Western Region, DFO. 46 p.

———. 1986. Distribution, abundance and behaviour of white whales in the Mackenzie Estuary. Environmental Studies Revolving Funds Report 036. Ottawa: ESRF. 73 p.

NULIGAK. 1966. I, Nuligak. The autobiography of a Canadian Eskimo. Toronto: Simon and Schuster of Canada. 191 p.

PERRIN, W.F., and MYRICK, A.C., Jr., eds. 1980. Report of the Workshop. Age determination of toothed whales and sirenians. Report of the International Whaling Commission, Special Issue 3:2.

O'CORRY-CROWE, G.M., and LOWRY, L.L. 1997. Genetic ecology and management concerns for the beluga whale (*Delphinapterus leucas*). In: Dizon, A.E., Chivers, S.J., and Perrin, W.F., eds. Molecular genetics of marine mammals. Society for Marine Mammalogy, Special Publication No. 3. 249–274.

O'CORRY-CROWE, G.M., SUYDAM, R.S., ROSENBERG, A., FROST, K.J., and DIZON, A.E. 1997. Physiology, population structure and dispersal patterns of the beluga whale, *Delphinapterus leucas*, in the Western Nearctic revealed by mitochondrial DNA. Molecular Ecology 6:955–970.

RICHARD, P.R., MARTIN, A.R., and ORR, J.R. 2001. Summer and autumn movements of belugas of the eastern Beaufort Sea stock. Arctic 54(3):223–236.

SAS (STATISTICAL ANALYSIS SYSTEM). 1996. SAS Users guide: Statistics Version 6. Cary, North Carolina: SAS Institute Inc.

SMITH, T.G., and TAYLOR, D. 1977. Notes on marine mammal, fox and polar bear harvests in the Northwest Territories 1940 to 1972. Fisheries and Marine Service Technical Report 694. Winnipeg: Dept. of Fisheries and Environment. 37 p.

SOKAL, R.R., and ROHLF, F.J. 1995. Biometry. 3rd ed. San Francisco: W.H. Freeman and Company.

STATISTICS CANADA. 1994. Canada's Aboriginal population by census subdivision and census metropolitan areas. Edmonton: Advisory Services, Statistics Canada.

———. 1998. Ad-hoc retrieval for census of population for 1981, 1986, and 1996 censuses. Edmonton: Advisory Services, Statistics Canada.

STEWART, R.E.A. 1994. Size-at-age relationships as discriminators of white whale (*Delphinapterus leucas*) stocks in the eastern Canadian Arctic. Bioscience 39:217–225.

STRONG, T. 1989. Reported harvests of narwhal, beluga and walrus in the Northwest Territories, 1948–1987. Canadian Data Report of Fisheries and Aquatic Sciences 734. Winnipeg: Western Region, DFO. 14 p.

———. 1990. The domestic beluga (*Delphinapterus leucas*) fishery in the Mackenzie River Estuary, Northwest Territories, 1981–1986. Canadian Data Report of Fisheries and Aquatic Sciences 800. Winnipeg: Western Region, DFO. 52 p.

SUYDAM, R., and FROST, K. 2001. Programs, activities, and research of the Alaska Beluga Whale Committee, 2000–2001. Annual Report to National Marine Fisheries Service, NOAA. Barrow, Alaska: Alaska Beluga Whale Committee. 99 p.

WAINWRIGHT, K.L., and WALKER, R.S. 1988. A method of preparing beluga (white whale), *Delphinapterus leucas*, teeth for aging. Canadian Manuscript Report of Fisheries and Aquatic Sciences 1967. Winnipeg: Central and Arctic Region, DFO. 15 p.

WEAVER, P.A. 1991. The 1987 beluga (*Delphinapterus leucas*) harvest in the Mackenzie River Estuary, NWT. Canadian Manuscript Report of Fisheries and Aquatic Sciences 2097. Winnipeg: Central and Arctic Region, DFO. 18 p.

ZAR, J.H. 1974. Biostatistical analysis. Englewood Cliffs, New Jersey: Prentice-Hall, Inc.