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Harvest-based monitoring of ringed seal body condition and reproduction in Amundsen Gulf, NT, Canada: 2004-2007

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EXECUTIVE SUMMARY

We examined body condition and reproduction of harvested ringed seals (*Phoca hispida*) from a core, stable habitat (eastern Amundsen Gulf, Ulukhaktok, n=232) and from a non-core, dynamic habitat (west coast of Banks Island, Sachs Harbour, n=149) during the open water period, 2004-2007. Seals of all age classes generally had higher body condition indices (LMD index = length-mass-blubber depth) in corresponding years at the Sachs site compared with the Ulukhaktok site, but there were no temporal or statistical trends over the four years of study for adults or subadults. The body condition indices of pups in one year, 2005, was signficiantly lower at the Ulukhaktok site compared with Sachs Harbour, and this may be a reflection of reduced marine productivity in that year due to a particularly late spring break up of the sea ice (Harwood et al. 2012a).

The open-water timing of this study, required to ensure an adequate sample size by coinciding with the months of peak seal hunting activity at Sachs Harbour, was not optimal timing for revealing trends in seal body condition. This is because seals harvested during the summer months have usually had several weeks to feed following spring break up (Smith 1987). This allows time to regain condition from the possible negative influences of a particularly harsh winter, or from fasting during spring (Smith 1987).

Somewhat more revealing were the annual ovulation rates and percent pups in the seal specimens harvested in summer at Ulukhaktok and Sachs Harbour. Ovulation and pupping occur in late spring at both sites (Smith 1987), and therefore reflect conditions of the preceding winter and the spring. Values at both sites were variable over the four years of study, but had parallel ‘peaks’ and ‘lows’ at both locations in the same years. The years 2004 and 2005 were

a time of low reproductive output, while 2006 and 2007 were years of increased ovulation rates and pup production.

Even this short, four-year pattern was similar to fluctuations that have been documented in the past for seals from the Sachs Harbour area (Stirling et al. 1977; Kingsley and Byers 1998), and over several decades for the Ulukhaktok area (Smith 1987; Smith and Harwood 2001; Harwood et al. 2012a). We found that variation in ovulation rates and percent pups were more readily discerned in the Sachs samples than influences on body condition, at least when condition was measured during the prey-rich open water hunting period. A further factor constraining our attempts to obtain an adequate sample size, especially from the more exposed Sachs Harbour area, is the climate-driven increase in frequency and strength of winds in recent years. This has in turn made the traditional local practice of harvesting seals from small boats more difficult and less common.

Key Words: ringed seal, ovulation, pups, body condition, Amundsen Gulf, Beaufort Sea, sea ice, subsistence harvest, ice clearance

INTRODUCTION

Ringed seals (*Phoca hispida*) have a circumpolar distribution, are the most abundant and widespread marine mammal in the Canadian Arctic, and the main prey of the polar bear (*Ursus maritimus*) (Stirling 2002). Their survival and reproductive success are closely linked to the extent, persistence and characteristics of sea ice (Smith 1987; Stirling 2002; Laidre et al., 2008), with changes to sea ice (Galley et al. 2012) expected to have both direct and indirect effects on ringed seals (Tynan and DeMaster 1997; Ferguson et al. 2005; Kovacs et al. 2010; Kelly et al. 2010). It is important to examine and understand the geographical scale of ecosystem and sea ice changes, and to interpret the results in the context of that scale. With this as our main objective, we undertook four seasons of sampling of harvested seals from two communities situated on the shores of Amundsen Gulf, Sachs Harbour and Ulukhaktok, NT.

In Canada's Western Arctic, scientific surveys of breeding habitat and sampling of specimens were initiated in the early 1970s (Stirling et al. 1977; Smith 1987; Stirling et al. 1982), and this work continued during the 1980s (Kingsley and Byers 1998) and 1990s (Harwood et al. 2000). Inuvialuit harvesters and scientists have worked together throughout this long period, bringing a wealth of local field expertise and shared knowledge of the ringed seal into our collective understanding (Smith 1987; Stirling et al. 1982; Kingsley and Byers 1998; Harwood et al. 2000).

Studies have revealed decadal-scale fluctuations in ovulation rate, percentage of pups in the harvest (Stirling et al. 1977; Smith 1987; Kingsley and Byers 1998; Harwood et al. 2000), density of birth lairs (Smith and Stirling 1978; Smith 1987), and seal abundance (Stirling et al. 1977; 1982; Smith 1987;

Harwood and Stirling 1992) in this region. Researchers suggested that changes were somehow related to variations in environmental conditions, particularly changes in sea-ice (Stirling et al. 1977; Smith 1987; Stirling 2002). Changes in seal productivity were also reflected in the body condition and reproductive output of polar bears in the 1970s (Kingsley 1979; Stirling 2002), and such changes were implicated in nutritional stress in polar bears in the Beaufort during 2004-2006 (Stirling et al. 2008).

Sachs Harbour is the most northerly community in the Northwest Territories, located on the southwestern shore of Thesiger Bay on Banks Island (71'59 N; 125'14' W), with a human population of 136 (2010). It is located 523 km northeast of Inuvik, NT, and was first settled in 1929. Ulukhaktok (formerly known as Holman Island, NT) is located on the shores of eastern Amundsen Gulf, on the western side of Victoria Island (70'43' N, 117'45' W). The two communities are separated by Amundsen Gulf and a linear distance of approximately 1000 km. The community of Ulukhaktok has a human population of 451 (2010), and was first settled in 1923.

The ringed seal is an important species in the subsistence economy of the Inuvialuit, the Inuit of Canada's Western Arctic. Seal harvests between 1988-1997 averaged 1085 seals annually for the region (Joint Secretariat, 2003), which is approximately 20-30% of harvest levels in the 1960's and 1970's (Smith and Taylor 1977; IRC 1989). Present day subsistence harvests from the Inuvialuit Settlement Region as a whole represent a small proportion (less than 1%) of the probable 0.65 million seals estimated for the Beaufort Sea and Amundsen Gulf (Stirling and Øritsland 1995). Most of the Inuvialuit harvest of seals (75.7% between 1988-1996) is taken by the residents of Ulukhaktok, with the entire seal harvest from Sachs Harbour rarely exceeding 100 per year

(Joint Secretariat, 2003). Historically, the local economy of Sachs Harbour was based on the exceptionally high availability of the Arctic fox (Usher 1975).

The large bays with stable fast ice in Amundsen Gulf are particularly important to ringed seals in the Western Arctic during the winter/spring breeding period (Fig. 1). Sea ice habitat in Prince Albert Sound, Minto Inlet and eastern Amundsen Gulf provide prime breeding areas for ringed seals of the Western Arctic, with the area supporting the stronghold of ringed seals in Canada's Western Arctic (Smith 1987). In contrast, there are no bays of comparable size and with stable fast ice in the Beaufort Sea/Amundsen Gulf areas near Sachs Harbour area, and this is not considered a core seal habitat, although they do occur there at lower densities in all seasons (Stirling et al. 1982; www.beaufortseals.com). When the sea ice melts in spring, ringed seal occurrence increases in the coastal waters off Sachs Harbour during the months of July and August, and it is at this time of year that most of Sachs Harbour's subsistence hunting for seals takes place. Seal hunting activity at Ulukhaktok takes place over a longer period, and in both ice-covered and open water seasons.

Methods

We examined ringed seal body condition, and two parameters of ringed seal reproduction (ovulation rate and percent pups in the harvest). These parameters provide a practical means with which to monitor the ringed seal population in an area (Smith 1987; Kingsley and Byers 1998; Harwood et al. 2000; 2012a), with the assistance of the local community hunters as monitors.

In 2004-2007, Inuvialuit seal hunters (here called 'seal monitors') sampled and measured 149 ringed seals from seal harvests at Sachs Harbour and 232 from seal harvests at Ulukhaktok (Fig. 1). The seal monitoring study at Sachs was timed to coincide with the open-water timing of peak seal hunting activity, in an attempt to obtain an adequate sample size. Samples collected from Ulukhaktok were more readily available and collected over a longer period of several months. To ensure standardized comparisons, we used only seals sampled during the open water season for our database, including those sampled at Sachs Harbour (n=149) and Ulukhaktok, NT (n=232) during 2004-2007 seasons.

All aspects of the field sampling and laboratory work involved the same procedures, described in Smith (1987), and which were used previously at Sachs Harbour (Kingsley and Byers 1998) and are used annually at Ulukhaktok (Harwood et al. 2000; 2012a). The monitors were trained prior to each field season, to ensure that the data were collected as consistently as possible.

The following information was collected from each seal: sex, date, location of kill, and the monitor's assessment of relative age. Then harvested seals were laid on their backs on a smooth, flat surface, and using a steel tape measure, standard length (nose to tail) ($\pm$ 1.25 cm), axillary girth and hip girth were measured (American Society of Mammalogists 1967). Body weight was measured to the nearest 0.5 kg using a spring dial scale suspended from a tripod, and fat thickness was measured at the sternum and at the hip (60% of distance from nose to tail). No corrections were made for blood loss.

The lower mandible was removed from as many of the sampled seals as possible, as were entire reproductive tracts from as many of the females in the sample as possible (Smith 1973). These specimens were labelled and preserved in the field in 10% buffered formalin. Other samples were collected for other scientific studies (mainly disease and contaminant load assessments), and shipped to southern laboratories in a frozen state.

In the laboratory, the lower jaws were boiled, lower canines were extracted, and one was cut in cross-section. Age determinations were made by reading the dentinal annuli of cross sections under transmitted light (Smith 1973). Duplicate readings by the same reader were made for each tooth, with the second reading done separately. If the first two readings did not agree, a third reading was done. A decision of the age was made based on recounts of the dentinal layers, a consideration of the clarity of the dentinal lines, the closure of the pulp cavity and the number of layers in the cementum, if it was readable.

Ages of ringed seals that are determined from counts of dentinal layers tend to underestimate the age compared to the reading of cementum layers, particularly in seals older than 10 years of age. For seals <10 years of age, a statistically signficant correlation has been reported for ages obtained using the two methods (Stewart et al. 1996). In our study, we used the same aging method (dentinal) that was used in our 1970s data set, to ensure the data sets were comparable.

Left and right ovaries were sectioned following the methods described by Smith (1973), and the presence of corpora lutea was recorded. Pregnancy could not be detected directly from the presence of a foetus due to the June-July timing of the study, because of delayed implantation which retards implantation and foetal development until September (Smith 1973; 1987). The mean date of ovulation in eastern Amundsen Gulf is 25 May (Smith, 1987), prior to the start of our sampling efforts. We classified a female as mature if there was a corpus luteum in an ovary, or if examination of the uterus provided evidence of at least one previous pregnancy. We considered a large, recently erupted corpus luteum to be evidence of recent ovulation in females that were sampled in June or July. Ovaries of immature females lacked any follicular structures and evidence of previous pregnancy in the uterine cornua, and were classified as nulliparous.

Data analysis

Data were entered into Excel, and statistical analyses conducted using SAS version 8.0 on a PC (SAS 1990). For seals taken in the open water period at both locations, and separately for adults ($\geq$7 y), subadults (1-6 y) and pups (0^+ y), body condition was calculated using the LMD index, according to Ryg et al., (1990):

$\sqrt{L/M}$ x d x 100, where L = standard length (m), M = body weight (kg), and d = blubber thickness (m) at the hip.

PROC GLM (General Linear Model) and Duncan's Multiple Range tests were used to examine annual differences in LMD between locations, years and age classes. Mean LMD values for each location, year and age class were plotted on scatterplots and trend lines applied and applied with linear regression. Homogenity of variances was examined using an F test.

Age-frequency distribution for both sites was constructed, and a bar graph of mean ages by site and year. The proportion of mature females that were ovulating in any given year (by age) was tabulated for adult females, with and without evidence of recent pregnancy. The age of sexual maturity (first ovulation) and age of first birth was calculated according to DeMaster (1981), using age-specific ovulation and reproductive tract data for 2004-2007 for the

Sachs sample. Comparable estimates for Ulukhaktok were obtained from Harwood et al. (2012a).

Mean LMD value for ovulating mature females was compared to the mean LMD of non-ovulating mature females using a Duncans multiple range test, controlling for year and season. The small sample size of mature non-ovulating females necessitated pooling the mature females for all years. Percent pups in the open water harvest was calculated as number of pups in the open water sample, divided by the total number of seals in the harvest sample, x 100.

RESULTS

A total of 149 ringed seals (47% male) were sampled from waters adjacent to Sachs Harbour between 2004-2007, mainly during the month of July (60.4%), with smaller numbers during June (9.4%), August (24.8%) and September (5.4%). The sample consisted of pups (29.8%), subadults aged 1-6 y (21.8%) and adults $\geq$7 y of age (57.0%) (Table 1).

During 2004-2007, a total of 232 ringed seals were sampled from waters adjacent to Ulukhaktok during the corresponding open water period, mainly during the month of July (81.5%) (Table 2). The open water Ulukhaktok sample for 2004-2007 consisted of pups (21.1%), subadults aged 1-6 y (15.6%) and adults $\geq$7 y of age (63.2%).

The age-frequency distribution for both monitoring sites had similar age classes represented in the samples (Fig. 2). The samples consisted mainly of pups and adults, with subadults being less well represented at both sites since they tend to disperse (Smith 1987; Harwood et al. 2012b). There were no statistical differences between the age-frequency distributions at the two locations for 2004-2006 (KSa = 0.385162, p>KSa=0.9984.). The mean age of seals sampled was 9.6 y (sd 7.4, range 0-36 y, n =192) at Ulukhaktok and 9.5 y (sd=7.0, range 0-26, n=89) at Sachs Harbour (Fig. 3). In 2006 and 2007, there was a shift to younger age classes at both monitoring locations.

Mean LMD for adult ringed seals during the open water period showed no temporal or statistical trends for subadults and adults (Fig. 4), at either location over the four years of study. Open water body condition remained relatively consistent across age class groupings, with the exception of pups sampled at Ulukhaktok in 2005 which were in significantly lower body condition than their counterparts from Sachs in that same year ($p<0.05$). Mean annual condition indices for seals sampled from Sachs were higher than those from Ulukhaktok, although differences were not statistically significant ($p>0.05$).

A total of 176 reproductive tracts from female ringed seals were obtained for 2004-2007 at the two study sites. The mean age of sexual maturity for our Sachs sample was 7.1 yr (sd 0.61, n = 54) and mean age of first birth was 7.5 (SE 1.01; n = 48). For the Ulukhaktok sample, mean age of sexual maturity was lower 6.32 yr (se 0.60) and age of first pregnancy was 7.08 yr (se 0.61) (n=461) (Harwood et al. 2012a). Age-specific reproductive status (Table 2) showed that less than half of the 6, 7, and 8 year old seals sampled were mature or ovulating.

Annual ovulation rates of mature adult females (aged 7-20 yr) ranged from 50 to 100 % for Sachs Harbour and 25% to 95.8% for Ulukhaktok during 2004-2007 (Fig. 5a). The lowest ovulation rates were in 2004 at Sachs and in 2005 at Ulukhaktok, with timing of the broad-scale ‘peaks’ and ‘lows’ being well matched at the two sites. Mature ovulating females (with evidence of previous pregnancy) had higher mean LMD values (LMD=16.0, n=85) than counterpart mature females that were not ovulating (LMD=11.8, n=25; F=22.89.0, df=1, 109, p>F<0.0001) during 2004 – 2007.

The percent pups in the open water harvests averaged 21.1% in Ulukhaktok (range 3.3-54.7%) and 29.6% (range 3.2%-79%) at Sachs (Fig. 5b). The annual percent pups in the harvests were highly variable, and also peaks and lows were relatively well matched at the two sites. Similar to the ovulation rates, 2004 and 2005 were among the years with lowest percent pups in the harvest, and as noted above, was the year of particularly poor pup body condition at the Ulukhaktok site.

DISCUSSION

We examined the body condition and reproduction in harvested ringed seals from a core breeding habitat (Ulukhaktok, n=232) and a marginal habitat (Sachs Harbour, n=149) during the open water period, 2004-2007. Results revealed seals of all age classes were generally in better body condition at the Sachs site vs the Ulukhaktok site, and overall there were no temporal trends at either site over the four years of study. Open water is available earlier in the season at Sachs Harbour compared with Ulukhaktok, and combined with vertical mixing from the Beaufort Gyre this might result in enhanced productivity earlier in the season and explain the earlier weight gain in the Sachs Harbour seals.

Body condition of one age class, pups, was significantly lower at the Ulukhaktok site in 2005 compared with Sachs Harbour, and this likely reflects reduced marine productivity in that particular year (Harwood et al. 2012a), which was discerned from a larger and earlier sample. A limitation to sampling seals during the open water season, at any site, is that the seals have been feeding for several weeks and thus usually have regained condition following any nutritionally-stressful situations such as winter or the spring moult. Signals in the body condition data are stronger and more easy to detect prior to or after break up of the sea ice in spring, as we have demonstrated in our Ulukhaktok study (Harwood et al. 2012a).

The open-water timing of the present study, chosen to coincide with the period of peak seal hunting activity at Sachs Harbour and thereby maximize opportunities for obtaining an adequate sample size, was not optimium for revealing differences in seal body condition because it is mostly regained by the open water period. This corroborates hunter reports, that sinking losses diminish as summer progresses, and by July and August, seals do not sink when shot due to increased fat content a phenomenon which is seen in most arctic seal hunting areas (McLaren 1958; Smith 1973; Johnson et. al. 1966, Smith 1987).

More revealing in the present study were the parallels in annual ovulation rates and percent pups in the harvests at Ulukhaktok and Sachs Harbour. Values at both sites were variable over the four years of study, but tracked similar ‘peaks’ and ‘lows’ at both sampling locations in the same years. The years 2004 and 2005 were years of low reproductive output, and were followed by increased reproduction and pup production in 2006 and 2007. This pattern was similar to fluctuations that have been documented previously for seals from the Sachs Harbour area (Stirling et al. 1977; Kingsley and Byers 1998), and previously (Smith 1987) and concurrently (Harwood et al. 2012a) for seals from the Ulukhaktok area.

The main challenge in delivery of this program was obtaining a sufficient sample size of seals from Sachs Harbour, a hunting area situated in the more variable and dynamic environment of west Amundsen Gulf and the Beaufort Sea. Frequent and recent reports from Ulukhaktok and Sachs Harbour harvesters of increasing winds and associated difficulties harvesting seals is an important point. Windier conditions, linked to a changing climate, constrain the ability of harvesters to access resources, and thus opportunities for scientists to obtain samples necessary to monitor changes in the seal populations over the long-term.

We did note that the strongest signal in the open-water body condition data for the 2004-2007 samples was in pups sampled at Ulukhaktok in 2005. This was a year of particularly late spring break up, harsh winter conditions and a time of lower marine productivity as revealed through sampling of adult and subadult seals earlier in the season in Ulukhaktok (Harwood et al. 2012a). This occurred in the same year as reduced proportion of pups at both Sachs Harbour and Ulukhaktok, and reduced ovulation rates at Ulukhaktok (Harwood et al. 2012a).

Overall seal body condition did follow consistent patterns at the two sites during 2004-2006, as did mean ages of the sampled animals. The parallel trends in ovulation rates and percent pups in the seal harvests at both study sites suggested that the changes in 2004-2007 were operating at a scale beyond the vicinity of the monitoring sites, and at a scale that involved more of Amundsen Gulf and the SE Beaufort Sea, than what we would consider a ‘local’ scale surrounding the two individual seal monitoring locations.

Although we cannot discount that the 'same' seals were being sampled in both locations (e.g., seals regularly moving between the two sites and thus available to harvesters at both sites), our satellite tagging results suggest this is not the typical open water movement pattern. We have observed only limited (4 of 17) and short-term (days – weeks) movements of instrumented ringed seals between Sachs Harbour and Ulukhaktok harvesting locations (www.beaufortseals.com) during the open water period.

An adequate sample size (= size of harvest to obtain samples from) must be assured, and the timing of the sampling effort is important. Strongest signals are apparent in the body condition data during late spring, a time at which only limited seal harvesting occurs in Sachs Harbour. From this perspective, the timing and size of the Ulukhaktok harvests are preferrable for obtaining a well-timed and adequate-sized sample. The latter also has limitations, however, since it is a core breeding habitat, and signals in the data may take longer to detect than in more marginal habitats such as near Sachs Harbour (Kingsley and Byers 1998) or along the Alaskan North Slope (Kelly et al. 2010), where the seals occupy marginal habitats particularly subject to vagarities of the environment. While sampling harvested specimens provides useful and otherwise unavailable data , the importance of considering scale, sample size and harvest timing is critical to the success of a study such as this (Bell and Harwood 2012).

Measuring body condition along with ovulation rate and pups in a subsistence harvest does provide a practical means with which to monitor the ringed seal population, with the assistance of the local community hunters as monitors. However, any program attempting to monitor and understand regional factors or large scale population effects must take care in selecting and standardizing the specific parameters used in making these long term assessments, as well as ensuring there are opportunities to obtain an adequate number of specimens annually (McLaren and Smith 1985). Considerations such as the timing of harvested samples and how these reflect body condition, and are linked to reproductive success, are important (Smith 1987). Sampling during the open water period is less likely to reveal changes in seal body condition, given the several weeks of feeding following ice clearance that the seals have had to regain condition. This points to sampling seals immediately after spring break up, which may not be practical in locations such as Sachs Harbour.

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Table 1. Number of harvested ringed seals sampled from Ulukhaktok and Sachs Harbour, NT, during open water period 2004-2007

Study Site	Ulukhaktok				Sachs Harbour			
	n	male	% male	% pups	n	male	% male	% pups
2004	63	32	50.8	6.4	23	12	52.2	4.4
2005	60	37	61.7	3.3	63	36	57.1	3.2
2006	45	26	57.8	20.0	38	18	47.4	31.6
2007	64	39	60.9	54.7	25	8	32.0	80.0
total	232				149			
mean			57.8	21.10			47.2	29.8

Table 2. Proportion of female ringed seals ovulating, by maturity status and age, Ulukhaktok and Sachs Harbour, 2004-2007

Year	Proportion Ovulating									
	Females with no evidence of previous pregnancy (nulliparous)					Females with evidence of previous pregnancy				
	6 yr	7 yr	8 yr	9 yr	10-20 yr	6 yr	7 yr	8 yr	9 yr	10-20 yr
ULUKHAKTOK										
2004		0/2	0/1			0/1		1/1	0/1	15/18
2005	0/3	0/2	0/1	0/1	1/4	1/1				3/9
2006	0/1	2/3			1/1		1/1		1/1	13/13
2007	0/1	2/2		1/1						15/15
total	0/4	4/9	0/2	1/2	2/5	1/2	1/1	1/1	1/2	46/55
SACHS										
2004					0/2	1/1				4/5
2005	0/2	1/2	1/2			1/1	0/1		1/1	9/11
2006	0/1	0/1			5/7					
2007										1/1
total	0/3	1/3	1/2		5/9	2/2	0/1		1/1	14/17

Figure 1. Location of ringed seal monitoring sites in Ulukhaktok and Sachs Harbour, NT, 2004-2007

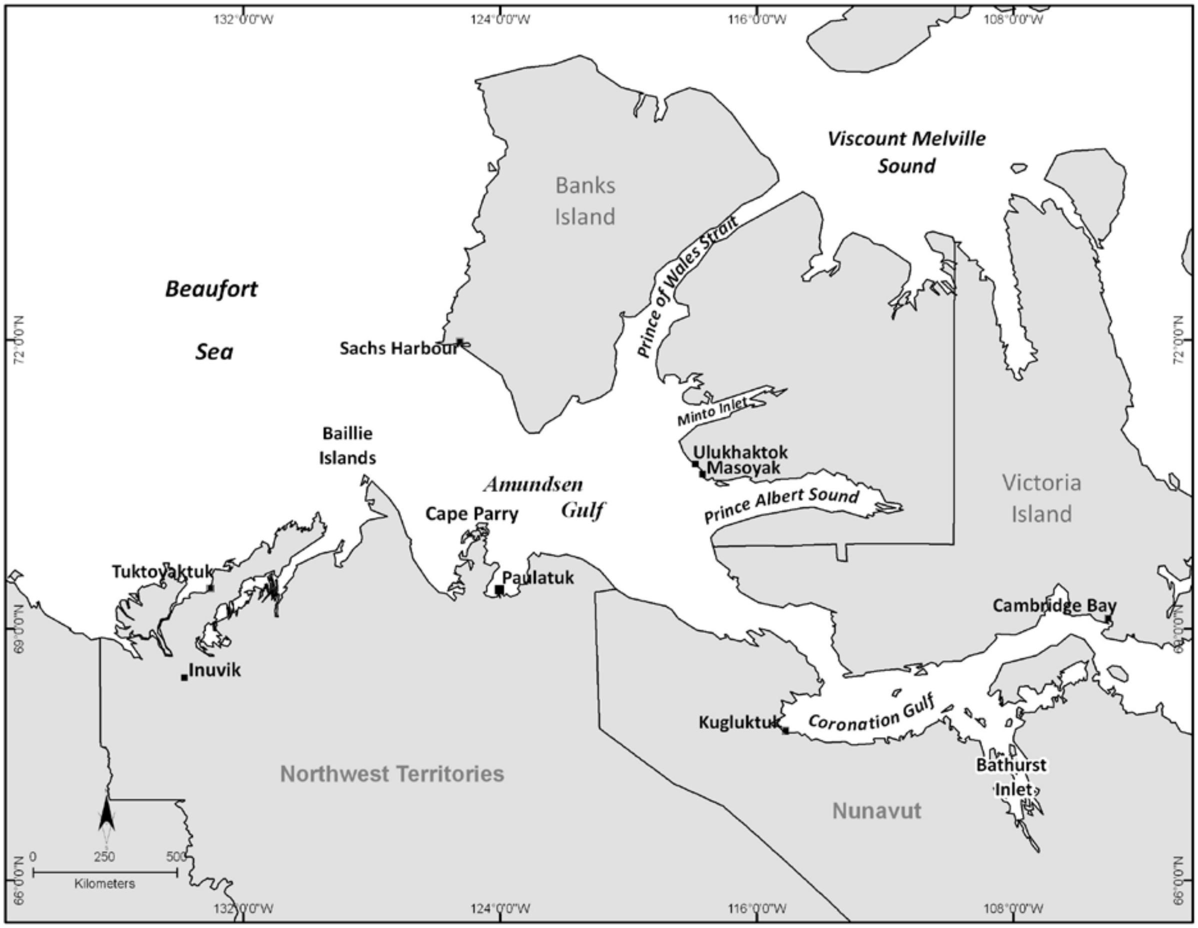

Figure 2. Estimated age of ringed seals sampled from subsistence harvests at Sachs Harbour and Ulukhaktok, NT, 2004-2007

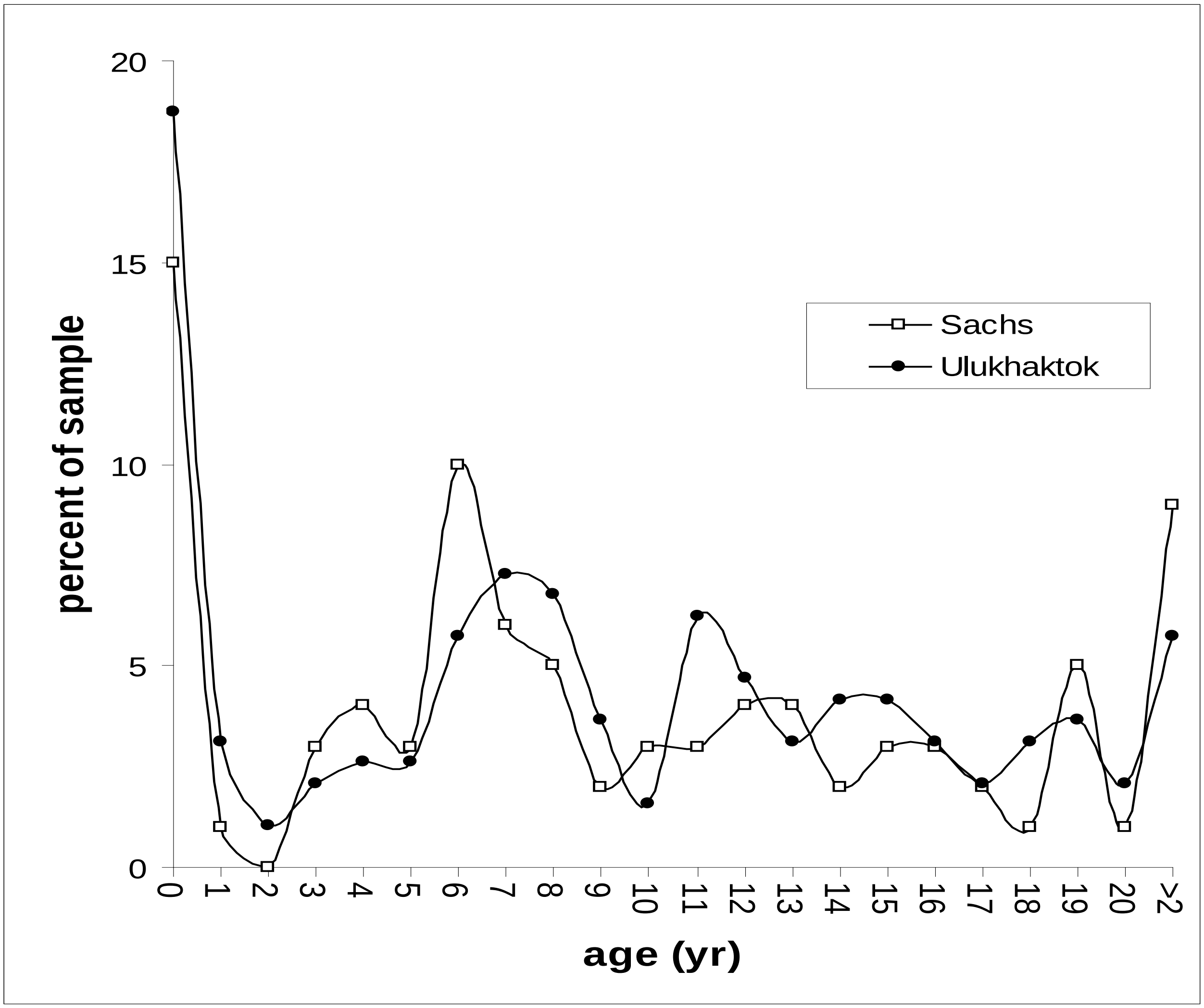

Figure 3. Mean age (± sd) of ringed seals sampled at Ulukhaktok and Sachs Harbour during subsistence montioring, 2004-2007

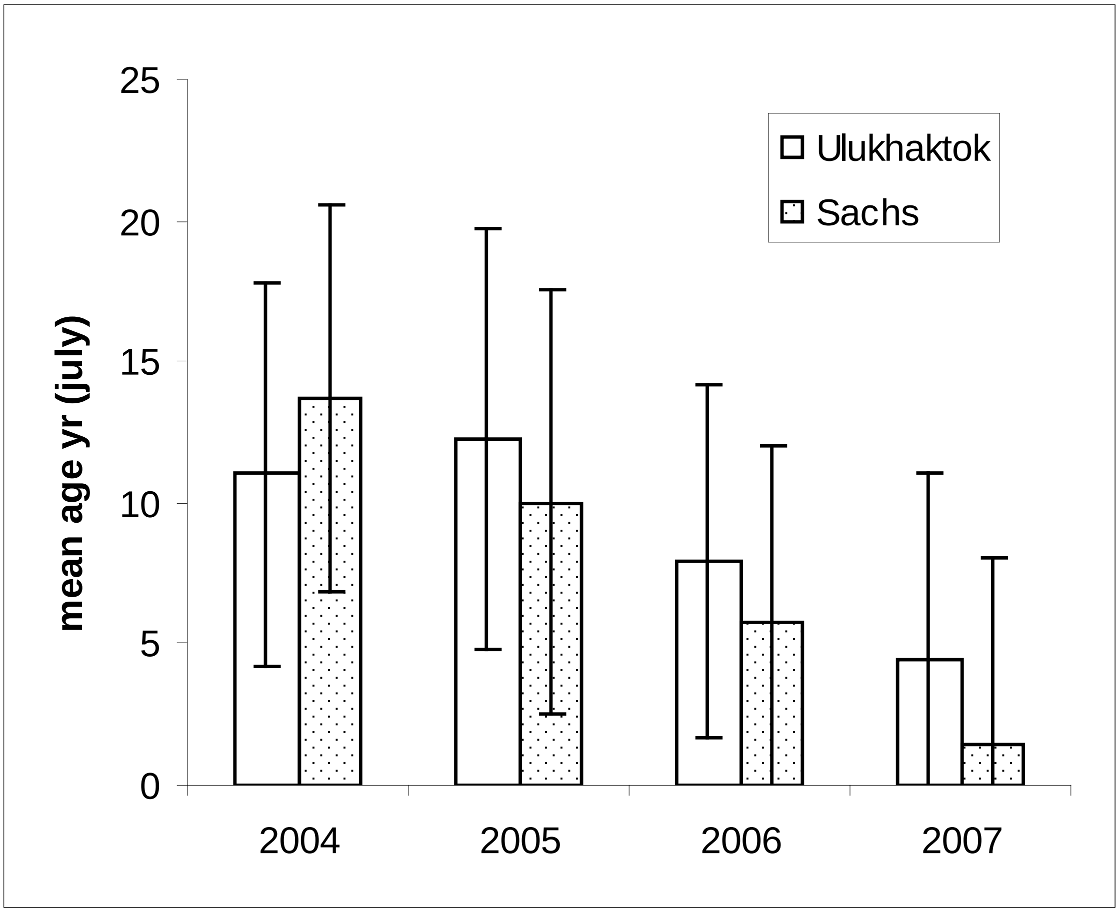

Figure 4. Mean LMD (length-mass-blubber depth) index of annual body condition (± sd) of ringed seal pups, subadults and adults sampled from subsistence harvests at Ulukhaktok and Sachs Harbour, July 2004-2007

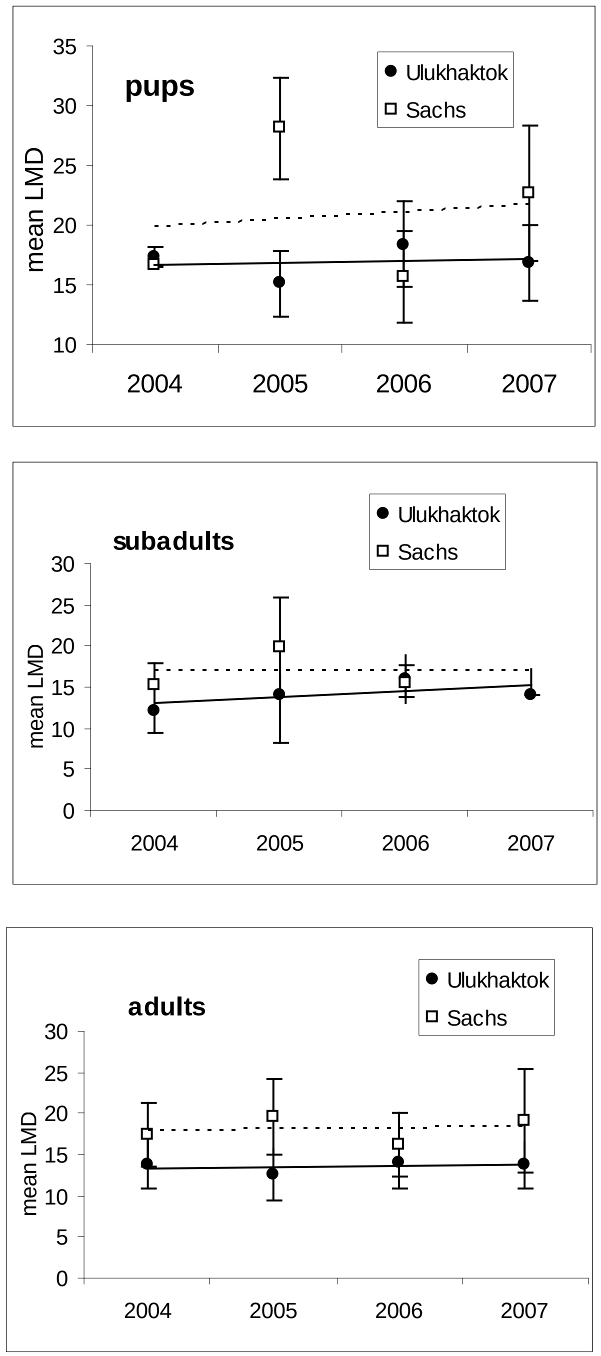

Figure 5. Proportion of mature female ringed seals that were ovulating (upper) and proportion of pups in the subsistence harvest sample (lower), by year and ice break up date, Sachs Harbour and Ulukhaktok, NT, 2004-2007